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Enhancing Research Data Management through Use Cases in Energy Research

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Abstract:

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1 Use Cases for Research Data Management Services

To establish Research Data Management (RDM) services and support their use in the research community, use cases for showcasing the services in a typical research project are defined. These use cases include realistic energy research projects with a typical research question. To improve existing workflows concerning RDM, research in the use cases will be conducted differently to the status quo, by focusing on the RDM aspect of the research process and using RDM services from NFDI and beyond. By doing so and providing best practices or tutorials, the use cases aim to improve RDM processes during the whole research life cycle. In the following, the specific use cases are presented including how their outcomes improve RDM services.

1.1 Use Case 1: Co-Simulation in Laboratories with Power-Hardware-in-the-Loop (PHiL)

Co-Simulation is a field that is used whenever multiple domains or topics need to be combined. It is especially interesting when including hardware components. However, many different approaches exist, and it is not easy to exchange components between simulators.

Within NFDI4Energy, the German consortium on RDM in energy system research, a new co-simulation ontology is being developed that shall simplify interoperability between simulators and co-simulation frameworks [1]. This use case will create an example application of this ontology to define the simulation scenario more generically and to demonstrate the simulation as a service (SimaaS) capabilities that shall help to perform such simulations in the future. Therefore, demonstrating the advantages of FAIRly published simulation models and the ease of running predefined simulations based on semantic co-simulation models, that are machine readable.

At the current stage of the research project, the technical boundaries and scenario for the use case are being defined to ensure that the use case is attractive and can test the critical features of the ontology and SimaaS. The current depiction contains the interconnection of a low-voltage power grid, an electric car charger, a photovoltaic system and one or more models of the thermal and electrical properties of buildings. All components will be interconnected via the VILLASnode framework [2]. Moreover, the voltage stability with and without controllable low-voltage transformer is investigated.

1.2 Use Case 2: Long term Energy System Scenarios, Society and Energy Politics

Energy system scenarios provide information about potential future system designs and corresponding transformation pathways. Such quantitative scenarios are derived using energy system models, often applying a techno-economic optimization approach under different types of boundary conditions [3]. From a RDM perspective, the area of long term energy system scenarios thus includes challenges at different levels of the research process. The underlying models integrate various methodological decisions and parameter settings, thus relying on concepts published in the literature and parameters drawn from databases. For transparent publication and communication of scenario results, both the underlying input and resulting output data from the modeling process must be made available in an accessible format. To derive robust information about trade-offs between different options or potential no-regret options, scenarios from different studies must be investigated from an overarching perspective, which poses a challenge when comparing results published using potentially inconsistent data structures [4]. The second use case addresses these issues in the context of research on long-term energy system scenarios focusing on Germany, but also including the European perspective. The different measures aim to provide transparent and open comparative information and data on these scenarios, including input and output data, and a representation of modeling concepts. Scenarios for the transition towards a climate-neutral Germany as well as selected European scenarios will be integrated into the database infrastructure of the Open Energy Platform (OEP) [5], annotated with terms from the Open Energy Ontology (OEO) [6]. This process has already been tested and documented for input and output data from the European CLEVER scenario [7]. Building on work from previous projects like SIROP [8], various scenario factsheets have been integrated into the scenario bundle framework. In the next steps, further scenario data will be integrated and annotated, allowing qualitative and quantitative comparisons over a wide range of existing energy system studies. At a later stage of the work on this use case, concepts for visualizations and interactive elements will be developed, facilitating the communication of the resulting analysis to a wide range of stakeholders [9].

1.3 Use Case 3: Distributed Simulation in Distributed Energy Systems

Distributed simulation is increasingly important in energy systems due to the integration of decentralized generators, potentially flexible demand and local storage options resulting from the energy transition. In this use case, we consider the research question: *How to design a robust distributed system to coordinate flexibilities for the electricity grid?*

We aim to improve the current workflow regarding RDM by providing best practices and tutorials for the specific steps in the research life cycle regarding RDM services.

