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Universities as Change Agents in the Hydrogen Transition? A Case Study in Germany and Australia

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ABSTRACT:
This study examines the role of universities in hydrogen projects regarding the social acceptance and legitimation of the hydrogen transition. Attention is paid to their contribution to socio-cultural sustainability through education and knowledge transfer. The study is based on the assumption that technological innovation alone is not sufficient to ensure acceptance of hydrogen technologies. Instead, universities play a central role in fostering acceptance for hydrogen projects by acting as knowledge brokers, legitimacy providers, boundary organizations/moderators, and regional anchor institutions. Education is considered as a core element of socio-cultural sustainability because it supports capacity building, skills development, and long-term acceptance.
The findings draw on data from the "HydroExchange" project conducted by the University of Koblenz and the University of Western Australia. The empirical material includes interviews, project documentation, and network analyses. The analysis reveals that universities most often act as knowledge brokers and co-creators of legitimacy. Moderator roles are less common but important for trust-building. Education and transfer activities strengthen regional anchoring and can be reinforced through participatory formats. Accordingly, this study examines how universities contribute to the hydrogen transition through their roles as knowledge brokers, legitimacy providers, moderators, and regional anchor institutions.

Keywords: hydrogen transition; universities; third mission; social acceptance; network analysis

1. Introduction

Research and development are key factors in accelerating economic growth and ensuring its sustainability, and universities play a central role in creating prosperity in society and the knowledge economy (Kangas et al., 2020). Today, however, universities no longer fulfill only the traditional roles of research and teaching. Increasingly, knowledge transfer to and with society, politics, culture, and the economy is also understood as an independent and equally important area of activity. This so-called "third mission" describes the expectation that universities, as publicly funded institutions, should make a concrete contribution to solving societal challenges and promoting economic development (Compagnucci & Spigarelli, 2020; Maassen, 2024). Universities can and should therefore act as change agents (Hansen & Lehmann, 2006; Peer & Stoeglehner, 2013), since "Institutions of higher education are critically important places of knowledge production, knowledge perpetuation, and knowledge dissemination. In addition to these conventional associations of universities and knowledge, institutions of higher education have unique potential to encourage synthesis and integration of different types of knowledge and to

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enhance the application of knowledge to social change. With regard to a societal transition toward sustainability, […] universities can be perceived as a potential change agent" (Stephens et al., 2008, p. 320).

This understanding of the role is reflected in the strategic missions of many universities, where research, teaching, and transfer are not conceived as separate domains. Rather, they are in a close interrelationship: scientific findings flow into societal contexts, while conversely, societal issues provide impetus for research and teaching. Knowledge transfer thus becomes a connecting element that embeds universities more deeply in societal processes. At the same time, the underlying understanding of knowledge transfer is changing. A linear model, in which knowledge is "passed on" from the university to society or the economy, is increasingly being replaced by a dialogical and reciprocal understanding. Transfer therefore no longer means mere mediation, but rather exchange, collaboration, and joint knowledge production with non-academic actors (Etzkowitz & Leydesdorff, 2000; Wissenschaftsrat, 2016; Hochschulrektorenkonferenz, 2017).

This development is also linked to changing expectations of universities. Today, universities are increasingly expected to contribute to innovation, sustainability, and social cohesion (Maassen, 2024). At the same time, the concept of transfer is expanding in scope: while technological exploitation, patents, and spin-offs were long the primary focus, social, cultural, and societal forms of transfer are now gaining significance (Kanning, 2022).

2. Case Study "HydroExchange"

Researchers from the fields of geography, social sciences, marketing, innovation management, economics, and chemistry at the University of Koblenz, the University of Western Australia, and Weihenstephan-Triesdorf University of Applied Sciences are collaborating on the "HydroExchange" project. The project will run for two years (2024-2026) and is funded by the German Federal Ministry of Research, Technology, and Space. The project combines engineering and chemical perspectives on the development of efficient hydrogen technologies with social science analyses of stakeholder constellations, regional network formation, and global supply chain integration. In addition to scientific synergies, the project aims to strengthen institutional partnerships, for example through mobility programs, joint workshops, and sustainable networking among early-career researchers.

