Bericht des Zukunftslabor Energie über das AP 2.2 des Teilprojekts 2

ZDIN
Zentrum für digitale Innovationen Niedersachsen

Eingereicht von: Rathjen, Saskia, Zukunftslabor Energie
Autor*innen: Ferenz, Stephan; Ofenloch, Annika; Penaherrera V., Fernando; Wagner, Henrik; Werth, Oliver

Sprecherin: Prof. Dr.-Ing. Astrid Nieße
Zentrum für digitale Innovationen Niedersachsen (ZDIN)

Beteiligte Institutionen:
Carl von Ossietzky Universität Oldenburg/OFFIS e.V. (Prof. Dr. Sebastian Lehnhoff, Prof. Dr.-Ing. Astrid Nieße)
DLR-Institut für Vernetzte Energiesysteme (Prof. Dr. Carsten Agert)
Leibniz Universität Hannover (Prof. Dr. Michael H. Breitner)
Technische Universität Braunschweig (Prof. Dr.-Ing. Bernd Engel)
Ostfalia Hochschule (Prof. Dr.-Ing. Lars Kühl)
Hochschule Emden/Leer (Prof. Dr. Johannes Rolink)

Im vorliegenden Dokument wird der Zeitraum von 01.04.2021 bis 31.03.2022 dargestellt.
Der vorliegende Bericht gehört zum Teilprojekt „TP2: Entwicklung einer Plattform für die Erforschung digitalisierter Energiesysteme“

Inhaltsverzeichnis

1 Generelle Informationen....4
2 Plattform für die Erforschung digitalisierter Energiesysteme....5
2.1 Introduction....5
2.2 Concept for an Open Digital Platform for Interdisciplinary Energy Research and Transfer....6
Core....6
Competence....8
Best Practices....11
Repository....13
Simulation....16
Transparency....19
2.3 Concept for a Prototype of an Open Digital Platform for Interdisciplinary Energy Research and Transfer....22
Core....22
Competence....24
Methods (for Open Energy Research)....27
Repository....31
Simulation....34
Transparency....37
3 (Geplante) Veröffentlichungen....40
4 Literaturverzeichnis....41

1 Generelle Informationen

Dieser Bericht sammelt die Ergebnisse von AP2.2 von April 2021 bis März 2022. Die Ergebnisse werden entsprechend ihrer Ausarbeitungsform sowohl in textlicher Form als auch in Visualisierungen dargestellt. Im Sinne der Open Science Declaration des ZLE [1] wird als Kommunikationssprache für die nachfolgende detaillierte Erläuterung des Plattformkonzepts Englisch gewählt.

Basierend auf der Anforderungsanalyse (D2.1) wurde in diesem Arbeitspaket ein Konzept für die Forschungs- und Entwicklungsplattform erarbeitet (Plattformkonzept). Anschließend wurde für alle Plattformelemente eine Recherche nach technischen Komponenten durchgeführt. Basierend auf diesen Recherchen und dem Plattformkonzept wurde ein Konzept für den Plattformprototypen erarbeitet und definiert (Prototypenkonzept). Dieses Prototypenkonzept soll im nächsten Arbeitspaket (AP2.3) umgesetzt werden.

AP2.1	**Verantwortlich: DES@UOL**
Kurzbeschreibung	
Im Rahmen dieses Arbeitspaketes soll einerseits das **Plattformkonzept** entwickelt werden. Andererseits sollen für die Teilaspekte der Plattform erste **Softwarelösungen** für einen **Prototypen recherchiert** werden. Am Ende des Arbeitspaket steht sowohl das Plattformkonzept als die Teilmenge, die als Prototyp implementiert werden soll.	
Start	**Ende**
M19	M30
Erforderliche Inputs	**Outputs**
D2.1	D2.2, M2.2

2 Plattform für die Erforschung digitalisierter Energiesysteme

2.1 Introduction

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. Based on an intensive requirements analysis, see [2] for details (work package 2.1), the ZLE developed a **concept for a research and transfer** platform for energy research based on six essential service elements. Figure 1 gives an overview of all elements. The *Competence* element enables researchers and developers to present their qualification and skills and to find suitable partners for their research and practice projects. The Methods (before *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 and discussed within the *Transparency* element to reach various interested stakeholders. The *Core* element contains basic functionalities to support the other elements and the linking between them.
Based on the broad concept, we define relevant functionalities for a **first prototype**. A functionality presents a technical module which has well defined interfaces to the user and other functionalities. For each functionality, we determine a priority level. For all high prioritized functionalities, we present first ideas for the technical realization using existing frameworks and approaches. The prototype will be implemented as demonstration of the general concept in the next work package (work package 2.3) within the ZLE.

