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Building Bridges: An Interdisciplinary (Energy) Research Framework

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Abstract: Given the multifaceted nature of sustainable energy transitions, interdisciplinary research is essential. It serves as a bridge, connecting relevant aspects from diverse disciplines like engineering, sociology, politics, and economics. Through this collaborative approach, we unlock the potential to generate novel findings and drive transformative solutions. However, despite its increasing demand, interdisciplinary research is accompanied by challenges from a funding, working or career perspective. In this paper, we explore the challenges of interdisciplinary energy research using the example of incorporating non-technical aspects into energy system models as a representative investigative approach. At the outset of our investigation, we aim to introduce and thoughtfully evaluate the design of our research framework for interdisciplinary (energy transition) research. By identifying key factors conducive to efficient interdisciplinary research collaboration, we provide guidance for different research communities interested in interdisciplinary energy research.

Keywords: Interdisciplinarity, Energy Transition Research, Research Framework, Non-Technical Aspects, Energy System Models, Open Science, Best Practice

1 Introduction

In today's energy research, collaboration across disciplines has become essential due to the multifaceted and intricate nature of the ongoing energy transition, encompassing technical but also economic, environmental, societal and political aspects [1]. Bringing these dimensions together holds a lot of potential for energy research, as it allows for more pertinent and comprehensive solutions, supporting informed decision-making and avoiding the pitfalls of one-sided policies [2],[3].

However, interdisciplinary energy transition research faces various challenges [4]. From a funding perspective, fewer financial resources are allocated to social science compared to natural science [5]. From a career perspective, it is still more challenging to gain recognition for interdisciplinary research, which is especially important in early career stages [6]. On a practical level, uncertainties exist regarding the content and methodological orientations of the project partners, as well as the development of a shared research agenda that genuinely combines the strengths of individual research approaches while minimizing their

weaknesses. Furthermore, questions about the most effective level of interdisciplinary cooperation and its constraints appear. Given the increase in multi- and interdisciplinary energy research initiatives [7], it seems vital to (re)evaluate and further improve collaborative research approaches. Developing research frameworks is valuable approach to foster effective interdisciplinary collaboration. This is because, framework development raises awareness for relevant aspect that need to be considered, create a mutual understanding between involved researcher and offer guidance for other researcher beyond the project context facing similar challenges (e.g. [8],[9]).

The aim of the paper is two-fold: First, we seek to investigate these interdisciplinary research challenges. Second, we aim to identify best practices for tackling these challenges by providing a framework for interdisciplinary energy research. Building upon the Methodology for Interdisciplinary Research (MIR) framework [10], we address the following research question: What factors need to be considered to foster efficient interdisciplinary collaboration? To do so, we use the example of the interdisciplinary research project nfdi4energy. In Task Area 2, the project aims to incorporate non-technical aspects, such as social, economic and political factors, into energy models since they are currently inadequately represented [11], [12]. While the detailed research plan for Task Area 2 has already been outlined [13], this contribution emphasizes the challenges associated with aligning the research interests and methodologies of the research partners, and therefore reflects on the practical implementation of the interdisciplinary research framework.

2 Method: Extending an Interdisciplinary Research Framework

To address the challenges of interdisciplinary cooperation, a well-coordinated interdisciplinary research framework is indispensable. It ensures that researchers from different disciplines can effectively work together towards common goals. Building upon the MIR framework of Tobi and Kampen [10], we provide a overview of the project phases, augmented with specific tasks. While our focus lies on enhancing interdisciplinary collaboration in energy transition research, the framework is adaptable to various research domains.

The framework comprises five project phases: i) conceptual design, ii) technical design, iii) execution, iv) integration and v) evaluation as well as ten associated tasks. Importantly, these tasks are not a linear process but rather iterative, requiring adaptation based on project dynamics and team requirements. Project evaluation is listed as a separate project phase, arguing that it is important to take time at the end of the project to identify lessons learned and reflect on the added value of interdisciplinary cooperation. However, reflection on the project work and collaboration within the team is a process that takes place throughout the entire project duration.

