



Towards a Low-Carbon Society via Hydrogen and Carbon Capture and Storage: Social Acceptance from a Stakeholder Perspective

Sabrina Glanz^{*1}, Anna-Lena Schönauer²

¹Chair of Sociology, Labour and Economy, Ruhr-University Bochum, Universitätsstraße 150, 44801, Bochum, Germany

e-mail: sabrina.glanz@rub.de

²Chair of Sociology, Labour and Economy, Ruhr-University Bochum, Universitätsstraße 150, 44801, Bochum, Germany

e-mail: anna-lena.schoenauer@rub.de

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ABSTRACT

Transformation concepts towards a low-carbon society often require new technology and infrastructure that evoke protests in the population. Therefore, it is crucial to understand positions and conflicts in society to achieve social acceptance. This paper analyses these positions using the example of implementing hydrogen and carbon capture and storage infrastructure to decarbonise the German energy system. The empirical basis of the study are explorative stakeholder interviews which were conducted with experts from politics, economics, civil society and science and analysed within a discursive and attitudinal framework using qualitative content analysis. These stakeholder positions are assumed to represent dominant social perceptions and reflect chances and risks for acceptance. The results indicate different positions while pursuing the common goal of addressing climate change. The general conflict concerns strategies towards a low-carbon society, especially the speed of phasing-out fossil energies. Regarding the combination of hydrogen and carbon capture and storage as instrument in the context of the energy transition, the stakeholder interviews indicate controversial as well as consensual perceptions. The assessments range from rejection to deeming it absolutely necessary. Controversial argumentations refer to security of supply, competitiveness and environmental protection. In contrast, consensus can be reached by balancing ecological and economic arguments, e.g. by linking hydrogen technologies with renewable and fossil energy sources or by limiting the use of carbon capture and storage only to certain applications (industry, bioenergy). In further decisions, this balancing of arguments combined with openness of technology, transparency of information and citizen participation need to be considered to achieve broad acceptance.

KEYWORDS

Energy transition, Discourses, Attitudinal research concept, Germany.

INTRODUCTION

At latest since the reactor accident in Fukushima in 2011 and the subsequent decision to phase out nuclear energy while simultaneously reducing fossil energy supply, the

* Corresponding author

energy transition (Energiewende) in Germany has been a central political and social issue. The Federal Government formulated the goals of the German energy transition in the Energiekonzept [1] and its amendment after Fukushima in 2011 [2]. The main objective of the concept is to reduce 80 to 95% of climate-damaging greenhouse gas emissions by 2050 compared to 1990.

One key aspect towards a low-carbon society is the implementation of new technologies. Next to preventing carbon dioxide (CO₂) emissions by using alternative energy sources, Carbon Capture and Storage (CCS) is another technology to reduce energy or industry induced CO₂ emissions. H₂/CCS chains – the combination of CCS and hydrogen (H₂) technologies – are an option to decarbonise the gas energy sector. In H₂/CCS chains, CO₂ is separated from natural gas and stored in deep underground. Hydrogen as remaining product after the separating process can be used as CO₂-free energy carrier.

However, the way towards a low-carbon society with its far-reaching interventions in the energy system affects the majority of society to broad extent. Being affected may manifest in changing energy infrastructures, rising energy costs, lifestyle patterns or consumption habits. In the past, especially energy technologies such as large-scale infrastructure projects or perceived risk technologies have lacked acceptance and evoked conflicts and protests in the population [3]. Thus, for the decision-making and the successful implementation of new (energy) technologies like H₂/CCS chains, social acceptance is crucial. Therefore, it is necessary to understand and reveal positions in society which reflect chances and risks for acceptance.

The study is based on the current state of acceptance research on CCS and H₂ technologies as well as on energy infrastructure in general with a focus on Germany. First acceptance studies on CCS technology were carried out between 2006 and 2014 and were related to planned or already abandoned CCS projects in Germany. These studies indicated rather little acceptance of CCS technologies, especially the storage of CO₂, in the German population. Yet, the level of awareness and knowledge of as well as familiarity with CCS technologies is rather low [4, 5]. Nevertheless, there is no general nationwide refusal of CCS as shown by the successful project implementation in Ketzin [6]. Dütschke *et al.* [7] revealed in their analyses that people evaluated CCS in the context of industry processes or biomass more positive than in the context of coal-fired plants. Braun *et al.* [8] found the perceived seriousness of climate change, trust in institutions and whether CCS is perceived as a technology that defers responsibility or manipulates nature to be central factors of acceptance. Regarding different stakeholder groups, especially the government, industry and energy experts have a mainly neutral or positive attitude towards CCS while environmental non-governmental organisations (NGOs) are rather critically towards the technology [9]. More recent data from 2017, comparing the public perception of CCS and Carbon Capture and Utilisation (CCU), stated a general acceptance of CCS and CCU. But CCS is perceived less positive than CCU, mainly due to risks associated with storage and transport [10].

Several acceptance studies on hydrogen technology in Germany, mainly on hydrogen mobility, have been performed. These studies exposed mainly positive perception of hydrogen technologies as well as its related infrastructure [11-14]. Especially green hydrogen was found to be more accepted while hydrogen produced from fossil energy sources is valued more critically [13]. Schmidt and Donsbach [12] worked out that hydrogen is presented with more positive than negative arguments in stakeholder communication and media in Germany.

While in the last years only few projects on acceptance of CCS and/or hydrogen have been carried out in Germany, many studies are available on acceptance of infrastructure projects in Germany concerning renewable energies. These studies are related to wind farms [15-17], geothermal energy [18, 19], transmission grid [20, 21] or several

renewable technologies [22, 23]. These studies are united by the observation that the technologies are generally perceived positively, while the infrastructure at the local level is met with rejection, although not always, by everyone and everywhere. The identified relevant parameters for acceptance range from positive/negative associations, perceived risks and benefits, concerns about (landscape) modification, distances, place attachment as well as participation and information.

