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TRANSITION TOWARDS A LOW-CARBON ECONOMY THROUGH GAS INFRASTRUCTURE MODIFICATION – ECONOMIC AND SOCIOLOGICAL INTERDISCIPLINARY INSIGHTS

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ABSTRACT

To evaluate potential infrastructure modifications in the energy sector that are required to mitigate climate change, interdisciplinary approaches are essential. Since the discussion is largely shaped by technical aspects, our objective is to combine a macroeconomic and sociological approach to exceed this perspective. As a result, we generated new insights by using the example of gas infrastructure modifications in Germany. These results would not have been possible with a single discipline's analysis. Focusing on relevant stakeholders, we examined five aspects that we regard as crucial determinants of future developments. By doing so, we discussed the value of interdisciplinary analysis in the context of assessing the transformation towards a low carbon economy. In conclusion, combining different disciplines' approaches revealed to be promising in at least two ways: first, to generate new insights and second, to provide feasible policy recommendation. To sum up, our paper exposes that interdisciplinary synergies have a large potential to strengthen research on factors that foster or hinder the transformation towards a low-carbon economy but also to foster social science in energy research.

Keywords: interdisciplinary energy research, macroeconomic scenario analysis, social acceptance analysis, stakeholder perspective, H_2/CCS chains, challenges energy transition

1. INTRODUCTION

The transformation towards a low-carbon economy to mitigate climate change comes along with infrastructure modifications in the energy sector. For a successful implementation of these modifications, evaluations are needed that exceed technical aspects. [1–3] Otherwise, research can result in policy recommendations that have little chance of being implemented and thus miss the intended goal. [4,5] Accordingly, we argue that assessing the transition towards a low-carbon economy is an interdisciplinary task. It is thus required to include further perspectives. The ACT project 'ELEGANCY – enabling a low-carbon economy via hydrogen and carbon capture and storage (CCS)' extends the technical discussion by including economic, sociological and legal aspects. [6,7] In this paper, we show how to combine a macroeconomic and sociological approach by using the case study example of ELEGANCY on gas infrastructure modifications in Germany. We apply a qualitative macroeconomic scenario analysis and a sociological acceptance analysis to get aggregate insights for the transition towards a low-carbon economy. While the former approach is rather theoretical and analytical describing dynamics and drivers, the latter is rather theoretical and empirical and adds explanations by providing reasons and arguments. Combining these two approaches leads to new insights regarding the assessment of gas infrastructure options, whereby we will focus on five aspects: (1) stakeholder dynamics, (2) CCS technologies, (3) hydrogen

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technologies, (4) technological feasibility, (5) infrastructure modifications. To conclude, we discuss the increment value of our methodical and conceptual approach.

2. METHOD

The aim of the macroeconomic approach is to assess factors and conditions that hinder or foster the transition towards a low-carbon economy and society. We do so by evaluating different infrastructure options in terms of their political and economic feasibility. [6] Therefore, we apply a qualitative scenario approach and develop six macroeconomic scenarios [5] which we classify as socio-technical scenarios [8]. The scenario development was based on brainstorming methods, interconnection, consistency analysis and cluster analysis and was accompanied by participatory feedback workshops. [9] In contrast to economic forecasting, that identifies the most likely development [10], scenario development does not predict the future [11,12]. Instead, it aims to identify a wide range of plausible future developments [13] including extreme futures [14] without assigning probabilities [15]. As a tool of thought [11] for policy and decision making [16], scenario development allows to consider non-economic aspects, complexity, stakeholder perspectives and uncertainties [5].

The aim of the sociological approach is to reveal social attitudes, interests and motivations as well as knowledge and experience regarding H_2/CCS chains in the German society. Based on the current state of acceptance research on CCS, H_2 technologies and pipeline infrastructure, a systematization of acceptance was elaborated. [6] To empirically examine social acceptance, explorative interviews with relevant stakeholders were conducted in a first step. The stakeholders are located at intersections between politics, economy/industry and society (N=10). [9] The interviews reflect positions and conflicts of stakeholders who can be seen as representatives of public discourses. [17] In a second step, an online survey on social acceptance will provide representative data.

To generate interdisciplinary insights that exceed a single discipline's perspective, we exchanged knowledge and mutual feedback between the macroeconomic and sociological approach at different steps (as displayed in figure 1). We chose an interdisciplinary collaboration to complement the different approaches and results. Although both approaches aim to evaluate the infrastructure options and have a special focus on stakeholders, they differ in other aspects which offers interesting synergies. While the macroeconomic approach is rather theoretical and considers stakeholders in a broader sense, the sociological approach provides empirical data from stakeholder interviews. These data enriched the understanding of dynamics and actions that where identified through the process of scenario development by providing insights of potential arguments and reasons from different stakeholder groups. Both approaches assume stakeholders to play a crucial role for the transformation towards a low-carbon society, which was shown in different ways. The scenario development benefited from feedback on how to adequately represent societal aspects such as social acceptance. Additionally, we discussed the interview and survey design as well as the completeness and desirability of the scenarios. Finally, we combined our results to get new insights, as we explain in the next section.