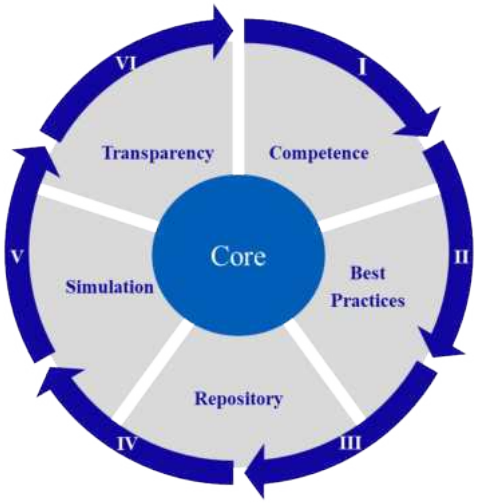

Figure 1 Service elements of the research and transfer platform

The structure of this report follows the two steps of the Work Package 2.2. Based on our requirement analysis (see [2]), we developed a concept for the ZLE research and transfer platform. For this we conducted multiple internal workshops with our research consortia. The concept is outlined in Platform Concept for all six elements.

Afterwards, we performed an analysis of existing technical components. Based on this analysis and the concept we discussed in multiple workshops which parts of the concept are important for a first prototype. The concept for the prototype is presented in the section Concept for a Prototype of an Open Digital Platform for Interdisciplinary Energy Research and Transfer.

2.2 Concept for an Open Digital Platform for Interdisciplinary Energy Research and Transfer

Core

Goals of the Element

The *Core* element supports the other elements with basic functionalities, which are required within multiple elements, e.g., persistent identifier (PID), federated search and user management. *Core* is not specific for the energy domain, but it defines additional requirements for the other element to achieve a coherent and working platform.

Functionalities for the Element

Core defines the technical backbone, including corporate design and interoperability requirements. It includes user management, a federated search and a PID service. Also, within *Core* the website structure and some general pages (e.g., about us page) are defined. With these functionalities, *Core* supports the other elements.

Subelement: Technical Backbone

All elements should run within one platform. Therefore, it is important to define interfaces, so they can all be included within the platform. Also, a corporate design will be defined to be used within all elements. The technical backbone includes the server, where the platform should run on. A common workflow for the development of new features and their integration will be defined as well.

Subelement: User management

Core will include the user management such as authentication, login and registration forms for the platform. It should be possible to create and change user accounts. The user accounts can be linked to other accounts, e.g., ORCID[1], gitlab[2]. The user can be added to different groups with different rights, depending on the platform elements. *Core* will define three global groups: administrators, moderators and general users.

Subelement: Energy Ontology

Core will provide an access point to ontologies in the energy domain for all platform elements. There are multiple different ontologies in the energy domain such as the Open Energy Ontology [3] and the Common Information Model [4]. By using common ontologies for the description of artifacts such as data, software or for the information stored in transparency or competence, the same words are used for the same things, which improves the interoperability and search functionality of the platform.

Subelement: Federated Search

There should be one search engine for the whole platform, which is integrated into *Core*. To enable this search, a search API will be defined. Using this API, *Core* can access the information in the other platform elements. Besides the stored entries, *Core* can also import possible filters from the different elements such as categories or artifact type to narrow the results.

To give an overview about search trends, *Core* will include a word cloud, as included in Mentimeter[3], based on past search queries. The word cloud can be used as inspiration for users of the platform.