This paper makes an original contribution to the existing literature as up to now, the acceptance of a decarbonised gas infrastructure via H₂/CCS chains has not been explored. By investigating acceptance of H₂/CCS chains, various aspects of other energy technologies are combined and linked with each other: among others, the restructuring and expansion of gas infrastructure, the installation of a new (pipeline) infrastructure to transport CO₂, respectively, H₂, the transport of CO₂ and H₂ and the use of H₂ as a new energy carrier. Furthermore, the potential to combine fossil energies with renewable energies is a particular aspect of H₂/CCS chains: while CCS technologies allow to decarbonise fossil energy carriers, hydrogen technologies allow to be combined with renewable energies.

This paper aims to better understand the factors which foster or hinder social acceptance of new technologies in the context of the energy transition and to recognise risks and opportunities during the process of decarbonising the energy system. Therefore, the study analyses positions and conflicts of stakeholders in the context of the energy transition using the example of implementing a full chain H₂/CCS infrastructure to reduce CO₂ emissions. As a preliminary to social acceptance in generic terms, the stakeholders' positions and conflicts are assumed to be crucial for the formation and progress of social debates and public discourses. Accordingly, they represent dominant social perceptions and reflect chances and risks for acceptance.

ATTITUDES AND DISCOURSES IN THE GERMAN ENERGY TRANSITION

Research on social technology acceptance implies the analysis of its origin, forms and effects in societies. Differentiation of everyday technology, technology at work and external technology (large-scale technology/external risk technology and infrastructure) appeared to be an effective classification for a more precise analysis. Compared to everyday technology and technology at work, external technologies evoke the highest refusal. The higher level of refusal towards external technologies is above all due to ambivalent perceptions considering risks and benefits and their distributive justice [24]. Based on knowledge, interests and values, controversial perceptions of risks and benefits are causing technology conflicts [25]. Energy technologies mainly apply to external technologies, but on the application level – like mobility or heating systems for private homes – they are also classified among everyday technology.

Alongside individual concern and risk perception, the acceptance of new energy technology is significantly influenced by the location of new technologies in the discourse of the energy transition. Therefore, the authors examine social acceptance of H₂/CCS chains in Germany by embedding central positions and conflicts in the discursive context of the German energy transition. With this procedure, arguments become visible that are in line with the general energy transition discourses as well as with diverging arguments.

Going back on Foucault [26], discourse is a language-produced context of meaning in form of statements that are reflected in social practices. Based on Foucault [26], diverse conceptualisations of discourse analytic approaches have been developed. The common basis of these approaches is the assumption that knowledge is the result of social constructed symbolic systems and orders, produced in and by discourses. Institutions, organisations and social actors lead these discourses [27]. Concluding, discourses can be defined as complex social and communicative manifestations as well as associated

negotiations to what is accepted as knowledge [28]. Transferred to the energy transition, discourses justify (energy) technologies, institutions and behaviours.

In order to systematise the positions and conflicts in the energy transition discourses, a concept is applied that classifies different dimensions of attitudes towards the energy transition. Attitudes within the energy transition are complex processes because of their relation to different technologies, goals, risks and chances. Therefore, it seems necessary to systematise these different dimensions for the analysis of attitudinal processes as well as for the investigation of discourses. For the development of this systematisation, the multidimensional research concept by Schönauer [24] is applied which was developed for a conceptualisation of attitudes towards industry. This concept divides attitudes into three dimensions: goals, instruments and consequences. Along these dimensions and its subcategories, Schönauer [24] examines statements on the object of attitudes to attain a multidimensional assessment. Central question in the dimension of goals is the intensity and extensity of the implementation of the object 'industrial production'. In this context the category 'extensity' means the responsibility for the realisation of objectives, and the category 'intensity' concerns the extent and extent of the realisation of these objectives. The category of resources is concerned with the evaluation of the instruments by which the objectives are to be achieved. Finally, the third output dimension of the consequences includes the outcomes of the various instruments. These are subdivided into the category of economic/technical and ecological effects [24]. This multidimensional research concept can be transferred to other objects, so that it represents a suitable conceptual framework for a differentiated consideration of the dimensions of the energy transition process and discourse.

Matching the discursive approach with the multidimensional research concept raises the possibility to capture and differentially analyse arguments on the macro/meso level and attitudes on the micro level as well as their correlations. The attitudinal dimensions of energy transition are conceptualised based on the model of Schönauer [24] (Figure 1). While the categories of the dimension 'goals' and 'consequences' are transferable from the original model, but extended by the category 'social consequences', the categories of the dimension 'instruments' are adapted to the object 'energy transition'. The instruments used to achieve the goals are very diverse as they include different sectors (electricity, heat, mobility) and also range from using technologies and phasing out energy technologies to various stakeholders involved in the implementation of the energy transition goals (companies, NGOs, citizens, politicians, etc.). The presentation of the instruments in Figure 1 is therefore certainly not comprehensive and can be extended with further instruments. Yet, the instruments are of particular relevance for the acceptance of the energy transition because they frequently cause discussions and conflicts. While there is a broad acceptance in the population of the basic goals of the energy transition, there is no agreement on the way to achieve these goals. This can be explained by the consequences which come along with the various instruments. The success of the implementation of new instruments is therefore related to the other dimensions – goals and consequences.