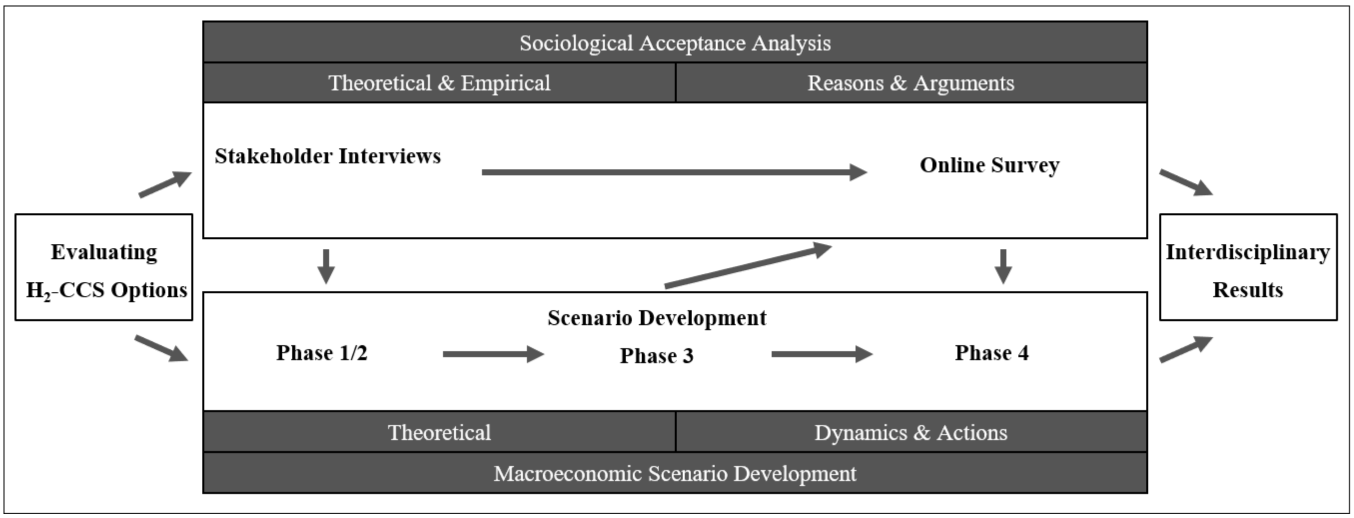

Fig 1 Combination of the macroeconomic and the sociological approach

3. RESULTS

The assessment of feasible gas infrastructure modification in terms of a successful implementation, depends on the (future) development of different factors. Thus, we combine sociological and macroeconomic results to generate interdisciplinary insight on five factors that we regard as crucial determinants of future gas infrastructure. This list of aspects is chosen for the purpose of this paper and is not meant to be exhaustive.

3.1 *Stakeholder dynamics*

As the macroeconomic socio-technical scenarios revealed, stakeholder dynamics play a crucial role. Referring to the key factor analysis this becomes clear. 5 out of 23 key factors, which we distilled from 111 influence factors with an interconnection analysis, represent stakeholders: (1) political decision makers, (2) economic lobby groups, (3) citizens & society, (4) public interest groups, (5) investors in gas sector. Additionally, analyzing the different scenarios showed that stakeholder dynamics play a crucial role since they mainly determine the overall level of transformation and the scenario setting. In the end, these factors are decisive for the questions which infrastructure options are most realistic to be implemented. Furthermore, stakeholder dynamics play a crucial role in determining social acceptance. Especially trust and credibility in stakeholder groups within an implementation process are essential factors to gain social acceptance. Thereby, the interviewees assume some stakeholder groups to be more trusted by the population than others. These 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 a dilemma in this circumstance, because stakeholders who have financial resources for investments often are not the trusted ones.

3.2 *CCS technologies*

The scenarios provide insight on key factors that influence the development of CCS applications in Germany. Since carbon capture is most economically effective for large point sources such as coal power plants, CCS can be regarded as bridging technology. The usage depends on phase-out scenario for coal-based power, but also on legal requirements on national storage. To put it in a nutshell, both national and international feasibility is crucial, since storage abroad represents an alternative option to storage in Germany. The feasibility does, however, not only comprise legal, political and economic considerations but depends mainly on social acceptance. All interviewed stakeholder groups recognize advantages of CCS as a bridging technology. Nevertheless, there are several controversial perceptions regarding the determining factors of CCS projects. Above all, it is controversial whether decarbonization via CCS is decelerating the phase-out of fossil energies. In this context, CCS applied on process-induced emissions in industry and bioenergy-induced emissions is even accepted by environmental stakeholders, while CCS used to decarbonize fossil energies is interpreted skeptical. Next to the stakeholder acceptance, also acceptance of CCS in the German population is assessed to be low, mainly due to perception as a high-risk technology.

