Requirements for an Open Digital Platform for Interdisciplinary Energy Research and Practice

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Abstract. Energy systems are changing rapidly and energy research is fundamental to enable and optimize this change involving academics, practitioners, and the public. Therefore, an open digital platform to share knowledge and experiences is crucial for the energy sector. We identify and discuss requirements from 36 semi-structured interviews with various stakeholders for a platform based on five essential elements. The *competence* element enables researchers and developers to find suitable partners for their research and practice projects, and the *best practices* element delivers ideas to structure cooperative energy research. The *repository* element helps to find available data and frameworks for energy systems' simulation and optimizations. Frameworks and models are coupled by using the *simulation* element. Last, results and contents from the energy community can be published within the *transparency* element to reach various interested stakeholders. We discuss implications and recommendations as well as further research directions.

Keywords: Energy research, digital platform, requirements engineering, qualitative research methods, design science research

1 Introduction

Digital transformation is a crucial process in the conversion of the current energy systems for the challenges of post-fossil power generation and supply systems. With the ongoing development in renewable energy generation and flexible infrastructures in the field of energy supply and distribution, the whole system, comprising multiple energy sectors, is continuously changing. The complexity of such multi-modal energy systems subsequently increases [1], which affects modeling and control in several fields, such as cost-efficiency, financial viability, technological push-effects, usability, and technology acceptance. Digitalization and digital transformation describe the process of continuously transforming energy systems to cyber-physical energy systems [2, 3]. This digital transformation of energy systems includes elements of high resilience requirements, interdisciplinary research settings, user acceptance issues and creates the need for collaborative research and collaboration among several stakeholders in cyber-physical critical infrastructures.

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Because the digital transformation does not only address technical aspects, features of the research itself must be considered, such as data management, privacy protection, research exchange, and the integration of the various system' stakeholders. Open science can help to overcome obstacles both in interdisciplinary research [4] and the promotion of young research talents by providing them a fundamental basis of freely accessible knowledge and tools. Thus, it simplifies participation in energy research and helps to produce new results and data more quickly. Therefore, new data management strategies are required in all research fields, e.g., the FAIR (Findable, Accessible, Interoperable, Reusable) criteria [5]. Energy research itself shows the need for a transformation to answer the questions raised by the energy systems transformation.

Besides the aspects derived from digital transformation and the required interdisciplinarity: Energy research involves diverse stakeholders besides scientific researchers, e.g., grid operators or energy providers, but also any citizens affected by the results and interested in energy research. These different stakeholders must be brought together to improve research as well as transfer its findings to the society. By combining research open data management and the involvement of these different stakeholders, redundancies in information can be reduced, usability and acceptance for energy research results can be increased. For this purpose, we propose an open digital energy research and development (R&D) platform. However, past research suggests, that the main challenge in designing such a platform is to meet the envisioned users' requirements, e.g., specific information needs, and apply them to an accepted and successful platform [6, 7]. Motivated by these argumentations, we examine the crucial requirements for an energy R&D platform that must support research activities, especially the collaboration within the energy research community, and foster the practical use of research results.

Since energy research is an interdisciplinary field with multiple links to the practical implementation of ideas from research, the requirements for such a platform should come from multiple stakeholders and carefully investigated. Therefore, we conducted 36 semi-structured interviews with various stakeholders in the energy sector in Germany. Our research follows the Design Science Research (DSR) paradigm [8] with the proposed methodology by Peffers et al. [9], which aims to build meaningful artifacts, e.g., software or tools, to solve real-world problems of organizations and humans in a structured manner. Consequently, we extract crucial requirements for a digital platform that tackle the above-mentioned challenges of the energy sector. Our research serves as fundament for a successful and sustainable technological solution that meets the requirements of the intended stakeholders, and thus ensures its later usage. We aim to answer the following research question (RQ) with this paper:

RQ: What are the critical requirements for an open digital platform to support interdisciplinary energy researchers and practitioners?

