

Towards a Simulation-as-a-Service Hub for the Energy Domain

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Keywords: Simulation-as-a-Service, Co-Simulation, Use Cases

1 Introduction

As part of the goals of the NFDI4Energy consortium, we want to simplify the use of simulations for research questions in the energy domain by developing a Simulation-as-a-Service (SimaaS) approach. SimaaS allows complex simulations to be carried out without high IT resource investments. Flexible scalability and easy access to powerful tools facilitate the analysis of scenarios such as the integration of renewable energies, which accelerates research processes and provides important findings to support the energy transition [1]. However, technical challenges and a lack of standardization often limit access to these tools.

To address these challenges, we have analyzed various use cases that highlight typical requirements and problems when using simulations in the energy domain. Based on these use cases, we developed a systematic workflow that defines the central steps and functions of a SimaaS for the energy domain. In addition, we examined existing services and assigned them to these use cases in order to identify potential gaps in the current service landscape. Finally, we created a mock-up for a SimaaS platform that visualizes the core vision and key functionalities of the system.

With this work, we provide an overview of the requirements and design of a SimaaS approach for the energy domain and offer first insights into a possible future service landscape.

2 State of the Art

SimaaS combines a service-oriented concept with the provision of modeling and simulation applications based on the as-a-service model of cloud computing. It enables

more composable simulation environments that can be provided and executed on demand. SimaaS offers users the ability to access simulation software and services without having to download, install or manage them themselves. Instead, the simulation runs in a cloud environment and the results are delivered to users over the internet [2].

SimaaS platforms offer numerous features aimed at simplifying and streamlining the development, deployment, execution and analysis of simulations. In a literature research, we found the following features in SimaaS applications:

1. Modeling and configuration:

- Web-based interfaces allow user-friendly creation and adaptation of models [3].
- Features such as parameter variation and scenario definition simplify the testing of different conditions [4].
- Data management tools support the management of input and output data [5].

2. Provision and execution of simulations:

- On-demand simulations allow users to start and stop simulations flexibly without having to worry about the infrastructure [2].
- Scalability ensures the dynamic adaptation of computing resources to variable requirements [3].
- Various simulation models, such as agent-based models or discrete event simulations, are supported [2].
- The integration of various simulation tools into a uniform environment facilitates use [1].

3. Interaction and control:

- Real-time interaction enables the adjustment of parameters during running simulations [2].
- Monitoring and visualization tools provide insights into the simulation progress and results [6].
- API interfaces facilitate integration with external applications [2].

4. Other functions:

- Reproducibility by recording all simulation steps [5].
- Collaboration options for joint projects [7].
- Security mechanisms for the protection of data and simulations [8].

In summary, SimaaS platforms offer a wide range of features that cover the entire simulation process. While the specific features vary across platforms and depend on the requirements of the respective use cases, they consistently address key challenges in utilizing simulations. However, none of the SimaaS approaches mentioned in this chapter incorporate multiple frameworks within their service. Therefore, we need to examine this aspect in greater detail from the NFDI4Energy perspective.

3 Use Cases

To better understand how simulations are currently applied in the energy domain, we examined various use cases, focusing on their relevance from the perspective of NFDI4Energy. These use cases provide valuable insights into the requirements and potential gaps in existing solutions. In this chapter, we present a series of use cases that exemplify the diversity of requirements and challenges in this area.

The use cases considered include:

- Search for simulation software
- Compare simulation software and models
- Find best-suited co-simulation framework

- Find simulation model and data for co-simulation
- Find and reuse existing co-simulation scenarios
- Creation of simulation scenarios
- Guided creation of simulation scenario based on research goal
- Automated execution of a simulation scenario
- Investigating and reproducing the results of a co-simulation
- Add software to the NFDI4Energy research software registry
- Add simulation model to the NFDI4Energy research software registry
- Sharing the results of a co-simulation FAIRly