Schönauer's empirical results reveal that especially the consequences have a strong impact on the global assessment of the attitude object. The results of a partial correlation analysis indicated a high correlation between the overall assessments, the instruments and the consequences. The dimension 'goals' is not highly correlating with the global attitude but is strongly connected to the dimension of consequences [24]. Also Zaunbrecher *et al.* [18] identified environmental impact on the one hand and economic and infrastructural consequences on the other hand as the two conflicting poles in evaluating energy technology. This in turn can be the reason for ambivalent overall evaluation of technologies.

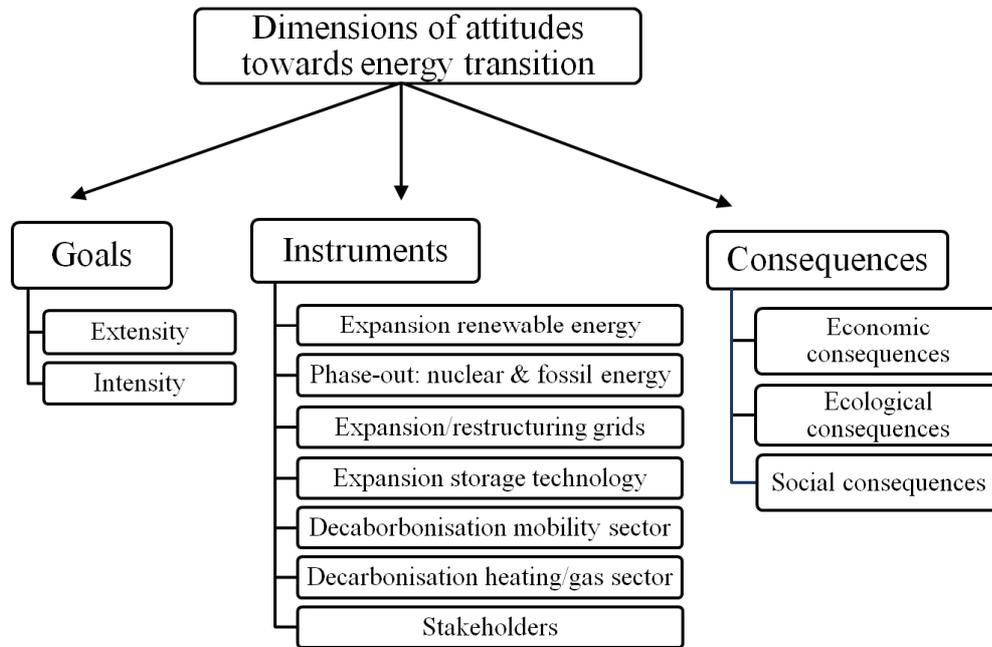


Figure 1. Dimensions[†] of energy transition (own illustration based on Schönauer [24])

These findings are consistent with the dominant discourses on the German energy transition. The German energy transition occurs on a timescale of decades and was politically decided within the *Energiekonzept* [1]. The Fukushima accident in 2011 can be interpreted as shift towards the German energy policy consensus. The discussion about whether Germany should phase out fossil and nuclear energy has been replaced by discussing the best way to achieve full energy supply by renewable energies [29]. Since then, not the general energy transition goals were object of conflict, but the intensity to achieve the targets of the energy transition, more particular the level of ambition and the specific design of renewable energy expansion [30, 31]. Leipprand [30] identified two main discourses which have emerged over the course of time that dominate in German parliamentary debates on energy policy: the ‘energy transition discourse’ and the ‘energy mix discourse’ persist “under the shared discursive ‘roof’ of Energy Transition” [30; p 45].

The ‘energy transition discourse’ focuses on environmental concerns and claims for fundamental changes in the existing energy system, decentralisation of the energy system and use of renewable energies. Established energy companies are perceived as actors who are merely interested in securing their profits. This discourse is led by ‘the proactive coalition’, which includes above all environmental NGOs and business associations and the Green Party [30]. In contrast, the ‘energy mix discourse’ considers environmental and climate challenges, but also focuses on economic feasibility regarding energy supply and energy security. The tenor is that holding up energy supply security, Germanys’ industrial competitiveness and affordable energy prices is not realistic without fossil energies. This discourse is led by ‘the reactive coalition’, including above all conventional energy companies and industry associations as well as the Christian, Social and Free Democrats Parties [30]. Slowly phasing out fossil energies is justified by labour-market and economic arguments [32].

The discursive consensus bases on the need to fight climate change, but apart from this, ‘[t]he persistent differences in the stories that are told by parliamentarians [...], all under the heading of energy transition, suggest that conflicts are far from solved. These

[†] The term ‘dimension’ refers to the concept of attitude by Dütschke *et al.* [7] to measure the attitudes towards the German welfare state.

conflicts now center on the implementation rather than the overall feasibility and desirability of the transition’ [30; p 45]. Buschmann and Oels [33] identify the German energy transition as ‘a clear case of the (discursive) institutionalisation of a decarbonising trajectory’ [33; p 11] with a parallel and not yet overcome carbon lock-in. With the election of the party Alternative für Deutschland (AfD) to parliament in 2017, the context has changed, since the discursive consensus is interrupted by climate-sceptic voices. As a result, changes in the main discourses are to be expected, but are not yet taken into account in the present study.

The attitudinal research concept as well as the central conflicts within the two discourses on the German energy transition underline the importance of economic and ecological consequences. Based on these findings, the authors assume social acceptance of the instrument ‘Transformation of the gas network via hydrogen and CCS’ to depend on its (discursive) connection with economic and ecological consequences.