During field stays lasting several weeks in Rhineland-Palatinate and Saarland, Germany, as well as in Western Australia and New South Wales, Australia, between March and November 2025, the researchers conducted 13 expert interviews with stakeholders from business, politics, science, and society, in accordance with the Quintuple Helix model proposed by Carayannis and Campbell (2012). In addition, the hydrogen transition and key players in both countries were examined in detail through document and media analyses. This article focuses on the question of the role of universities in the hydrogen transition. The argument is based on the results of the interviews conducted with stakeholders in Australia, all of whom clearly highlight the importance of social acceptance and the social license to operate in their region during the hydrogen transition, while collaboration with universities and scientific institutions is scarcely mentioned in the

interviews. From a university perspective, the question arises as to how these two statements can be reconciled in relation to the third mission of higher education institutions.

2.1 Hydrogen transition and social acceptance

It is clear that technological innovations alone are not enough to successfully drive the hydrogen transition forward. In addition to the many technical and economic challenges, social acceptance also plays a role in the hydrogen transition (Häußermann et al., 2023; Gordon et al. 2025). Social acceptance can be divided into three dimensions: socio-political acceptance, community acceptance and market acceptance (Wüstenhagen et al., 2007). In the context of energy transitions, acceptance can be understood as a multidimensional concept that operates across different social arenas. At the socio-political level, it concerns the degree to which energy-related policies, infrastructures, and technologies are regarded as legitimate and desirable by the broader public, organized interest groups, and political institutions. At the community level, acceptance is shaped more directly by local perceptions of concrete projects, particularly decisions about the siting of energy infrastructure and their implications for residents, municipalities, and other place-based actors. Market acceptance, by contrast, refers to the extent to which energy technologies and related services are adopted, supported, or resisted by actors within economic exchange, including producers, investors, firms, and end users (Wüstenhagen et al. 2007). Local opposition to energy infrastructure is frequently discussed through the lens of the NIMBY phenomenon ("Not in My Back Yard"). Rather than reflecting a general rejection of a technology, such resistance often emerges when communities perceive the local burdens associated with a project—such as a hydrogen fuel cell power plant—as disproportionate to the benefits they are expected to receive. In this context, community perspectives play a central role: residents' concerns, expectations, and evaluations of fairness can substantially shape public debate, planning procedures, and the eventual implementation of energy projects (Emodi et al. 2021). This definition makes clear that, in terms of social acceptance, all stakeholder groups, according to the Quintuple Helix, play a role in the hydrogen transition.

There are now many studies worldwide on the acceptance of hydrogen in all its forms, for example in the areas of transportation, household use and refueling stations. Emodi et al. (2021) found that most of the surveys were conducted in the United Kingdom, Germany, and Japan. Australia ranks eleventh. These studies highlight that demographic factors, economic factors, governmental policies, psychological needs, environmental awareness, infrastructure construction and social influence are important criteria concerning the social acceptance of hydrogen. Regarding the three dimensions of acceptance, the demographic component is influenced by factors such as the level of education, family size, household structure, and population size. In terms of market acceptance, key criteria include taxes, public engagement, trust in government and industry, and water scarcity. Infrastructure factors, such as land availability and the type of hydrogen produced, are key factors in socio-economic acceptance (Emodi et al. 2021)

It is also clear at the political level that social acceptance plays a key role. As the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) notes: "If public perception is poor, it doesn't matter how good the technology is.

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Perception is reality" (Carr-Cornish et al., 2019, p. 3). Similarly, the European Union states: "Hydrogen technology holds significant potential for decarbonizing energy systems across the whole European continent. However, in Central Europe, a region heavily reliant on fossil fuels (particularly coal and natural gas), the widespread adoption of hydrogen faces various challenges, with social acceptance emerging as a critical factor in determining its success. Public perception, local concerns, and socioeconomic factors all influence the trajectory of hydrogen's integration into the energy mix" (Zdenek 2025, p. 3).

The results of interviews and media analyses in Australia show that, unlike in Germany, the issue of social acceptance—or the "social license to operate"—already plays an important role in the discussion surrounding the hydrogen ramp-up . It can be assumed that the topic of green hydrogen will also be increasingly discussed in Europe, and particularly in Germany, as soon as the hydrogen economy and related projects are scaled up further and the topic consequently enters the public discourse more strongly. Studies on social acceptance in H_2 pilot projects are already available. These findings indicate that trust, transparency, knowledge exchange, participation, and communication play an immense role in social acceptance (Häußermann et al., 2023; Huang & Min, 2025; Vespa & Hildebrand, 2025; Zdenek, 2025). From the perspective of universities as key players in the transition of hydrogen, this raises the question of whether and how universities, in addition to teaching and research in the field of hydrogen, can contribute to social acceptance as part of their third mission. In this context, universities could fulfill their role as change agents. This aspect will now be examined in greater detail, and examples of its implementation will be provided in the conclusion.