The rest of the paper is structured as follows: In Section 2, we introduce challenges in energy research, discuss different platforms already focusing on these challenges and define the platform concept. Based on the methodology, data collection, and analysis, described in Section 3, we discuss critical requirements and implications for an energy R&D platform in Section 4. We describe limitations, identify future research directions, and conclude the study in Section 5.

2 Foundations Towards a Platform Concept

2.1 Challenges in Energy Research and Practice

Energy research is facing multiple challenges both, from practitioners as well as an academic point of view. The energy systems' transition requires the integration of more renewable decentralized energy increasing the complexity of energy systems [10, 11]. Additionally, multi-modal interaction gains more relevance [1]. The digitalization towards cyber-physical energy systems addresses both issues by enabling a new level of automation, like artificial intelligence. As a consequence, the complexity of digital simulations increases even more and their development requires additional technical skills and theoretical background. Keeping results from simulation reproducible presents an additional challenge.

From a social point, the energy systems' transition is a task for the whole society, which will also be effected by it [4]. The participation of citizens is crucial for a successful energy systems' transition because chosen measures must be widely accepted [12]. Therefore, there is a special need to involve citizens early in the identification of meaningful research questions and projects.

Due to the political, societal, and economic relevance of the energy systems' transition, energy research receives extensive funding from federal and state governments. More efficient use of research funds can be achieved by opening models and data, as proposed by Open Science [4]. Using the results of energy research for policy advice results in a need to include transparency in all steps of research [13]. Especially assumptions must be communicated comprehensively [14].

Energy systems provide essential services for social and economic life and thus constitute a critical infrastructure [15]. On the one hand, this adds additional challenges to energy research; on the other hand, this is the reason for the high degree of regulation on energy systems. Therefore, the research heavily depends on the complex interplay of energy markets, and the regulation of the commercial stakeholders, which differs between countries. Also, it is based on basic research results in a typically slow innovation cycle. Early involvement of all stakeholders enables this cycle to be designed in a targeted manner and under the restrictions of all parties involved. The group of stakeholders includes grid operators, electricity suppliers, electricity-intensive industry, and others. Joint and application-oriented research needs to include the various stakeholder groups and results in a need to deal with real-world data from diverse sources, like e.g. markets, private households, or industrial sources [16].

In addition, the science involved is diverse and presents a special feature of energy system research. It includes, but is not limited to, the domains of energy engineering, electrical engineering, economics, computer science, natural and social sciences [17]. This results in the use of a broad range of methods and models from these different fields, which makes it complex to understand and interpret the results. Also, the comparability of research methods and results becomes more demanding [14]. Additionally, a common cross-disciplinary language is often missing [15].

Based on these challenges, we identified five key services, i.e. elements, which must be addressed to support researchers and practitioners in the energy sector: (1)

Competence to help to navigate the interdisciplinary research field and to find suitable industrial research partners, (2) *Best Practices* to get information about successful research projects and to avoid pitfalls in the future, (3) *Repository* to find suitable data sets and software modules, (4) *Simulation* to couple existing simulations and reuse existing software, and (5) *Transparency* to involve more stakeholders in all research stages and to convey the appropriate key research results to all relevant stakeholders.

2.2 Comparison of Related Platforms, Tools, and Frameworks

To get an in-depth view into already existing functionalities, we reviewed existing platforms, tools, and frameworks by exploratory searches in various databases or by own knowledge and present an overview in Table 1. While this review does not claim as to be complete, it serves also as a preparation and knowledge base for the later interview situations with the stakeholders. All presented platforms only deliver parts of the required elements identified in Section 2.1 to tackle the challenges in energy research and practice. By integrating the different functionalities into one platform, close linking and improved interoperability between the different elements becomes possible. Therefore, we aim to examine the crucial requirements for a platform, which covers all named aspects.