RESEARCH DESIGN AND METHODS

The stakeholders’ points of view are of central importance for this study as they reflect different social objectives, interests and motivations. The stakeholders can be seen as multipliers, which are crucial for the formation and progress of social debates on energy transition and determine public discourses. Stakeholders like companies, industry associations, environmental associations or consumer advisors make themselves heard in order to assert and establish their views and interpretations, whereby they essentially shape and determine the public debate [25, 28]. To cover the different social positions, stakeholders of the four societal subsystems politics, economy/industry, civil society and science or at intersections between the systems were identified (see Table 1). The systems have different functions, according to which the stakeholders act.

The level of awareness as well as knowledge are relevant variables for technology perception and acceptance. Accordingly, the awareness and knowledge of the interviewed stakeholders is highly relevant for the interpretation of their statements. Since in the present study, the interviewed stakeholders were defined as experts, the focus of the selection process was to ensure that they were experts in at least one of the key issues ‘CCS’, ‘H₂’ or ‘acceptance of energy infrastructure’. The expertise of the interviewees from energy companies and industry focused more on the technologies, while the expertise of the interviewed civil society stakeholders focused more on the social acceptance of the technology and infrastructure. In this way, a comprehensive view of positions and conflicts arising from decarbonising the gas infrastructure via hydrogen and CCS is obtained.

Table 1. Selected stakeholders and their function (own illustration based on Renn and Zwick [25])

Societal subsystems	Stakeholders	Function	Interviews (N = 10)
Economy	Companies	Pursue economic interests, thematic positioning depends on economic interest	Representatives of: Federal ministry Competence centre for energy
Politics	Political stakeholders	Decision makers, define the political and legal framework for energy and climate policy	Hydrogen organisation Environmental NGO Consumer organisation
Civil society	e.g. NGOs, civil associations	Represent public opinion	Association for technical professions Industrial association
Science	e.g. universities, research institutions, institutions for knowledge transfer	Influence public opinion, dependent on public/private research funds	Company for: Energy production Energy transport Energy Storage

The authors conducted explorative interviews ($N = 10$) with the above mentioned stakeholders (see Table 1). The interviews included following topics:

- Evaluation of H₂/CCS technologies to decarbonise the energy system;
- Experience with and evaluation of technology acceptance in society;
- Experience with public participation during planning processes;
- Information and communication needed to evaluate technologies.

The interviewed stakeholders were assured of anonymity. The interviews were transcribed and analysed using the method of thematic coding. Based on theoretical considerations, categories were developed and further differentiated and adapted during the analysis [34]. By applying a qualitative research method, the analysis of the interviews is inductive, flexible and data-driven with the aim to generate and develop descriptions, interpretations and explanations. Every argument is equally valued, independent of the frequency of its mention [35].

EMPIRICAL RESULTS

The stakeholder interviews reveal challenges and risks as well as opportunities and strengths of implementing H₂/CCS chains in Germany. The necessity to address climate change and therefore to reduce CO₂ emissions is common sense among all stakeholders. But the interviews indicate different positions and assumptions on how to achieve reduction of CO₂ emissions.

The ones promote a fast phase-out of fossil energies and prevention of CO₂ emissions through sufficiency, efficiency and consistency, the others promote a fast implementation of CCS to save time for phasing-out fossil energies next to instruments of especially efficiency and consistency. These two opposite positions – in particular represented by the environmental organisation on the one side and the industry on the other side – are in line with one of the central conflicts of the energy transition represented in discourses: whether energy transition is based on a radical change from fossil energies to renewable energies or whether fossil energies also play a significant role next to renewable energies in the long term.

Regarding the hydrogen part of the H₂/CCS chain, argumentation about hydrogen technology is not discourse specific but compatible with both the energy transition and the energy mix discourse. The most important question in this context is whether the energy system will focus on one or more than one energy carrier as in Germany, hydrogen technologies are competing with electrical applications. Technology-openness is more or less shared position of the stakeholders.

“[...] commitment to a single energy source ‘electricity’ will not be effective in the future.” (Industry II: 00:19:32-7)

“Actually, we are open to technology, which is why we do not have a clear opinion on hydrogen and batteries either.” (Environmental NGO: 00:12:09-5)

All stakeholders realise the necessity to act quickly to achieve the climate goals, but are stating political and legal uncertainty. From their perspective, a legal and political framework is needed to invest in development and expansion of technologies and energy infrastructure, but focusing on different instruments.

Significantly greater differences exist in technical feasibility.

“[...] from our perspective, [CCS] is technically covered.” (Industry II: 00:29:55-8)

“[...] because somewhere [the CO₂] is still there when you’re honest. You just hope that it [the CO₂] will stay there for a long, long time, but actually it’s difficult.” (Consumer association: 00:09:01-5)

“[...] for an infinitely long time, I imagine [CO₂ storage] to be technically virtually impossible [...]” (Environmental NGO: 00:41:45-3)

While industrial stakeholders evaluate technological feasibility of H₂/CCS chains mainly positive – technological challenges play a rather minor role when assessing H₂/CCS chains – environmental and civil stakeholders express clear concern about the technological feasibility regarding the permanent storage of CO₂.

Ecological and economic consequences from stakeholders' perspective

On the level of consequences, economic and ecological consequences as well as social consequences in the sense of social acceptance became apparent as main challenges during the interviews. The relevance and prioritisation of the challenges differed between stakeholders. The central line of conflict seems to be running between the ecological and economic consequences.

Ecological consequences. The stakeholders acknowledged the general potential of reducing CO₂ emissions as opportunity and strength of H₂/CCS chains, albeit to varying degrees. Ecological consequences of H₂/CCS chains and sustainability concerns are mostly identified by the environmental organisation. Environmental based argumentation clearly sets its focus on prevention of CO₂ emissions and taking new paths instead of decarbonising via CCS and is in line with the energy transition discourse.