3. Methodological Approach

The study is based on a multi-stage methodological approach. In the first step, a literature review was conducted to identify potential roles for universities in the context of the third mission and sustainability. Four key role categories were derived from the literature, which serve as an analytical framework for the subsequent stages of the study.
In a second step, a network analysis of hydrogen stakeholders in Rhineland-Palatinate was conducted to assess the position, visibility, and involvement of universities within the relevant stakeholder network. Building on this, a third step involved examining those hydrogen projects in Rhineland-Palatinate in which universities were or are actively involved. In this process, the existing project websites and project reports, where available, were analyzed using a deductive qualitative content analysis based on predefined categories and keywords according to the four categories and their associated keywords. The identified projects were then evaluated according to the four previously developed categories to determine the roles of the universities in the respective projects.

3.1 Literature Review

A structured conceptual literature review was carried out to identify and systematize the different roles ascribed to universities in processes of transformation and innovation. The review was designed as a conceptual synthesis rather than a comprehensive bibliometric mapping. Its purpose was therefore not to provide an exhaustive overview of all publications on universities and innovations, but to identify

recurring conceptualizations of university roles and to develop an analytical typology for the empirical part of the study.

The search strategy was based on combinations of the term "university" with the keywords "change agents", "third mission", "knowledge transfer", "innovation", "co-creation", "sustainability", and "transformation". The literature search was conducted using Google Scholar and Scopus. Only publications from the period 2000 to 2026 were considered, with a thematic focus on sustainability-related research. This delimitation was intended to capture the increasing academic attention paid to the societal role of universities in the context of sustainable development, regional transformation, and collaborative knowledge production.

The initial search yielded 90 publications. After removing duplicates and clearly unrelated records, 52 publications were screened based on title and abstract. Publications were included if they addressed universities or higher education institutions in relation to at least one of the following themes: sustainability-related transformation, innovation, third mission activities, knowledge transfer, regional development, co-creation or collaborative knowledge production. After title and abstract screening, 33 publications were selected for full-text review. The final analytical corpus consisted of 20 publications.

The selected publications were analyzed using qualitative content analysis. In a first step, passages referring to the societal, regional, innovative, transformative, or collaborative functions of universities were identified and extracted. In a second step, these passages were coded thematically. The coding combined deductive and inductive elements: deductive codes were derived from the initial search themes, such as third mission, knowledge transfer, innovation, co-creation, and transformation, while inductive codes were added when the literature introduced additional or more specific conceptualizations of university roles. The coding process focused on recurring arguments, role descriptions, institutional functions, and relationships between universities and societal actors.

In a subsequent step, similar codes were compared and clustered into broader role dimensions. These role dimensions were refined through an iterative comparison between the emerging categories and the reviewed literature. This procedure resulted in four distinct but partly overlapping university roles. The typology thus emerged from a structured synthesis of the reviewed literature and provided the analytical basis for the empirical investigation of how universities are represented in the selected project materials.

3.2 Social Network Analysis

In addition, a social network analysis was conducted. Networks can be understood as structures consisting of multiple actors and the relationships between them. A characteristic feature of social networks is thus that the analysis focuses not only on individual actors but, above all, on their relational connections (Wasserman & Faust, 1994). For the present study, a network map of actors in Rhineland-Palatinate was created (Fig. 2) who are involved in hydrogen projects. The aim was to map the state's hydrogen landscape and gain an overview of key actors and their involvement in projects. The data was based on the Rhineland-Palatinate Energy Atlas, which documents existing and planned hydrogen infrastructure activities in the state. The analysis focused specifically on the actors, including companies, clusters, and networks, as well as educational and research institutions. The information was transferred into an edge list in which project leads and

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project partners were identified on a project-by-project basis. This was used to evaluate a one-mode network, i.e., a network in which all nodes belong to the same level of aggregation and relationships between similar actors are analyzed (Wasserman & Faust, 1994). In this case, these are organizations connected through joint hydrogen projects. The relationships were modeled as directed, as a distinction is made between project management and involved partners. An edge runs from the project management to each participating partner organization. The network analysis thus makes it possible to visualize the structure of project-related connections between key actors in the hydrogen landscape in Rhineland-Palatinate.