Table 1. Overview of related platforms, tools and frameworks addressing certain service aspects

Platform \ Platform Element	*Competence*	*Best Practices*	*Repository*	*Simulation*	*Transparency*
enArgus [18]	x				
Energy Research Center of Lower Saxony [19]	x				
open energy modelling initiative [20]		x	x		
Open Energy Platform [21]			x		
FfE Open Data Portal [22]			x		
Open Energy Modelling Framework [23]				x	
Co-Simulation Model Catalog [24]				x	
Energiesystemforschung [25]					x

enArgus [18] is the central information system for energy research in Germany. It presents an overview of all recent and ongoing energy research projects in Germany and, therefore, addresses the *competence* service. The website provides a search functionality based on a light ontology [26]. While the website gives basic information on research projects, it misses information on the outcomes of the projects, like projects reports, publications, or information on the used software and scenarios. The open energy modelling initiative (openmod) [20] aims to promote open energy modeling in Europe. It includes a mailing list, a discussion forum, and a wiki. The wiki contains information on how research can be done in a more openly, e.g., by describing different licenses. In this way, openmod provides parts of the *best practices* service without linking them to concrete projects or persons. The wiki lists different models with links to source code [16] with limited search functionality. The whole platform addresses researchers as the main user group. Another platform is the Open Energy Platform (OEP) [21]. It aims to improve transparency, reproducibility, and quality in energy research. The platform includes a database on different frameworks, scenario descriptions, and data. All information is searchable and filters can be applied [13]. The OEP offers *repository* services, e.g., by using an application programming interface. An ontology to better describe the energy data is provided and but not yet included in the metadata of data and frameworks [17]. A presentation of the results to recipients other than researchers is out of scope for the OEP [13]. Multiple frameworks exist to build large-scale energy simulations: The Open Energy Modelling Framework (oemof) [23] provides a toolbox that can be used to build comprehensive energy system models. The different parts of the framework can be combined in various ways to perform offline simulation [27]. Co-simulation tools like mosaik, for which multiple open source models are already offered, can also be used as modeling frameworks [2]. Schwarz et al. [24] present a framework to assist in the planning of co-simulation based on semantic knowledge representation. Both frameworks address the *simulation* service idea but only link a few projects using them without referring to their results. Energiesystemforschung [25] presents research results in an understandable way for multiple stakeholders and, therefore, provides a *transparency* service. For further details, the website references to enArgus, which only contains management information and misses technical details.

2.3 Development of a Platform Concept

As the proposed platform will support energy research and practice, we took a detailed look into a typical research process that problem-solving and derives academic and practical implications. By aligning the key services with a research process, it becomes possible to develop the ideas of the key services further and achieve a more useful and problem-solving information technology (IT) artifact, i.e., the digital platform.

Energy research is based on scientific theory and includes insights from practice. Therefore, energy research often follows the DSR paradigm [8] since it is interested in the development of real-world solutions that addresses current problems. Peffers et al. [9] propose six steps for a typical DSR project: (1) problem identification and motivation, (2) requirements analysis and definition of goals, (3) design and development, (4) demonstration, (5) evaluation, and (6) communication. While each of these steps requires multiple of the five key services, i.e., elements as derived in Section 2.1, there are one or two key services for each step, which are especially needed. Therefore, we map each of the six steps to its most important key services, i.e., elements in Figure 1. Since the development of new solutions and concepts in energy systems is iterative itself [10], these steps can be arranged in a cycle. While we focus on linking the different service elements, we propose at least one service element for each key step according to [9]. In the following, each service element is presented in detail.

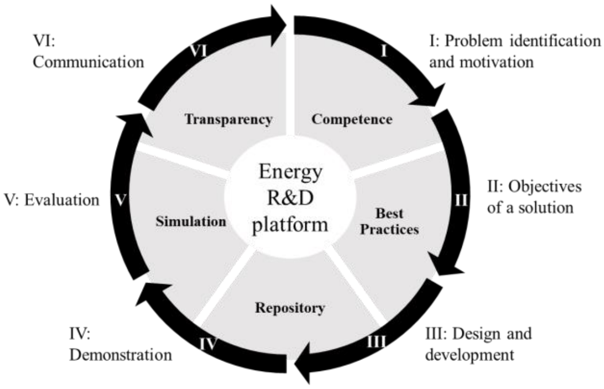

Figure 1. Service elements of the platform and the supported steps of the design research as described by Peffers et al. [9]

Competence. In the first phase of research, starting from a specific research question, the *competence* element can help to identify the right research partners like scientists or companies. *Competence* holds a detailed overview of various institutions and their properties, such as research and methodological focus, as well as publications, research projects, and technical details of laboratories. This element can include information as presented in enArgus but can also be more detailed. Therefore, the overview can be used as a foundation to link models and data to the specified research institutes or departments. A good mechanism for searching and information presented appropriately for suitable partners are the main goals of *competence*.