“Because our point is the reorganisation of economic structures away from fossil energy carriers and a technology like CCS is of course not helpful for us, because it basically supports the existing structures [...]” (Environmental NGO: 00:06:11-2)

While the stakeholders have controversial perceptions of the benefit to decarbonise fossil energies via CCS, the benefit of decarbonising bioenergy-induced emissions is rather met with approval, even by stakeholders with non-industrial background. In this context, a link between the energy transition discourse and the energy mix discourse regarding CCS seems to be possible.

Speaking about industry-induced CO₂ emissions, several industrial stakeholders point to effects of carbon leakage – the relocation of industry to countries with lower emission requirements and thus an overall increase in emissions.

“You can't say: let's stop [the industrial burning process] in Germany, because it is so harmful to the climate. Because then we import it from [other countries]. That's what we call 'carbon leakage', and that does not help the environment at all, on the contrary, it only has disadvantages, because then even more CO₂ is emitted and CO₂ is a global issue [...]” (Industrial Association: 00:58:55-6)

Regarding the hydrogen part of the chain, the difference of evaluation is made by the source of hydrogen. While green hydrogen fits in the requirements within the energy transition discourse, blue or grey hydrogen – which is produced through fossil energies – does not. Nevertheless, the construction of a hydrogen infrastructure provides the opportunity to integrate renewable energies and therefore may be acceptable from an environmental perspective.

Another argument concerning the ecological dimension are environmental hazards caused by interventions in the landscape for the construction of new infrastructure. This argument refers to new large-scale infrastructure projects in general and relates likewise to infrastructure for renewable energies (e.g., construction of wind turbines or

expansion of power grid) as to new infrastructure for fossil energies (e.g. restructuring of natural gas grid).

“[...] that’s the dilemma we're in sometimes. We want [climate action]. Only the planning process is frequently not good enough and does not fit in with the objects of [natural] protection. That is why we have adopted the philosophy that a nature-friendly energy transition must be strongly associated with energy saving and energy efficiency. The focus must actually be on this and not just on substituting fossil fuels for renewables, because space is already scarce.” (Environmental NGO: 00:23:11-8)

Ecological consequences and sustainability are recognised as central factors for social acceptance. Several stakeholders perceive a general aversion to fossil energies because of its contribution to climate change and its finite availability.

“But if we talk about gas, many think immediately of natural gas, which is seen as fossil, which is bad in many discussions because it is fossil.” (Industry II: 00:29:36-0)

Economic consequences. New large-scale infrastructure and the implementation of new technologies require high investments. Yet, competitiveness and energy supply have to be secured and energy costs affordable. Therefore, the issue of cost distribution needs to be addressed. Consequently, economic feasibility is one main aspect problematised by nearly all stakeholders, but with different justifications. Regarding energy costs and competitiveness, economic based argumentation focuses rather on continuing the existing structures. This is mainly based on the assumption of energy industrial stakeholders that in the near time, security of energy supply at reasonable costs is not possible without fossil fuels. Evaluations from environmental and economic stakeholders diverge on the matter whether security of energy supply is feasible without fossil energies.

“This expansion which we are now making with renewables in order to provide the amount of energy and to cover power peaks, [...] is not particularly efficient, it becomes extremely expensive.” (Industry II: 00:29:36-0)

Besides, following the energy mix discourse, CCS is a possibility to reduce the urgency of phasing-out fossil energies to achieve the energy transition goals. Due to current debates in Germany, this mainly concerns coal.

“[...] it is not understandable why I should not, at least in the bridging, in the transitional period, basically include coal.” (Industry I: 00:25:54-1)

Economic feasibility not only concerns competitiveness and affordable energy costs, but also costs for implementing H₂/CCS chains. On the one hand, costs for CCS are evaluated too high because of a missing business case and a missing political and legal framework. On the other hand, especially for energy-induced emissions, costs are not seen as justifiable by environmental and social stakeholders and are assumed to compete with costs for the expansion of renewable energies or other more sustainable solutions.

“It is the question, what is actually important to us. Are the climate targets important to us or are the costs closest to us and we will not do [CCS] because the costs are simply too high? Because there will never be a business case and because nobody in Germany might be interested in the fact that a possible CO₂ price is that high or that the emission certificates are that expensive.” (Federal Ministry: 00:29:35-5)

From the perspective of industry, CCS is absolutely necessary to achieve energy transition goals and to maintain competitiveness and employment.

“[...] ‘opportunity’ may not be the right word, because like I said, [...] it is simply the case that CCS has to deliver a relatively high proportion in order to achieve these CO₂ reduction targets. Therefore, it is not an opportunity, it is simply a necessity.” (Industrial Association: 01:00:56-9)

In the context of industry induced CO₂ emissions, CCS is not completely rejected even by the opponents. This consensual attitude mainly refers to arguments of competitiveness of energy-intensive industry in Germany that is supported by stakeholders from different sectors. This presents again a possible link between the energy transition discourse and the energy mix discourse.

“But that’s a scenario where I don’t think we can completely rule out CCS, that’s what we want. If we want to achieve climate targets and [...] we want to stay well below 1.5 degrees, then of course it must also mean that it must somehow work without everything having to be shut down overnight. And here, CCS may be more relevant at industrial sites than at power plant sites.” (Environmental NGO: 00:14:02-5)

All stakeholders recognise high investments for new infrastructure as major challenge for implementing new energy technologies. Using existing infrastructure was unanimously pointed out to be an important aspect. Next to positive effects on the economic feasibility, it is assumed to positively affect social acceptance and environmental sustainability.