Subelement: Persistent Identifier (PID) Service

Over the whole platform, different entities will be created, e.g., data description in *Repository*, institution profiles in *Competence*. To increase the usability of the platform these entities should be

[1] https://orcid.org/

[2] https://about.gitlab.com/

[3] https://www.mentimeter.com/features/word-cloud

linked, so that an institution in *Competence* can be used as responsible institution in data description in *Repository*. To enable a persistent linking, these entities need persistent identifier (PID), which do not change over time. *Core* will include a service to define PIDs for these entities and an API to interact with the different elements based on the PIDs.

Subelement: General Pages

Core will include some general pages needed for the platform. “About us” gives on overview about the history and last developments of the platform as well as over the involved institutions. “Privacy policy” includes the privacy policy, required on European Websites. “Error page” is required if a page is not found.

Interaction with the other Elements

The subelements of *Core* are required for multiple other elements. All elements will use the technical backbone, user management, federated search and PID service.

Competence

Goals of the Element

The goal of the Competence element is the demonstration of multi-layered competences in ZLE's research network considering:

- Subject-specific and user-oriented presentation of competences
- Easy and multi-sided access to competences
- Multiple functions enhancing an effective use of competences (see functionalities)
- Automated aggregation and updating of competences

The central element and function of Competence are profiles which allow a proper presentation of the user's proficiencies. The research clusters that emerge from the profiles provide a connecting point for new researchers and enable the ZLE network to grow steadily.

Stakeholders for the Competence element are scientists and researchers, which use the networks range to spread their knowledge as well as finding new research partners to generate new insights. Companies and industrial partners use this element to enable collaborations with scientists and researchers profiting from synergies in the development of new technologies. Research networks connect to the ZLE's network to profit from a joint network and largely grown range.

Functionalities for the Element

The *Competence* element consists of multiple functions to adequately present the competences of registered stakeholders on the research and transfer platform. The presentation of competences is elemental for stakeholder's satisfaction enabling a constant extension of the network. The functionalities and properties differ in their focus on presentation of competences, their accessibility and their aggregation.

Subelement: Profile

The fundamental functionality of the *Competence* element is the profile. Each interested stakeholder is able to create a profile by a) creating a new profile following a questionnaire or b) completing an automatized pre-created profile (more information see subelement "automatically aggregation of competences"). The within b) automatically generated profiles proposed at the initial registration reduces the entrance barrier.

Each profile will get a unique PID from the *Core* element enabling a persistent linking over all platform elements. The level of detail respectively identification for each profile will be workgroup-level (e.g. workgroup "energy systems" at elenia Institute for High Voltage Technologies and Power Systems). Higher level of detail or person-specific profiles are not intended as they will drastically increase the amount of needed profiles. Person-specific profiles create the risk of many similar profiles and at the same time high risk of inactivity among the profiles as they are just maintained by one person.

Each profile consists of basic information about the stakeholder (e.g. institution, address), a representative (e.g. for elenia's workgroup "energy systems" – Prof. Bernd Engel) and a contact person (e.g. for elenia's workgroup – Henrik Wagner; project employee for ZLE). The contact person should also be in charge of maintaining the profile. The representative and the contact person may be the same person but it is not recommended as representatives tend to be too occupied than to maintain the profiles.

Other than that, the research focus, research projects and current publications (including papers, data and simulation models) will be listed together with the membership in other research networks. The information and competences listed in the profiles are accessible by the *Core* elements search engine.

For adequate search results, a common keyword scheme can be used as assistance in in filling out the profile.

Subelement: Competence Ontology

On the basis of the Energy Ontology of the *Core* element the *Competence* element will provide an ontology helping to fill out the profiles. The same competences then will be described with the same words, reducing imprecise descriptions and enabling the formation of competence clusters and displaying them e.g. in the form of a word cloud. This word cloud may be a good inspiration for new users and a summary of the existing competences on the platform.

Subelement: Research Cluster

The functionality of research clusters allows grouping of competences based on a common research focus (e.g. co-simulation of energy) or membership. This grouping or clustering helps to synthesize groups of researchers which may not belong to the same institution or research project but still focus on the same topic. An implementation referring to the visual presentation of the website "Connected Papers[4]" will be considered.