3.3 Qualitative Content Analysis

In this process, the existing project websites and project reports, where available, were analyzed based on the four categories and their associated keywords. The analysis followed a deductive coding approach derived from the conceptual framework outlined above, which distinguishes four analytically separable yet empirically interrelated roles of universities: knowledge brokers, legitimacy providers, moderators or boundary organizations, and regional anchor institutions.

For each category, a set of keywords, recurring formulations, and thematic references was used to identify how universities were positioned and represented within the respective projects. The analysis focused on whether universities were described as translating and disseminating knowledge across societal sectors, providing scientific authority and credibility, facilitating dialogue and cooperation among heterogeneous actors, or contributing to the long-term embedding of projects within regional innovation and governance structures. The keywords thus did not function merely as isolated search terms, but as heuristic indicators for broader patterns of role attribution. This made it possible to systematically compare the available material across projects and to assess which university roles were particularly visible, emphasized, or only marginally articulated. At the same time, the analysis accounted for the fact that these roles frequently overlap in practice. Individual passages could therefore be assigned to more than one category, reflecting the intertwined character of universities' contributions to transformation and innovation processes.

The purpose of this analytical procedure was not to measure the actual effects of university involvement, but rather to reconstruct how the role of universities was discursively framed and made visible in the projects' publicly available self-descriptions and reports.

4. Results

The results of the three analyses are presented below. First, the four roles of universities are explained. Next, the results of the network analysis are presented, and finally, the current roles of higher education institutions in Rhineland-Palatinate are outlined.

4.1 Results of the Literature Review

In today's processes of transformation and innovation, universities can be

described in terms of four analytically distinct yet closely intertwined roles: as knowledge brokers, legitimacy providers, boundary organizations/moderators, and regional anchor institutions (Fig 1). As knowledge brokers, they translate, aggregate, and disseminate scientific knowledge across different sectors of society. They provide data, expertise, and analytical frameworks, making complex scientific findings actionable for politics, business, and civil society. Their contribution lies not only in the production of knowledge but, above all, in its translation tailored to the audience and its strategic communication (Kangas et al., 2020). Furthermore, universities function as providers of legitimacy. Due to their institutionally anchored scientific authority, their relative independence, and their commitment to verifiable procedures, they can lend additional credibility and public justifiability to projects, decisions, and innovation processes. In this role, they help stabilize trust in controversial or knowledge-intensive fields by validating expertise, drafting expert opinions, substantiating assessments, and providing orientation knowledge (Cash et al., 2003). Through this role, universities can in turn also gain legitimacy: "In any case, the university's potential for changing established relationships, creating new ones, and thus playing an active role in the ecosystem by shifting collective understanding is also functional for its legitimacy" (Wooten & Hoffman, 2008).

As moderators, universities also assume a mediating role between actors—for example, from civil society, business, and politics—with differing interests, knowledge bases, and time horizons (Parker et al., 2012). They create forums, real-world laboratories, dialogue platforms, and other cooperative formats in which understanding, negotiation, and joint problem-solving become possible. Their function here lies less in dictating content than in structuring exchange and learning processes across institutional boundaries (Cash et al., 2003; Trencher et al., 2014). Finally, universities should be understood as regional actors. In this role, they anchor projects and topics in regional innovation and governance structures over the long term. Through education, networking, institutional continuity, and their embedding in regional ecosystems, they create the conditions for sustainability, capacity building, and societal participation: "In the final stage, the university focuses on its engagement with stakeholders in order to participate in the development of the regional innovation environment" (Compagnucci & Spigarelli, 2020, p. 8).