Social consequences from stakeholders’ perspective

Social acceptance is one of the main challenges recognised by all stakeholders. In transferring their experience to H₂/CCS chains, main challenges in terms of social acceptance is seen in the requirement of new infrastructure, in the lack of social acceptance of CCS technologies and in the perception of H₂ technologies and CCS as risk technologies. Social acceptance of H₂/CCS chains from stakeholders’ perspective is analysed on three levels. The first level is about the general acceptance of decarbonisation by H₂ technologies and CCS as part of the energy transition. The second level is about the acceptance of the implementation and its consequences. The third level concerns the acceptance of the planning process of the implementation and the acceptance of relevant stakeholders – like perceived fairness of the planning process and trust in stakeholders.

Acceptance of decarbonisation by hydrogen and CCS as part of the energy transition. On the general level of acceptance of H₂/CCS chains to decarbonise the energy system, stakeholders expect a lack of acceptance. The reason for this evaluation lies in the CCS part of the chain and its combination with fossil energy carriers. CCS technologies are expected to be associated with fossil energy carriers and competing with the expansion of renewable energy carriers. In this context, CCS to decarbonise industry-induced emissions is assumed to be more accepted than CCS to decarbonise fossil energy-induced emissions.

Although the H₂ part of the chain is assumed to be more accepted than the CCS part, the type of H₂ is assessed to be relevant for acceptance. Green hydrogen is supposed to be more accepted than blue or conventional hydrogen, because on a general level – as most stakeholders pointed out – renewable energies gain the highest acceptance of energy technologies in Germany. With this assumptions, public acceptance is following the energy transition discourse.

The stakeholders evaluate public knowledge about CCS and H₂ technologies as rather low. Knowledge about H₂ technology in the society is assessed to be low due to its low market penetration and absence in the everyday life of consumers. Nevertheless, it is assessed that many have heard of it before and have a rough idea about it. The technology is marginally discussed in public, mostly within the context of mobility. CCS technologies are assumed not to be present in current public discussions.

Several stakeholders draw attentions to contradictions that – from their perspective – are present in society. These contradictions concern consistent demand for energy, absence of acceptance for fossil energy carriers and technologies and yet, no acceptance for infrastructural consequences of renewable energies. Some stakeholders consider a general lack of social acceptance regarding energy technologies and/or large-scale infrastructure for a contradiction, which is among others attributed to a lack of knowledge:

“[...] if someone would accept to be at home with candles for two days, without electricity. There is no acceptance. On the contrary. The expectation is that electricity or any energy carrier is 100% available every minute. In my opinion, there is a lack of information.” (Industry II: 00:26:54-5)

Acceptance of the implementation and its consequences. On the level of implementation and consequences of an H₂/CCS chain, stakeholders mainly referred to risk perception of the technologies and infrastructural consequences. Several stakeholders referred to previous CCS projects, especially on-shore CO₂ storage in Germany, that have been rejected. Main reasons for the rejections were its perception as hazard sources due to possible leaks and seismic risks. Risk perception of CO₂ capture and transport is assumed to be lower, but still present.

The expected acceptance of H₂ technologies is different between the stakeholders due to different assumptions regarding public risk perception of H₂. One stakeholder describes rather positive feedback and open-mindedness about H₂ as energy carrier in the mobility sector. Reservations regarding the technology are more related to aspects of technology reliability and availability at acceptable costs than about risks and safety. Other stakeholders expect a high level of risk perception because it is perceived as highly explosive substance and therefore risky in its application.

“There’s that connection with the zeppelin, of course. Isn’t that dangerous? Isn’t that a bomb? But it’s something that’s more likely to play a minor role. [H₂] is perceived rather positive and this connection with renewable hydrogen is what already has relatively wide acceptance.” (Hydrogen Organisation: 00:25:46-0)

Regarding H₂ storage technologies, stakeholders noticed that social perception is rather positive because of their relevance to renewable energies. In contrast to natural gas storage sites, which partly are associated with high risks for residents and environment, H₂ storage sites and electrolyzers have not raised acceptance problems thus far. However, this could also be because currently, H₂ storage sites don’t have the same dimensions as natural gas storage sites. The second main aspect regarding acceptance of H₂/CCS chains is seen in the degree of adaptation of infrastructural consequences. In this context, especially new pipeline infrastructure was assumed not to be accepted and to cause Not In My Back Yard (NIMBY) effects as well as concerns about landscape and environmental protection.

All stakeholders think that avoiding new large-scale infrastructure and using existing infrastructure is very relevant to increase acceptance. Nevertheless, some stakeholders indicate that using existing infrastructure is not automatically increasing acceptance:

If new risks are associated with infrastructural retrofitting and modification, acceptance will be just as low.

“Well, of course, if you use existing infrastructure that hardly requires any intervention, that’s of course always a big argument in favour of acceptance. But if you want to transport CO through that pipeline or other things that would be publicly relevant, that are regarded as toxic, then of course it is of no help [for acceptance] that you use existing infrastructure.” (Association for technical professions: 00:46:51-5)

Several stakeholders draw comparisons between pipeline construction to transport CO₂, respectively, H₂ and power line construction. Referring to the rejection of power line construction in large parts of Germany, same trends are expected regarding the construction of a CO₂ or H₂ pipeline. Furthermore, several stakeholders expect a mix up of CO₂ or H₂ pipelines with the constructed but not operating CO pipeline of Bayer AG in North Rhine-Westphalia in 2009. They pointed out that the pipeline evoked strong protests in the local population, mainly due to high risk perception. Transport via ship and/or lorry are assumed to be more accepted and suggested as possible alternatives.

Although CO₂ capture is assessed as less relevant for social acceptance, some differences of the capture technologies were remarked: in contrast to oxy-fuel technology, post combustion capture takes larger construction works and brings a visible and significant change of the existing plant. Therefore, acceptance-relevant aspects may occur because of construction sites and changes in the landscape.