Best Practices. As a next step, after finding the right research consortium, collaborative research can start. The *best practices* element will provide an overview of good practices in research projects to support the cooperation between the various partners (academics and practitioners). This category offers descriptions of successful research plans and examples of data management in large research projects. It includes information similar to some found in the openmod wiki but links them to concrete examples. *Best practices* mainly address the need of the scientific community but also includes best practices and success stories on the collaboration with industrial partners.

Repository. After defining an appropriate research scenario, finding relevant simulation models and data is the next step for many research questions in energy systems. Sophisticated simulation models and input data already exist for most components in the energy domain. The *repository* element supports the researchers to select the right models and data. Besides the availability of models and data, reusability and adaptability are important aspects. This element builds on the ideas of the OEP. *Repository* extends it by consequently using semantic web technologies and by linking the information to *competence* and *simulation*. Therefore, *repository* defines common interfaces between models and data. Models and data compatible with these interfaces are labeled accordingly to support their use in the *simulation* element. Also, *repository* supports researchers in the process of publishing data and models. *Repository* addresses the needs of researchers in the energy domain, while the data and models will also be usable in business applications.

Simulation. After identifying the right data and models to answer specified research questions, their combination is the next step. Cyber-physical energy systems are complex systems, whose various parts can be represented by independent simulation tools. To couple these with the needed precision regarding simulation time and real-time modeling, a co-simulation is needed and constitutes a research field in itself [2, 28]. S*imulation* helps in that aspect, by addressing typical use cases in interdisciplinary research. The element extends co-simulation tools or frameworks like mosaik or oemof by adding assistance to build simulations including the information from *repository*. The focus especially lies on the combination of open source software and non-open source software as well as on the integration of laboratory infrastructure into the co-simulation. The initially intended users of *simulation* are researchers and businesses, while later an intuitive interface should enable the usage for the public and policymakers.

Transparency. In science, results are regularly published in scientific journals as well as in academic conferences. But it is important to convey new information to the public as well as to businesses. Therefore, the *transparency* element helps scientists to present assumptions for new work as well as to prepare results for various stakeholders. Transparency is important throughout the whole research process [10,11]. So, *transparency* will be used within the whole research cycle and is the place to present simulation plans and discuss them with the scientific community. In this way, the transparency element goes far behind platforms like Energiesystemforschung, which only presents results of research. Besides data and scientific publications, short articles, white papers, and opinions can be uploaded, appropriately supported by illustrative material such links to videos materials. *Transparency* is the place to make this information accessible and addresses businesses, the public, and policy makers.

3 Research Design and Method, Data Collection and Analysis

In this study, we want to examine the critical requirements for an energy R&D platform, see our RQ in Section 1. With a structured requirement analysis, we want to build a meaningful knowledge foundation for the upcoming development phases. Consequently, we concentrate on the first two stages according to Peffers et al. [9], namely problem identification and motivation as well as requirements analysis.