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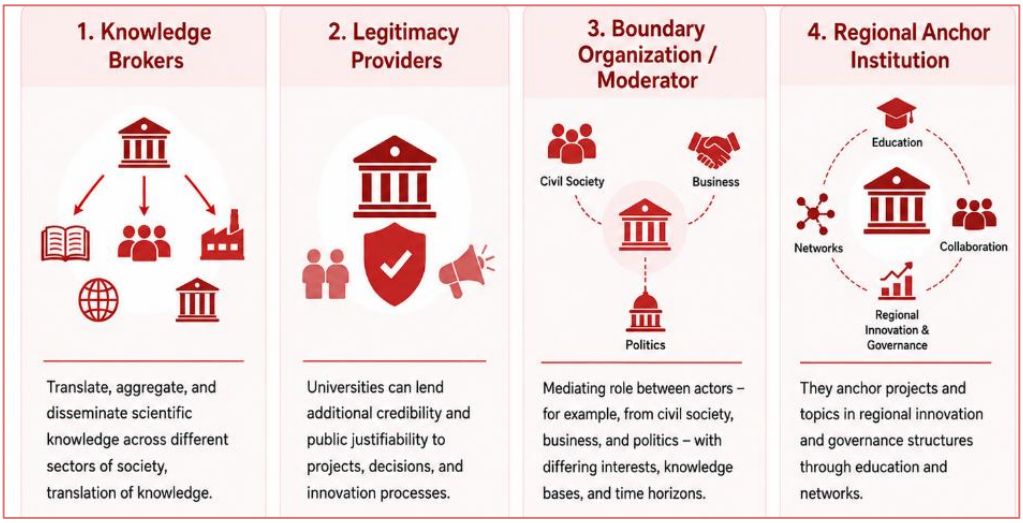

Figure 1. Key roles of Universities in the Hydrogen Transition (own illustration)

In summary, these four roles demonstrate that universities extend far beyond their traditional function as centers of research and teaching and act as central intermediary actors in linking science, politics, business, and society.

4.2 Results of the Network Analysis

The Energy Atlas (Energie- und Klimaschutzagentur Rheinland-Pfalz GmbH, n.d.) is based on data from 22 hydrogen projects in Rhineland-Palatinate listed in this database. Higher education institutions and universities are involved in 13 of these projects, playing various roles and functions, which will be discussed in more detail in the next section. First, the network and various indicators related to Higher education institutions will be analyzed in greater detail. The universities are highlighted in the figure, and it is immediately apparent that they are not dominant players. The analysis of centrality measures illustrates that, overall, the colleges and universities do not play a uniform role in the network under consideration, but rather a distinctly differentiated one. Overall, they appear less as dominant centers of the network and more as selectively integrated knowledge and cooperation actors, whose involvement and influence vary depending on the institution. While universities are thus visible as relevant components of the network, they shape its structure only to a limited extent. The analysis indicates that, in the network under examination, universities generally function primarily as knowledge and cooperation partners, though their role is predominantly supportive and only in isolated cases intermediary in nature. The results thus point to a differentiated higher education landscape within the network: While individual universities and colleges assume networking and, in some cases, bridging functions, other institutions remain rather marginal. Overall, this suggests that universities in the present network should be understood less as dominant control centers and more as actors in knowledge transfer and cooperation with varying degrees of involvement. A limitation of the analysis to be considered is that the source used likely does not fully represent the underlying field of actors. Accordingly, the network map generated from it should not be read as a complete

representation, but rather as a trend-based and heuristic approximation of the network's structure. However, this network analysis suggests an expansion of the university's role as a regional actor. While, by definition, the role of a regional actor initially involves merely participating in networks, the network analysis reveals that universities can also act as active bridge-builders by connecting previously unconnected actors and clusters (Marin & Wellman, 2011).