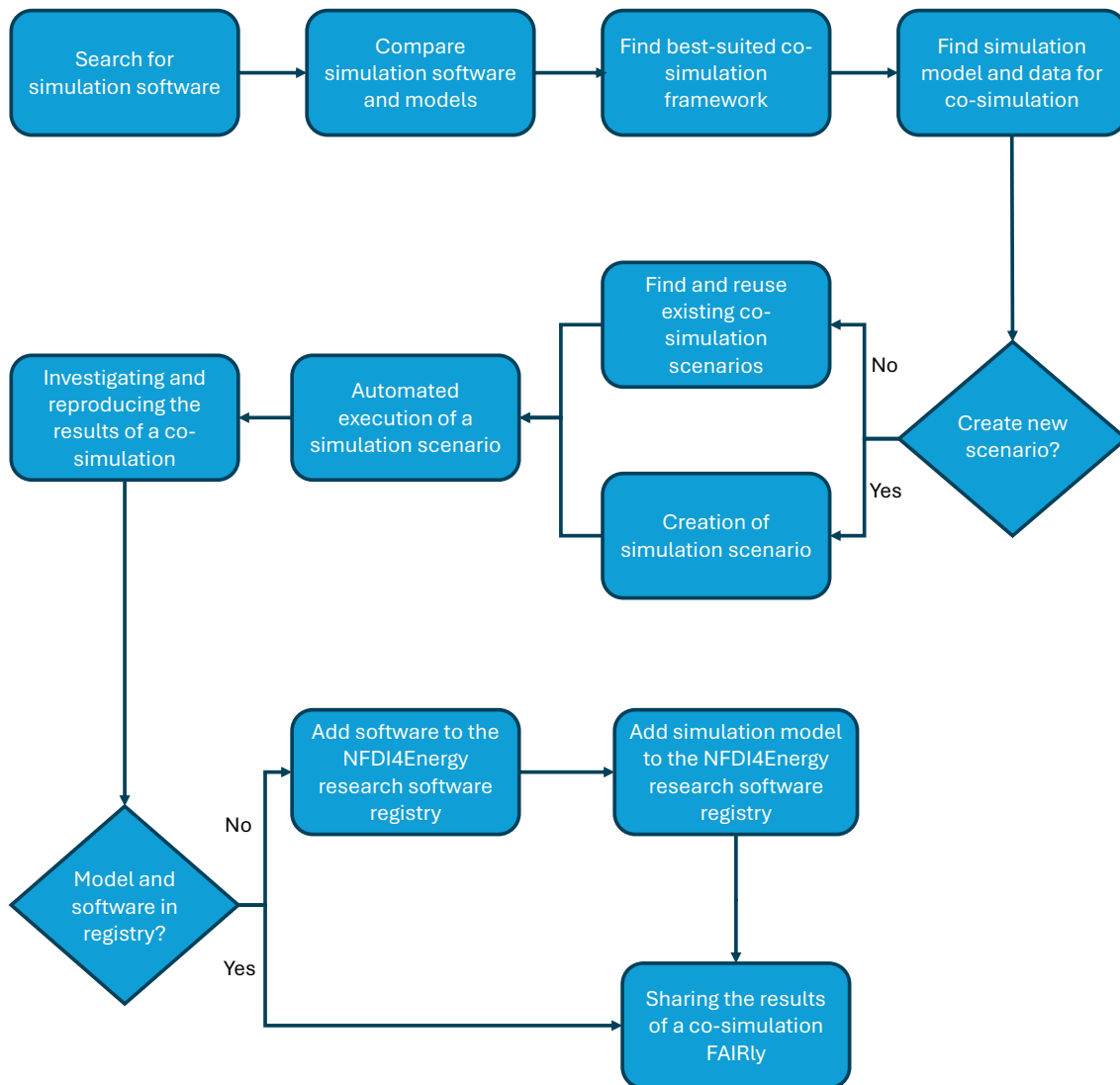


Figure 1. workflow for using simulation in the energy domain

To ensure that the use of co-simulations in the energy systems research is extensively covered by our use cases, we have arranged the identified use cases in a workflow. This workflow is based on the research and transfer cycle within energy system research projects as described by Stephan Ferenz et al. [9].