The problem identification in this section is based on the argumentations presented in Section 1 and 2.1.: Digital transformation affects the energy sector with new technical aspects for practitioners, but also researchers with data management and research exchange. While the aim is the conduction and identification of critical requirements for a digital platform to support interdisciplinary energy R&D, the opinions and thoughts of various stakeholders must be investigated with a structured requirements analysis. In doing so, we followed a qualitative approach with expert interviews. Resulting from the initial RQ and the identified platform concept, we developed a semi-structured interview guideline to conduct the interviews with an appropriate level of reliability [29]. Hence, the guideline served as a rough outline, affording both the interviewees and researchers considerable liberty. With this procedure, we gave the participants as much as space to answer our questions, express their ideas and thoughts about the planned R&D platform. Furthermore, we promise confidentiality of the interview transcripts to avoid possible response biases [30]. The interview guideline was structured into seven parts, beginning with starting questions about the energy sector, five question blocks about chances and challenges as well as requirements regarding the five elements of the digital platform and concluding questions. We performed a pretest round to validate the guideline with post-docs and research assistants and adapted the interview guideline on comments derived from this pretest. To recruit interview participants, we looked for experts according to the defined stakeholder groups, i.e., academics and practitioners that have a strong focus on the energy sector. Possible interviewees were identified through the researchers' networks. We looked for interviewees that had profound knowledge about the energy sector as well as their business or research activities. Equipped with such knowledge, they were able to express their impressions and thoughts about the planned R&D platform. We invited identified stakeholders for a possible interview through e-mail or telephone. All semi-structured interviews [30] were conducted in German and lasted between 30 and 90 minutes. Data collection took place from January 2021 until June 2021. In total, we were able to conduct 36 expert interviews distributed over 11 stakeholder groups (see Table 2). After these 36 interviews, we feel that we achieved theoretical saturation since no new content and concepts emerged through additional interviews [31]. Thus, we stopped the interview acquisition and data collection. All interviews were transcribed afterwards and served as primary data for this study.

Table 2. Profiles of the Interviewees

<table>
<tr><th>Perspective</th><th>Interview</th><th>Stakeholder Group</th></tr>
<tr><td rowspan="2">Academic</td><td>I1, I2, I3, I4, I5, I6, I7</td><td>Energy Researchers</td></tr>
<tr><td>I8, I9</td><td>Research Data Management Providers</td></tr>
<tr><td rowspan="9">Practice</td><td>I10, I11, I12, I13, I14, I15; I16</td><td>Manufacturers of Generation Plants and Operating Resources Manufacturers</td></tr>
<tr><td>I17, I18, I19, I20</td><td>Energy Providers</td></tr>
<tr><td>I21, I22, I23</td><td>Aggregators and Prognosis-Providers</td></tr>
<tr><td>I24, I25, I26</td><td>Grid Operators</td></tr>
<tr><td>I27, I28</td><td>Housing Associations</td></tr>
<tr><td>I29, I30</td><td>Electrical Trading Companies</td></tr>
<tr><td>I31, I32</td><td>Industrial Associations and Energy Consulting</td></tr>
<tr><td>I33, I34</td><td>Public Administration</td></tr>
<tr><td>I35, I36</td><td>Heating Engineers</td></tr>
</table>

We analyzed the primary data with qualitative content-analytical methodologies [32]. For data analyses, the software MAXQDA 2020 Analytics Pro was used. First, we went through all available data, the interview transcripts, to identify exemplary statements, i.e., anchor examples. We compare them through constant comparison for similarities in contents and label them with first order codes, e.g., “Statements regarding gaps and requirements”. These statements were accumulated and summarized to areas, i.e., second order themes, like “Requirements” for a specific platform element. As a result, we classified the statements from the interview transcripts as well as the second-order themes to the aggregated dimensions, i.e., platform elements such as *competence*. The results identified for the elements were discussed to receive a meaningful set of critical requirements in an exploratory manner without ranking them. Anchor examples, first order codes, and second order themes for *competence* as well as an exemplary interview guideline used for this study can be found in the online appendix of this article here. Anonymized transcripts and MAXQDA datasets are available upon request by the first author of this paper.