Project Phase	***Task***	
Conceptual design	1	Define individual and joint research objectives (general)
	2	Define individual and joint research questions (specific)
	3	Define shared vocabularies and concepts
Technical design	4	Plan study and data analysis design (method triangulation)
	5	Make arrangements on data storage and data formats
Execution	6	Define project roles to implement arrangements
	7	Conduct individual analysis
Integration	8	Synthesis of research results
	9	Test and discuss results
Evaluation	10	Reflection on research process

Figure 1. Interdisciplinary Research Framework with Tasks

Although some of the described research steps are common to every (mono)disciplinary research project, the essence of successfully orchestrating interdisciplinary research lies in discerning how these perspectives can be effectively combined to yield to innovative solutions. Given time constraints, this work must be conducted efficiently, necessitating adept navigation through multiple disciplinary lenses. It entails developing research approaches that bridge disciplinary and methodological boundaries, resulting in research outcomes that are unattainable through efforts of one discipline but can only be achieved through collaboration of the interdisciplinary team members.

Still, every research project can be carried out in varying degrees of inter- and multidisciplinarity. By identifying shared research interests and objectives early in the project and agreeing on a level of targeted collaboration, interdisciplinary teams can harmonize their efforts, reduce redundancy, and maximize efficiency. As a result, the outcomes of individual sub-tasks become more accessible and applicable to all project partners, fostering a synergistic environment.

3 Results: Case Study Application

In the following, we apply the research framework to Task Area 2 in the nfdi4energy project to provide a concrete example of its application and describe the challenges identified during the execution of the initial tasks, along with (first) corresponding solutions. To begin, we present a more detailed overview of the thematic context of the task area.

In Task Area 2 we examine the interdependencies between relevant dimensions for energy scenarios and models. In doing so, we draw on the conceptual considerations of political feasibility [2], which consists of technical feasibility, as a necessary precondition and legal, economic and social feasibility as additional aspects. Since techno-economic parameters, such as prices and the share of different types of electricity, are often essential components in energy system models, we mainly focus on the dynamic relationship between aspects related to economic policies, politics and societal sentiments [14],[15],[16]. It is evident that social attitudes and political decisions are not isolated entities but instead influence each other in a complex web of cause and effect. The importance of considering these aspects in energy models becomes evident when looking at the example of the deployment of large-scale wind farms. Technically, the feasibility of these wind farms relies on factors such as wind resource availability, turbine technology, and grid infrastructure. Socially, their acceptance by local communities, potential visual and noise impacts, and perceived benefits plays a critical role. Moreover, politically, the regulatory framework, including zoning laws, permitting processes, and government incentives, significantly influences the feasibility and expansion of wind farms [17]. To bridge the gap between these technical, social, and political elements, we collect and analyze data to explore their interdependencies and account for the constraints imposed by political decisions and the boundaries set by societal acceptance.

In the next step, the presented framework for interdisciplinary research is systematically applied to Task Area 2 of the nfdi4energy project to demonstrate the added value and the lessons learned so far from the project work. Since we are at the beginning of our research project, we focus on the project phases of conceptual and technical design.

Task 1: Defining individual and joint research objectives (general)

Challenges: While the research proposal defines research topics and deliverables for each institute, translating this from theory to practice presents significant challenges. Project members first need to grasp the project and its goals, and then align their own research interests and expertise with it to identify individual research objectives. While it is important for an academic career that researchers pursue discipline-specific topics to establish themselves

in their community, this also inherits challenges to identify joint research objectives. Moreover, this initial "harmonization" phase often leads to confusion and questions regarding deliverable procession and may necessitate adjustments. Additionally, the absence of research proposal authors in the working group and asynchronous filling of research positions across institutes hinder reconstructing the rationale behind deliverables and task-topic links, causing internal information loss in the project. Lastly, making the individual harmonization process of each researcher transparent to colleagues from different disciplines presents another hurdle and has proven to be quite time-consuming.

Solutions: To reduce information loss within the team, it was helpful to invest time in meeting protocols to document the discussed topics and decisions made. This facilitated closing information gaps and integrating new project members into content-related discussions, thereby avoiding redundant meetings. In identifying joint research objectives, it proved beneficial to prepare presentations for the institutional research agenda and to formulate written questions for the colleagues of other institutes. Short presentations serve as effective introductions to information exchange, promoting topic setting within the institute while providing a condensed and structured overview of the research partners' topics and questions. Formulating open questions for team members is useful for reflecting on the information needed from research partners to progress one's work. It aids in structuring individual ideas and concepts and offers a reference point for further discussions.