The workflow, shown in Figure 1, starts with the “Search for simulation software” and ends with the “Sharing the results of a co-simulation FAIRly”. The use case “Guided

creation of simulation scenarios based on research goals” was excluded from this workflow, as it focuses on guiding the user through the entire process of creating a co-simulation thereby including other use cases, rather than representing a single step within the workflow. However, the workflow is not designed as a strictly sequential process, but allows each use case to act as both a start and end point. This flexible structure serves as a guide for researchers to plan the use of simulations in a targeted and efficient manner. At the same time, the workflow helps us to improve the design and functionalities of the SimaaS platform.

After developing the workflow, we analyzed existing services mostly from the NFDI Community that are designed to support the research process in the various phases. These services were systematically mapped to the identified use cases in order to recognize gaps in the service landscape and identify opportunities for improvement. The result of this mapping is shown in table 1.

Table 1. Services related to the use cases

Use Case	Related Services
Search for simulation software	Open Energy Factsheets Open Energy Databus
Compare simulation software and models	Open Energy Factsheets Ontology Mapping by NFDI4Ing OEKG
Find best-suited co-simulation framework	Open Energy Factsheets Open Energy Databus
Find simulation model and data for co-simulation	Open Energy Factsheets Open Energy Databus
Find and reuse existing co-simulation scenarios	Open Energy Factsheets Open Energy Factsheets
Creation of simulation scenarios	Open Energy Academy IAM4NFDI
Guided creation of simulation scenario based on research goal	Open Energy Database
Automated execution of a simulation scenario	Leibnitz Data Manager Open Energy Database EOSC EV Node
Investigating and reproducing the results of a co-simulation	Jupyter4NFDI
Add software to the NFDI4Energy research software registry	Helmholz.Software Software Heritage Open Energy Factsheets re3data.org IAM4NFDI PID4NFDI
Add simulation model to the NFDI4Energy research software registry	re3data.org Open Energy Factsheets IAM4NFDI
Sharing the results of a co-simulation FAIRly	Jupyter4NFDI Terminology Service DBpedia Lookup PID4NFDI

The mapping makes it clear that individual use cases cannot be covered directly by a single service. Some of the services mentioned only provide support for the completion of the use cases. Services such as IAM4NFDI and PID4NFDI function exclusively as infrastructures that provide the basis for the development of additional services.

For this reason, in the next step, we developed a mock-up for a SimaaS hub, which integrates the essential services and provides a central platform for the application of

the use cases. When creating the mock-up, it became clear which additional services still need to be implemented to fully cover the identified use cases. It also showed how and which existing services should be linked in a meaningful way to enable smooth and efficient use.

4 Conclusion

The analysis of the state of the art and the use cases has shown that SimaaS offers great potential to simplify and standardize the use of simulations in the energy domain. The developed workflow serves as a guideline for the integration and use of simulations. It becomes clear that some use cases cannot be covered by individual services and that existing services often only take on supporting functions.

The creation of a mock-up for a SimaaS service hub has provided important insights: It became clear which new services need to be implemented and how existing services need to be coupled with each other in order to meet the requirements of the use cases. Although the SimaaS hub is still at a prototype stage, it represents a central basis for further development. Overall, the work underlines the need for a holistic approach to SimaaS in the energy domain in order to significantly improve efficiency and user-friendliness when using simulations.

Data availability statement

Not applicable.

Underlying and related material

Not applicable.

Author contributions

Conceptualization: C.S., J.S., L.F.G.; Data curation: C.S., J.S., L.F.G.; Investigation: C.S., J.S., L.F.G.; Methodology: C.S., J.S., L.F.G.; Project administration: C.S.; Supervision: R.G., S.L., A.M., A.N.; Validation: C.S., J.S., L.F.G.; Visualization: C.S.; Writing – original draft: C.S.; Writing – review & editing: C.S., J.S., L.F.G., R.G., S.L., A.M., A.N.;

Competing interests

The authors declare that they have no competing interests.

Funding

The authors would like to thank the German Federal Government, the German State Governments, and the Joint Science Conference (GWK) for their funding and support as part of the NFDI4Energy consortium. Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 501865131.

Acknowledgements

The development of the use cases and its workflow described in this work was discussed in the Task Area 5 of the NFDI4Energy project. Thus, special thanks go to the members of the working group for their assistance: Alexandro Steinert, Zhiyu Pan, Philipp Schmurr, Nan Liu, and Ramiz Qussous.

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