4 Towards a Digital Platform for Energy Research and Practice

4.1 General and Element-specific Requirements

General. It can be stated that the idea of the platform concept was evaluated positively by both, the research-oriented and partially by practice-oriented interview partners. A focus on information, tailored for specific states in Germany, e.g. Lower Saxony, does not appear to be a critical success factor for the platform. However, the interview partners point out that this can be a useful small-scale addition to already existing R&D platforms. Furthermore, in the beginning and in the long run, the added value of the platform must be made visible to the intended stakeholders to ensure the long-term success of the energy R&D platform. Additionally, it must be prevented that the planned platform is not perceived as “yet another” platform by its users. Therefore, a certain liveliness of the content and communication on and through the platform is crucial. To sum up, critical general requirements were the presentation of a clear added value for the users and the provision of up-to-date open-access content to ensure a long-term survival of the planned energy platform.

Competence. For this element, very clear requirements were given by the interviewees. First, several previous sources of information for the interviewees were identified during the interviews. These include newsletters, (offline) conferences, exchange platforms such as internet forums, or simply through already existing personal contacts and networks. In this element, the clear presentation of expertise’ and (research) interests, e.g., linked with social media channels or hashtags on the research platform, were identified as requirements. In addition, the “profiles” must be up-to-date, and the maintenance of this data must be straightforward, otherwise, there would be a risk of no ongoing maintenance by the stakeholders of the platform. Despite the required simple profile structure, the administrators of the platform must ensure the seriousness and information quality of the content. Interview partners will use the *competence* element to find (local) contacts on certain topics, such as photovoltaic systems or electric mobility. In addition, a network or research map, i.e., network representation, must be visible in this element to see who has already collaborated with whom. Furthermore, a kind of matching is advantageous to achieve a better interlocking of scientists and companies. This is considered relevant for future cooperative research projects, for example. To conclude, topical and intuitive maintenance for the presentation of expertise and interests by the users were mentioned as a crucial requirement for *competence*.

Best Practices. During the interviews, we encountered a diversified understanding among the interview partners of exactly what the intention should be and what content should be included in this element. The usefulness of the element is seen especially, but not only, by the scientific interview partners. The element can be useful for beginners, e.g., new PhD students and new employees in science and companies without research experience. For this, the content must be prepared in a stakeholder-specific way. Intrinsic motivation must be ensured to fill the content in this element by the potential stakeholders. The content must be objective and neutral without being self-congratulatory. Administrators of the planned platform should ensure content quality. Content in this element should be iteratively processed. For the ongoing development process, a renaming of the element should be further discussed by the development team. A possible example could be “How to Research” as a working title. Concluding all statements regarding *best practices*, a stakeholder specific elaboration of the contents provided for beginners and experts in academia should be ensured.

Repository. A clear understanding of the element was identified from the requirements analysis. Here, it is crucial that the platform provides, e.g., load profiles or useful dimensioning’s of photovoltaic installations. Harmonized interfaces for simulation models, which form a great potential for reusable energy research software, were considered very positive in the interview situations. In addition, it should be stated which data can be made available to whom for which purposes to achieve trust between users. A basic provision of data, such as anonymized load profiles is viewed as critical, especially by practitioners. An indirect provision of possible data, models, and components on request is needed through the planned platform. Possible filter functions, integrated into the platform, can help to find specific data sets the stakeholders are interested in. Furthermore, a need for a licensing system for the usage of the dataset provided was mentioned by the interview partners. In addition, requirements for the practical relevance of the element were identified: The data sets and models should have clear practical relevance and must be problem-solving oriented. This could also be relevant for interested citizens. In any case, information quality must be ensured as well. To sum up, the platform should be able to deliver tailored data and model descriptions in a user-friendly manner for the intentions of each stakeholder on the platform.

Simulation. The interview partners confirmed meaningfulness and possible opportunities, e.g., economic efficiency calculations with suitable indicators, of this planned platform element. Interfaces to already existing simulation tools, e.g., oemof, should be created, if possible. The need for the platform element is seen more by scientific interview partners since practitioners partially use their own modeling tools. In general, a user-friendly interface for this element was desired to couple and merge various simulation models. To conclude, an appropriate, useful dimensioning and tailoring of the simulations conducted is an advantage to draw specific results from this platform element, e.g., as mentioned by energy provider I19.