3.3 *Hydrogen technologies*

When assessing the feasibility of different gas infrastructure options, not the type of hydrogen, but the total usage of H_2 revealed to be crucial. Whether investments in the modification of infrastructure are made, depends on the demand of hydrogen. In our scenarios, the demand is determined by developments in the mobility and heat sector. Additionally, the demand to feed in H_2 to the gas grid is relevant for H_2 power plants and Power-To-Gas plants. However, for social acceptance of H_2 infrastructure and applications the type of hydrogen is relevant. Green hydrogen is assumed to be more accepted as it is based on renewable energies. While hydrogen technologies in general seem to be rather accepted, its application is relatively unknown in society and is competing with alternative technologies, for example electrical applications.

3.4 *Technological feasibility*

Against the initial intuition, the 'availability and progress of technology' plays a minor role from a macroeconomic perspective. As the interconnection analysis revealed, this key factor has only very little influence on other factors. Instead, it is the actual usage of technologies that is crucial. The usage is influenced, e.g., by the openness towards new technologies and governmental subsidies. In the same vein, technological feasibility and maturity is important for acceptance. Regarding CCS and H_2 technologies this factor is evaluated positive, at least by the interviewed technology experts. Instead of technological challenges, rather legal and political challenges were named as constraining factors when it comes to the investment in technologies and new infrastructure. All stakeholder groups stated openness towards technologies and the necessity to concentrate on more than one technology as important to secure energy supply.

3.5 *Infrastructure modifications*

New large-scale infrastructure is recognized as an important factor of acceptance. Consequently, using existing infrastructure is assessed desirable by the stakeholders. Regarding the H_2/CCS chain, existing natural gas infrastructure can be used for hydrogen technologies. For the CCS part of the chain, new infrastructure is needed which therefore represents a constraining factor for acceptance. Similarly, the scenario analysis showed that the higher the overall level of transformation, which includes the social acceptance, the more feasible it is to implement extensive infrastructure medications.

4. DISCUSSION

Combining different disciplines' results is a promising way to improve the assessment of climate change mitigation strategies [1], such as infrastructure modifications. The following insights, which we distilled from combining sociological and macroeconomic results, serve as a good example: (1) Stakeholder dynamics are the central factor for a successful infrastructure implementation from an economic and sociological perspective. (2) For CCS, the relation to fossil energy and its phase-out mainly determines the economic feasibility and the social acceptance. (3) For investments in hydrogen technologies, the legal and political framework is important. However, for the success of hydrogen technologies both total demand and its perception as 'green' energy carrier are decisive. (4) Progress and availability of technology plays a minor role for the investment in infrastructure, whereas openness towards technology as well as the political and legal framework are essential. In contrast, it is important for social acceptance. (5) The smaller the overall level of transformation, the less feasible it is to implement extensive infrastructure modification. The smaller the degree of modification, the higher is the social acceptance and the chances of a successful implementation.

As H_2/CCS chains can present a promising measure to reduce CO_2 emissions, these findings are especially relevant in the light of the German *Energiewende*. Like there were great synergies in combining our sociological and macroeconomic analysis, interdisciplinary exchange should not be limited. Especially for climate change issues, it seems useful to integrate different disciplines such as engineering, law, politics, meteorology. For the case study example of ELEGANCY, we thus also consider results from a technical [9] [19]and legal perspective [18]. In a next step, all disciplines' results are combined to assess the infrastructure options and subsequently to develop a best case scenario. [9] This rather practical assessment is accompanied by basic research on H_2 thermodynamic properties and property models at Ruhr University Bochum (see, e.g. [19]) and by work on a broad variety of technical and multidisciplinary aspects carried out by our European partners, which aims at validating the point of view that technical understanding and progress is no constraining factor.

Research that exceeds a single discipline's boundary poses several challenges such as conflicting understanding of the problem and of key issues [20], different use of language [21], methodological and scientific standards [22], fight for competences [23] or fear of failure [24]. Thus, interdisciplinary work can be unpleasant for the researcher him/herself as it requires to leave the discipline's protected comfort zone [20]. Referring to our sociological and macroeconomic approach, it is challenging to work on a joint synthesis in the sense of interdisciplinarity instead of generating rather multidisciplinary results [25]. In the end however, the interdisciplinary work is of great value for scientific progress and allows for learning by broadening one's own horizon. This value becomes clear referring to the results concerning the five aspects. As an example, the multidimensional nature of the role of hydrogen types rests uncovered without combining our discipline specific results. Otherwise, different conclusions were drawn.

5. CONCLUSION

The aim of the paper was to show how to combine a macroeconomic scenario development approach with a sociological acceptance analysis to assess different infrastructure modifications for Germany. By using synergies between the two approaches, we identified factors that foster or hinder a transition towards a low carbon economy that exceed a single discipline's perspective.

The need to include different kinds of perspectives to capture the complexity and uncertainties related to climate change mitigations strategies such as infrastructure modification is hardly deniable. Especially stakeholder dynamics and social acceptance issues should not be neglected in the process of political decision-making. In case of not considering all relevant aspects and discipline perspectives, there is the risk that policy recommendations lead to misguided results.

In this sense, our joint approach contributes not only to improve research on energy strategies and thus offers support for decision-making. It also helps to establish the perspective and research of social science in a still technically dominated discussion.

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