Controversial perceptions regard the ‘legitimacy’ of missing social acceptance on the implementation level. Thinking on previous CCS projects in Germany, one stakeholder sees the risk assessment storylines as pretended arguments for individual interests:

“[...] so it was always said CCS is dangerous, or CO₂ storage is dangerous. [...] there were two reasons for refusing CCS. One was NIMBY and the other was [...] we don’t want CCS, because we don’t want coal. With the argument that [CCS] is so insanely dangerous, we have also robbed ourselves of the possibility of using it in the industrial sector.” (Federal Ministry: 00:16:27-8)

At this point it becomes clear that, with regard to social acceptance, a very contradictory argumentation is applied that can be observed in principle in the discussion and implementation of the energy transition: on the one hand, the citizens follow the transition discourse, on the other hand, with regard to the NIMBY effect, a slow step-by-step implementation as it is intended in the mix discourse, is necessary.

“[...] we can see that everyone is in favour of the renewable world when you look at surveys so commonly. But as soon as the closer neighbourhood is influenced by it [...] the opinion changes.” (Industry III: 00:26:04)

Acceptance of procedures and relevant stakeholders. In the interviews, it is recognised that trust and credibility in stakeholders is essential for public acceptance. Thereby, some stakeholder groups are more trusted by the population than others. These groups are especially (environmental) NGOs and local stakeholders, for example local politicians and local investors who are attributed to represent local and civic interests. In contrast, non-local stakeholders and large (energy) companies are less trusted due to a lack of this attribution. Several stakeholders see it as a dilemma, because stakeholders who have financial resources for investments often are not the trusted ones.

“The problem is that many things that need to be solved in this energy system can only be done by large companies, because only they have enough money and resources to

do it. [...] They have to do a task, but then face a population that is very critical [...].” (Industry II: 00:49:04-5)

“For an investor who comes completely from outside it is more and more difficult, because it is assumed that he has completely his own interests, while as soon as it is more about local actors, they have it a bit easier, because if they say we want to do something for the region, then at least more people believe that [...].” (Competence Centre for Energy: 00:35:33-4)

Next to project or technology acceptance, the importance of acceptance of planning processes is emphasised by one expert. Which stakeholders are part of the planning process and if there is a possibility for public participation is assumed to have crucial impact on its acceptance. Yet, the interviewed stakeholders have controversial perceptions of public participation in planning processes. Not all stakeholders experience it as helpful and necessary for the implementation of large-scale infrastructure projects.

Also, the meaning of communication is differently interpreted by the stakeholders. Several stakeholders have a more rational understanding that it is necessary to educate people, that peoples arguments are contradictory or that the lack of acceptance is based on NIMBY.

“[...] at the latest, when the pipeline passes the front garden, this general acceptance [of H₂] will be over, this no longer works today.” (Industry I: 00:51:41-4)

“Not everyone has a background in the energy industry and has detailed knowledge, so in the end you also have to adjust the level of communication, the content, according to your audience, in order to be able to transport as much information as possible at first, in order to give people the opportunity to clear up any concerns they may have at the beginning.” (Industry III: 29:28)

Contrary, stakeholders who are experts in the field of social acceptance make clear that sensitivity is important and concerns and fears of citizens must be taken seriously. It should not be a strategy of justification or relativisation, but the possibility for the population to classify the project.

In addition, risk perception is expected to be high for hydrogen as well as for CCS technologies. Finally, stakeholders assume that rising costs for energy would negatively affect acceptance regardless of whether the energy is renewable or fossil.

DISCUSSION

This study set out to better understand social acceptance of H₂/CCS chains in Germany. Therefore, the authors applied dominant discourses on the German energy transition and a multidimensional concept of attitudes to embed and link acceptance of this specific technology in general debates on energy transition and infrastructural changes. Stakeholders' perspectives, gathered from explorative interviews, present and clarify argumentation regarding H₂/CCS chains alongside goals, instruments, ecological and economic consequences and social acceptance. Furthermore, connectivity to the discourses 'energy transition' and 'energy mix' is revealed (Figure 2).

While pursuing the common goal of addressing climate change, the main diverging positions regard the instruments to achieve reduction of CO₂ emissions. Regarding H₂/CCS chains as an instrument in the context of the energy transition, the stakeholder interviews indicate controversial as well as consensual perceptions. The assessments range from rejection of an H₂/CCS chain to deeming it absolutely necessary. Central controversial aspects and therefore challenges concern economic,

environmental consequences, social acceptance and political and legal uncertainty. The evaluation of relevance and prioritisation of these challenges differ between the stakeholders. While the attitudinal concept includes economic, ecological and social consequences, legal/political uncertainty extends the model and could be integrated as reliability of goals.