Transparency. In the interview situations, a high relevance of the platform element was attested. The platform can help to understand both, the results of research, and its derivations, and to present them more transparently. However, some interview partners found it difficult to define concrete requirements for the planned platform. The platform element can serve to exchange information on trends, e.g., regulatory changes and frameworks, and research results in the energy sector across disciplines. The interview partners saw an opportunity for the platform to develop it into a place for a citizen dialog, where energy researchers can answer energy sector-related questions with or without a geographical focus. The various stakeholders and target groups, should be given specific presentations, graphically and verbally, through podcasts or short videos of the content. Similar platforms such as Bayern Innovativ [33] can serve as further inspiration here. In addition, especially the information quality of the platform compared to standardized results such as Google searches was seen as relevant. To conclude, the development of an exchange platform, e.g., a forum for interested stakeholders about different topics (regulatory changes or technologic trends) and a stakeholder-specific presentation of information regarding the complexity of the content is advisable.

4.2 Implications and Recommendations

From an academic point of view, our study shed light on critical requirements for a digital platform that supports interdisciplinary energy R&D. It serves as a meaningful knowledge foundation for the successful development of an accepted and sustainable digital platform in the energy sector. In addition, researchers from other disciplines who plan such a platform can use our study and its presented requirements as a starting point for other R&D platform development projects. Data collection took place with German-speaking participants. Therefore, our results presented may be only applicable for the German-speaking countries Germany, Austria, and Switzerland. However, this study can serve as a starting point for a discussion regarding efficient requirements engineering for R&D platforms in the energy sector in other countries but also for other (technology-oriented) research disciplines.

An appropriate requirements analysis is an important step within DSR. Therefore, an iterative development process with feedback from stakeholders is advisable. As another implication for research, we identified a lack of precise verbalization on how exactly research results can be made transparent for all stakeholders within the *transparency* element. While some interview participants from the academic side articulated possible communication formats like workshops or physical discussion rounds (I4), practitioners were somewhat unprecise. Therefore, it is advisable to expand the requirements for *transparency* as identified in this study with recommendations from the literature regarding appropriate research communication in other research domains and transfer it to the energy sector.

With our qualitative analysis for several stakeholder groups, we were able to receive a holistic view on the requirements, both, from an academic and practitioner's perspective. Several respondents argued that they are many platforms (with or without) an energy focus available on the internet or elsewhere. As a recommendation for practice, the promotion of the planned platform, especially at the beginning of its life cycle is crucial. A critical mass of active users must be reached and acquired to achieve long-term survival and acceptance of the planned platform. More active users can connect even more stakeholders. A promotion, e.g., in cooperation with ministries and federal agencies to gain attention by the envisioned user groups is therefore advised.

5 Limitations, Future Research Directions, and Conclusions

First, a subsequent implementation and an evaluation are necessary as future research. A practical validation is missing, up to this point. Further research must implement the conducted requirements into a real-world artifact and evaluate it [9]. For this case, already existing tools or source code, e.g., from Semantic MediaWiki [34] for the element *best practices* can be used to implement the functionalities easier. The development of a digital platform that supports interdisciplinary energy R&D is a dynamic and iterative process. In addition, observation of long-term acceptance from stakeholders and success is crucial for such R&D platforms. Acceptance of the platform should be constantly observed and efficiently measured, e.g., with the Information Systems Success Model of DeLone and McLean [35].

Another limitation lays in the selection of interview participants for this study that also leaves room for further research. We conducted interviews with various academics and practitioners. However, we did not incorporate views and requirements from conventional citizens into our study. This stakeholder group is interesting to investigate, since citizens are interested in the contents of the platform for their own purposes, e.g., investing in sustainable technologies like electric vehicles. While the energy systems' transition includes all opinions of stakeholders [12], focus group interviews with citizens regarding requirements to the platform would be advantageous.

We investigate requirements for an energy R&D platform in an exploratory manner through 36 expert interviews with academics and practitioners. With the presented work and results, we lay a meaningful knowledge foundation for the successful implementation afterwards. Furthermore, it fosters the discussion of critical requirements for such platforms among academics and practitioners in the energy sector in Germany or elsewhere.

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