Task 2: Defining individual and joint research questions (specific)

Challenges: While it is desirable to identify common research questions at the beginning of a project, the first year revealed that it is often difficult to define specific joint research questions from the outset. Although institutional teams have identified their research questions and broad intersections of research objectives among them, formulating joint research questions poses challenges, as the individual research output of the partners is still difficult to foresee.

Solutions: While we have not yet pinpointed specific joint research questions, it is evident that this step requires ongoing reflection throughout the research process. Notably, as concrete research results emerge from a disciplinary perspective, they may serve as catalysts for identifying collaborative research questions.

Task 3: Define shared vocabularies and concepts

Challenges: Among the research teams, establishing a common understanding of energy models and scenarios was one of the first hurdles. As it serves as the shared framework for integrating gathered data and information, it was important to determine the types of models and scenarios available and how the new information could be collectively integrated into them. Furthermore, initial discussions arose regarding the categories of analyzed policies or the concepts of acceptance and acceptability.

Solutions: Despite engaging in discussions to reconcile differing understandings of terms and underlying concepts to establish a shared understanding, the teams reached a consensus to develop an analytical framework for the task area. This framework aims to interconnect individual concepts coherently, forming a cohesive storyline. The framework's design aims to enhance the collective comprehension of the individual concepts while facilitating the identification and exploration of connections pertinent to project objectives.

Task 4 and Task 5: Plan study and data analysis design + make arrangements on data storge and formats

Challenges: As we are just at the beginning of steps 4 and 5, which are closely intertwined, we reflect on these two tasks together. We have noticed that potential problems arise when individual research processes and options for cooperation are not made transparent. This may

impede colleagues in conducting their data collection and analyses, and prevent the utilization of synergies. Moreover, we have realized that the teams in the task area are aiming to work at different analytical levels: namely, at the local level, conducting single and group interviews with citizens, and at the national/international level, creating large-scale datasets [18]. These different scales and methodologies employed by the project partners also result in disparate data formats, which need to be harmonized to integrate them into a shared energy model in the end.

Solutions: Clear communication regarding feasible collaboration types at different project stages is crucial during study design, while maintaining flexibility in the research process. This includes defining 'windows of opportunity' for the integration of new results and methods. Furthermore, to achieve a shared understanding within the team regarding their willingness for conceptual and methodological integration, it seems helpful to establish agreement on the minimum and maximum levels of interdisciplinary cooperation within the team (i.e., which collaborations should definitely be implemented and which are optional). To bridge the gap in analysis scope and data format, we explored how various research methods can complement each other. For example, supplementing local case study findings with a representative survey could validate findings and generate missing data for national datasets, thereby overcoming the scope gap and harmonizing data types.

4 Discussion and Conclusion

The aim of this paper is to raise awareness of the challenges in interdisciplinary energy research projects and to provide a research framework that facilitates efficient collaboration. The application of the framework to Task Area 2 of the nfdi4energy project demonstrated the multifaceted challenges, such as harmonizing research objectives and identifying joint research questions but also revealed initial solutions, such as targeted communication and the definition of collaboration levels, aimed at addressing these challenges. While the framework requires further testing and refinement, it can serve as a foundational guideline for organizing interdisciplinary projects. Future research directions encompass the investigation of additional aspects such as the time expenditure involved in interdisciplinary cooperation, disparities in funding, hurdles in recognition, and uncertainties in coordinating project partners. The ongoing development of the framework will also include methodological tools and best practices on how to address identified cooperation hurdles, following the example of Cohen et al. [19]. In the dynamic landscape of interdisciplinary energy research, such frameworks have the potential to catalyze contributions to dialogue, innovation, and collaboration, intending to encourage reflection on successful interdisciplinary practices.

Author contributions

Conceptualization, N.K., F.M.H ; methodology, N.K., F.M.H; writing—original draft preparation, N.K.; writing and editing, N.K., F.M.H., review M.S., J.L., C.S.

Competing interests

The authors declare that they have no competing interests.

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