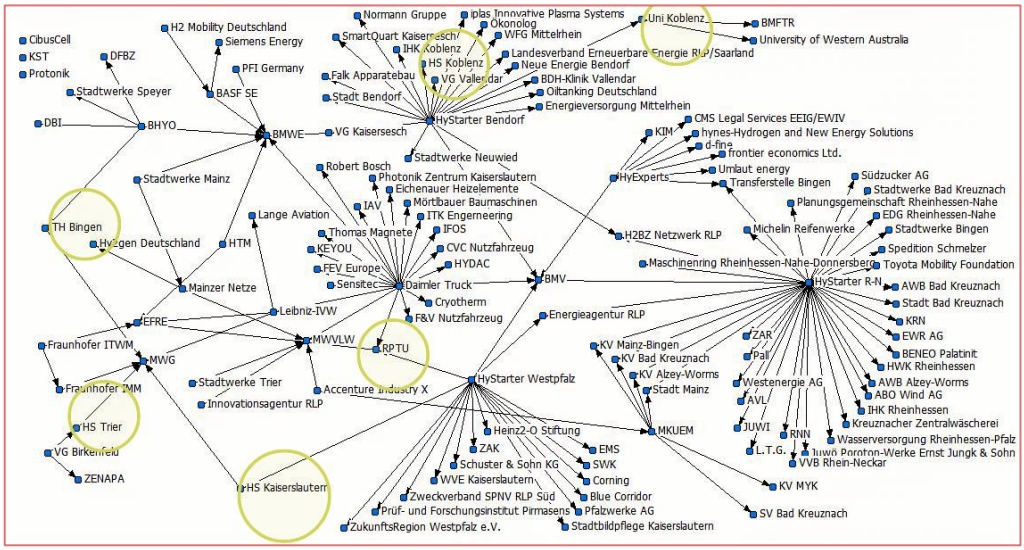

Figure 2. Hydrogen stakeholders in Rhineland-Palatinate, Germany

4.3 Defining the Roles of Universities within the H2 Landscape in Rhineland-Palatinate

Of the 22 hydrogen projects listed in the Rhineland-Palatinate Energy Atlas, 13 involve universities or colleges. The analysis shows that higher education institutions primarily act as knowledge brokers; this role was evident in 12 of the 13 projects. It manifests itself particularly in the testing, analysis, and validation of technological solutions in test benches and pilot plants. Furthermore, in three projects, universities can be classified as legitimacy providers, moderators, and regional actors. As legitimacy providers, they contributed to the social and political embedding of the hydrogen transition through lectures, expert assessments, and scientific evaluations. In their moderating role, they supported the design of exchange and cooperation processes, for example through real-world laboratories, workshops with various stakeholders, or the establishment of a competence center. Finally, as regional actors, they contributed to regional networking and the interconnection of key stakeholder groups in three projects.

Overall, the findings suggest that universities and colleges in the analyzed hydrogen projects are involved primarily through their scientific and technical expertise, while broader intermediary functions are less frequently institutionalized. Their dominant role as knowledge brokers indicates that higher education institutions are especially valued where complex technological development, testing, and validation processes are

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concerned. At the same time, the smaller number of projects in which they appear as legitimacy providers, moderators, or regional anchor institutions points to a more selective involvement in the social, political, and organizational dimensions of the hydrogen transition.

This pattern suggests that the contribution of universities within the hydrogen ramp-up in Rhineland-Palatinate remains strongly shaped by their traditional research-related functions, even though individual projects demonstrate that their role can extend far beyond knowledge production alone. Where universities are involved in communication, stakeholder coordination, or regional networking, they also contribute to stabilizing cooperation structures and linking technological innovation with societal embedding.

5. Discussion

5.1 Summary

The findings indicate that universities are already involved in the hydrogen transition, but their level of participation varies depending on their functional role. In the projects analyzed, universities primarily act as knowledge brokers and, to a lesser extent, as sources of legitimacy. In contrast, their roles as facilitators of interaction processes and as regionally rooted actors remain comparatively limited. This asymmetry suggests that universities are most visible in areas where scientific expertise can be directly translated into technological development and validation. However, the hydrogen transition is not merely a technical process but also a socio-political transformation that depends on trust, communication, and public acceptance. The comparatively weak presence of universities in facilitating and regionally anchoring roles therefore points to a gap between their potential societal function and their actual engagement in practice.

From the perspective of the third mission, this gap takes on relevance. Universities are increasingly expected to contribute to societal transformation processes, particularly by fostering dialogue, supporting collective learning, and collaborating with non-academic actors. The results of this study suggest that this broader role is not yet being fully realized in the context of hydrogen projects. While universities contribute to legitimacy through scientific expertise, their potential to actively shape transformation processes remains only partially realized. This observation is consistent with existing research that highlights universities' ability to function as neutral forums for discussion and as a knowledge broker of social change. However, the empirical findings suggest that such roles depend on specific project structures, incentives, and forms of collaboration and are not automatically generated. Consequently, universities tend to be involved where their technical expertise is needed, while their more process-oriented and socially embedded functions remain contingent and are activated less systematically. At the same time, the results should be interpreted considering the study's limitations. The network analysis is based on project data from the Rhineland-Palatinate Energy Atlas and therefore represents a selective and potentially incomplete picture of the relevant stakeholder landscape. The qualitative and project-based perspective provides insights into specific constellations rather than a comprehensive picture of all activities in the hydrogen sector. Nevertheless, the results offer valuable insights into how universities currently position themselves within

observable cooperation structures and how their roles are distributed across various functional dimensions.