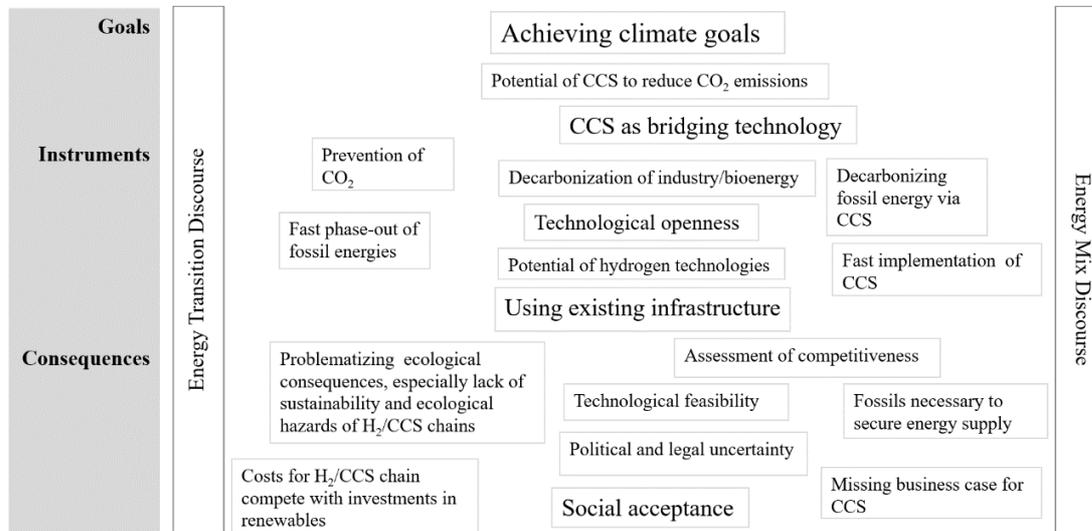


Figure 2. Stakeholders' argumentation regarding hydrogen and CCS chains alongside goals, instruments and consequences and connected to the discourses 'energy transition' and 'energy mix'

The general conflict concerns the strategy towards a low-carbon society, especially how quickly fossil energies are phased out. Argumentations behind these positions refer among others to economic viability versus environmental protection and different assumptions on dealing with societal demand and needs as well as whether security of energy supply is feasible without fossil energies. Thus, the evaluation of H₂/CCS chains represents the central conflicts within the discourses on energy transition, identified by previous studies (e.g. in [30, 33]). From the perspective of the energy transition discourse, CCS supports the existing 'fossil' structures rather than creating a transition. From the perspective of energy mix discourse, it enables a slower phasing-out of fossil energies and secures security of energy supply and competitiveness. The main conflict along environmental and economic consequences has already been found in previous studies [18, 24].

Regarding the stakeholders' evaluation of social acceptance, it becomes apparent that on the level of instruments, arguments are mainly in line with the energy transition discourse and require the expansion of renewable energies. Also, regarding acceptance of stakeholders, representatives of the energy transition discourse are assumed to be the more trusted ones. On the level of consequences, the stakeholders' evaluation of acceptance involves elements from the energy transition as well as from the energy mix discourse. These concern for example new infrastructure in the context of renewable energies as well as in the context of fossil energies (natural gas, CCS) which is expected to be met with refusal.

NIMBYism [36] was mentioned in several interviews as a reason for lack of acceptance. Nevertheless, the concept of NIMBY was critiqued in several studies in the last years for being too reductive in explaining (lack of) social acceptance [37, 38]. Personal factors, project-related factors or place-based factors were identified as further variables explaining social acceptance [37, 39]. It therefore seems important to transfer a more differentiated understanding of acceptance in the discourse of relevant (industrial) stakeholders.

Alongside opposing and conflicting arguments within and between the social areas of politics, economy/industry and society, there are also consensual perceptions and intersecting sets in evaluating H₂/CCS chains. A general openness to technologies is the more or less shared position of the stakeholders in the context of the energy transition. Especially the hydrogen part of the H₂/CCS chain represents a compatible element for positions within the energy transition discourse, because it represents a link to the expansion of renewable energies. But also in the CCS part of the chain, consensual perceptions were identified. Albeit to varying degrees, all stakeholders acknowledged the general potential of reducing CO₂ emissions as opportunity and strength of H₂/CCS chains. The consensus must, however, be limited to the decarbonisation of industry-induced or bioenergy-induced emissions via CCS. The higher approval of CCS in the context of industry processes and biomass than in the context coal-fired plants was already found in previous results on social acceptance [7]. Considering this restriction, H₂/CCS chains seem to be a scenario, which is linkable with ecological arguments and the energy transition discourse. On the infrastructural level, using existing infrastructure is preferred from an economic and ecological perspective. These consensual perceptions indicate chances to approach solutions for broad acceptance by stakeholders who are assumed to represent the different social perspectives in the context of the energy transition.

The interviewed stakeholders were experts in the field of energy technologies with a focus on CCS technologies and/or H₂ technologies or in the field of social acceptance with a focus on energy technologies or large-scale infrastructures. Industrial perspectives from further energy technologies (e.g., renewable energy industry) have not been included. Furthermore, climate-sceptical voices were not considered. This has to be taken into account when interpreting the results as it would certainly result in an even broader range of evaluation of H₂/CCS chains.

CONCLUSIONS

The aim of the present study on acceptance of H₂/CCS chains in Germany was to reveal chances and risks of implementing new (energy) technologies in the context of the energy transition. The results mostly confirm the current state of research on attitudes towards CCS, H₂ technologies and large-scale infrastructure as well as on discourses on energy transition. In addition, new insights supplement and specify it in regard to the specific framework of H₂/CCS chains. Applying the two dominant discourses, the study revealed links to the energy transition discourse as well as to the energy mix discourse. Applying the attitudinal concept, the authors exposed consequences of the implementation as the main conflicts of H₂/CCS chains within the energy transition. These consequences are closely related with the targets of the energy transition, more specific with the level of intensity to pursue the targets. With this approach, central aspects relevant for social acceptance of implementing technologies within the energy transition were identified which can serve as a blueprint for further technologies and instruments.

To conclude, resolving these conflicts is not an easy task, but there are some possible starting points. For example, the compatibility of hydrogen technologies with renewable and fossil energies or the restriction of the use of CCS only for certain applications (industry, bioenergy) represent compromises which are supported by different stakeholder groups and which provide a balance of ecological and economic arguments. Furthermore, the importance of technology openness must be taken into account in further (political) decisions.

Finally, even if social perception and acceptance of technologies often appear to be contradictory, it is nevertheless important not to rashly reduce these arguments to selfish, irrational and uninformed motivations of residents. It is important to take these seriously and to include them in implementation processes in form of transparency and participation.

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