As typical research begins with finding the right models to work with, i.e. simulation models, we explicitly recommend using the Open Research Knowledge Graph (ORKG)[1] for this step. While using it for different tasks within the use case, as in [10], we collected our findings to prepare best practices on using the ORKG for energy research. An explanation video will be created, focusing on the relevant aspects for energy researchers, i.e. using the correct ontologies. The video will help researchers to use the ORKG specifically for energy research and simplify the process of finding the correct models for the simulation. We additionally consider the simulation of Distributed Energy Resources (DER) in energy systems, including their flexibility. However, modeling flexibility is a challenge due to its complexity. For this reason, we provide best practices on which criteria to consider when dealing with flexibility. These guidelines support others to easily find the correct model of flexibility for their use case. By publishing a website providing an overview of existing flexibility models, this step in the research data lifecycle is simplified.

2 Conclusion: Use Cases to improve RDM

By demonstrating the usability of RDM services, providing example applications, and making existing data easily accessible, the use cases presented will support workflows, whether for analysis or implementation. In addition, tutorials and best practices for existing services are prepared. In this way, the use cases showcase how the concepts and services developed in NFDI4Energy simplify existing workflows along the research lifecycle by supporting users in applying RDM services and thus promote their use in the research community.

Author contributions

Conceptualization, E.F., P.S., A.N. A.W., M.S.; methodology, E.F., P.S., M.S. writing—original draft preparation, E.F., P.S., M.S.; writing—review and editing, E.F., P.S., A.W., A.N., M.S.; supervision, A.W., A.N.

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Competing interests

The authors declare that they have no competing interests.

References

[1] C. Seiwerth, J. S. Schwarz, L. Fuentes Grau, *et al.*, “D5.3.1.1 Requirements for the Implementation of NFDI4Energy Use Cases,” Jan. 20, 2025. DOI: 10.5281/ZENODO.14699093. [Online]. Available: https://zenodo.org/doi/10.5281/zenodo.14699093 (visited on 02/10/2025).

[1] https://orkg.org/

[2] A. Monti, M. Stevic, S. Vogel, *et al.*, “A Global Real-Time Superlab: Enabling High Penetration of Power Electronics in the Electric Grid,” *IEEE Power Electronics Magazine*, vol. 5, no. 3, pp. 35–44, Sep. 2018, ISSN: 2329-9207, 2329-9215. DOI: 10.1109/MPEL.2018.2850698. [Online]. Available: https://ieeexplore.ieee.org/document/8458285/ (visited on 02/10/2025).

[3] M. Chang, J. Z. Thellufsen, B. Zakeri, *et al.*, “Trends in tools and approaches for modelling the energy transition,” *Applied Energy*, vol. 290, p. 116 731, 2021.

[4] M. Ragwitz, A. Weidlich, D. Biermann, *et al.*, *Szenarien für ein klimaneutrales Deutschland. Technologieumbau, Verbrauchsreduktion und Kohlenstoffmanagement*, Schriftenreihe Energiesysteme der Zukunft, München, 2023.

[5] K. Reder, M. Stappel, C. Hofmann, *et al.*, “Identification of user requirements for an energy scenario database,” *International Journal of Sustainable Energy Planning and Management*, vol. 25, pp. 95–108, 2020.

[6] M. Booshehri, L. Emele, S. Flügel, *et al.*, “Introducing the open energy ontology: Enhancing data interpretation and interfacing in energy systems analysis,” *Energy and AI*, vol. 5, p. 100 074, 2021.

[7] F. Wiese, N. Taillard, E. Balembois, *et al.*, “The key role of sufficiency for low demand-based carbon neutrality and energy security across europe,” *Nature Communications*, vol. 15, no. 1, p. 9043, 2024.

[8] H. Förster, M. Stappel, L. Emele, A. Siemons, and C. Winger, “Climate and energy scenario and projection comparison. Draft workflow & typology,” This work was supported by grant 03EI1035A-D (SIROP) from the Federal Ministry for Economic Affairs and Climate Action (BMWK.IIC5)., Dec. 2022. DOI: 10.5281/zenodo.7456286. [Online]. Available: https://doi.org/10.5281/zenodo.7456286.

[9] M. Schäfer, R. Qussous, L. Hülk, J. Lilliestam, and A. Weidlich, “NFDI4Energy Case-Study: Comparative Analysis and Visualisation of Long-Term Energy System Scenarios,” in *Proceedings of the Conference on Research Data Infrastructure*, vol. 1, 2023.

[10] E. Frost and A. Nieße, “Communication incidents in self-organising cyber-physical energy systems: Assessing robustness,” in *5th International Conference on Communications, Information, Electronic and Energy Systems (CIEES)*, 2024, pp. 1–6.