Overall, the analysis reveals that universities are already contributing to the hydrogen transition, but primarily in roles related to knowledge production and validation. Their potential to support the societal anchoring of transformation particularly through facilitation, participation, and regional integration—has so far been only partially realized. Strengthening these dimensions could enhance the ability of hydrogen projects to address not only technological challenges but also issues of societal acceptance and legitimacy. The findings therefore suggest that universities can realize their potential as change agents in the hydrogen transition only if they are not confined to technical knowledge production but are also enabled to shape the social and institutional dimensions of transformation.

5.2 Strength and Limitations of the Case study

The case study in Rhineland-Palatinate should be viewed as an illustrative analysis and represents only a limited snapshot of the hydrogen transition in Germany. Due to the differing industrial priorities across the federal states and the federal structure of research, innovation, and funding policies, the funding landscapes and the development of hydrogen-related projects have evolved differently from region to region. Against this backdrop, it can be assumed that a nationwide survey could yield different results. In particular, the role and involvement of universities in hydrogen projects could vary depending on the regional innovation system, the industrial landscape, and the funding policy context. The analysis draws on a single database, the resulting network should not be interpreted as a complete representation of the hydrogen stakeholder landscape. Rather, it reflects those actors and relationships that are visible within the selected data source.

5.3 Conclusion and Future Research

The findings suggest that universities possess considerable yet still underutilized potential to contribute to transformation processes beyond their established roles in research and knowledge production. In particular, universities may act as important intermediaries in facilitating participation, fostering dialogue among diverse actors, and supporting stakeholder engagement across institutional, economic, and societal boundaries. Their position at the interface between science, policy, industry, and civil society enables them to create spaces for exchange, translation, and co-production of knowledge that are particularly relevant in complex transition processes such as the development of hydrogen economies. Through campus-community partnerships, universities could play a central mediating role in the hydrogen transition by working with municipalities, civil society actors, and local stakeholders to identify regional needs, challenges, and existing knowledge. Such cooperative frameworks make it possible to view transformation processes not solely through a technological or economic lens, but rather to align them more closely with specific local challenges, usage contexts, and societal expectations. In this way, practice-oriented solutions can be developed that are both scientifically sound and socially and spatially embedded. In this context, the social sciences play an important role in the green transition. That discipline is often marginalized or subordinated to the technical disciplines because of widespread techno-optimistic beliefs and attitudes that

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view technology as a kind of panacea for all ills (Blackley & Howell, 2015; Pinheiro et al. 2026).

In addition, the citizen science approach can help involve citizens not only as recipients of technological transformation but also as active co-creators in research and development processes. Through the joint production of knowledge by scientists, municipal actors, and the public, regional perceptions, uncertainties, everyday knowledge, and specific needs can be systematically documented and integrated into the design of the hydrogen transition. This can be particularly relevant where new infrastructure, changing energy practices, or local site decisions require social negotiation processes.

Such a participatory approach can also help strengthen self-efficacy and trust, as citizens experience that their perspectives are not merely solicited but are incorporated into research and decision-making processes. By taking local needs seriously and addressing them with scientific support, universities can contribute to the transparency, legitimacy, and social acceptability of the hydrogen transition. In the long term, this can promote societal acceptance of the corresponding transformation processes.

At the same time, the extent to which universities can assume these broader roles appears to depend heavily on the institutional and regional contexts in which they are embedded. This highlights a tension between ambitious sustainability expectations and the persistence of traditional organizational logics within universities. Universities can only fulfil their role as transformative change agents if their third mission is integrated into their core missions and governance structures rather than addressed through isolated initiatives (Karo et al., 2026).

Future research should therefore investigate more systematically which institutional arrangements enable or constrain universities in expanding their engagement beyond conventional research activities. This includes examining how funding regimes, governance structures, incentive systems, and regional policy frameworks shape the opportunities for universities to participate in transformation processes as facilitators, coordinators, or boundary-spanning actors.

Moreover, comparative studies across different regional and national contexts could provide valuable insights into the conditions under which universities develop more active roles in stakeholder engagement and participatory governance. Such research would help clarify whether these roles emerge primarily from specific funding opportunities, regional innovation strategies, established networks, or broader political expectations placed on higher education institutions. In doing so, future studies could contribute to a more nuanced understanding of how universities are positioned within socio-technical transitions and how their transformative capacities can be institutionally supported.

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