Subelement: Research Map

Within the Research Map all registered user profiles will be displayed on an interactive map. The map includes sorting functions (based on address, perimeter, cluster), allowing to filter for certain research focuses. Other than that, network representation of research clusters can be selected showing the geographical spread of in terms of clusters connected profiles.

Subelement: Research Tender

Current research tenders functionate as starting points for a matching process. Profiles can be reminded to participate in a research tender or join a matching process based on the research priorities which are listed in the profile. The research tenders will be crawled from the respective websites, e.g. from the ministries.

Subelement: Matching

The matching functionality of the *Competence* element helps to form new research consortia and alliances. Based on the needed competences for a new research proposal the matching algorithm seeks the profiles on the platform. Then, the identified profiles are invited to participate in the research tender. Based on these results the new research consortia and alliances are formed. Within the matching process there must be a differentiation between depth (thematic) and width (related area). The matching process itself can be started based on new research tenders from the subelement Research Tender.

Subelement: Automatized Aggregation of Competences

Pre-created profiles and new competences will be generated based on automatically evaluated information sources. For the generation of pre-created profile, the accessed information sources are scanned for potential users of the research and transfer platform. This collection of information only will be started on the first registration of a new profile. No data will be stored in advance.

All competences and information, which can be connected to a profile's correspondent workgroup, is filled into the profile after the first registration. Before the new profile can be accessed the identity will be checked, e.g. using e-mail validation. The crawled and filled-in information can then be checked by the profile maintainer, before the profile is set active on the platform. The automatic profile creation will significantly reduce the amount of time needed to create the full profile.

[4] https://www.connectedpapers.com/

The already listed competences in the profiles will be updated (e.g. scientific publications) using the automatized aggregation of competences. Additionally, the automation will propose other profiles based on the current viewed one. Information sources for the subelement research tender and matching are also listed.

Sources of information are:

- Projects: enArgus
- Profiles: Websites of universities, researchgate, ORCID
- Scientific Publication: Zenodoo, IEEE, Web of Science
- Research Tender / Matching: DFG, BMWi, BMWF, MWK, PTJ

Competences and information sources which require a manual post-processing are excluded as they require a too high workload for the ZLE's moderators. The competences and information provided on the research and transfer platform will be made accessible for others via an API.

Subelement: Quality Management

The automated competence and information gathering can lead to listing of false information in profiles on the research and transfer platform. Therefore, an efficient quality management with a short update interval needs to be implemented to avoid an "information laundering". Moreover, privacy rules are applied to protect the personal data of the user of the research and transfer platform.

Interaction with the other Elements

Core

Competences which are listed in profiles need to be found by the *Core*'s search engine and will get a PID from the PID service. The Competence Ontology is derived from the Energy Ontology of the *Core* element.

Best Practices

In connection with research tenders and matching processes a link to the methodological description of "How to Write a Research Proposal" is possible.

Repository

The Repositories for data and simulation models which are managed by users of the research and transfer platform are directly linked to their profiles.

Simulation

The simulation scenarios generated or used by the users of the research and transfer platform are directly linked in their profiles.

Transparency

The *Competence* element is strongly connected to the *Transparency* element. The *Competence* needs the *Transparency* as communication channel for the provision and spread of information. The attended events, activities in the *Transparence* forum and other shared information from the *Transparence* element are directly displayed in the profiles of *Competence*.

Best Practices

Goals of the Element

The “Best Practices” Element has two broad objectives:

- First, an introduction for the use of the different elements of the platform is required, as to provide an introduction for the use of the website, and thus maximize the usability of its elements.
- Second, general guidelines for conducting energy research are to be presented, gathered from successful experiences from research projects. Best Practices and standards for cooperative project development, scenario modeling, data management are here required, to deliver ideas to structure cooperative research.

Functional requirements are oriented towards the stakeholders. Based on the analysis of interview results (see [2] for details), the application of this element is oriented mostly towards the research community. The key use of this element is to provide an overview of best practices during the different stages of the research lifecycle.

Functionalities for the Element

The main functionality of this element is to give an overview of "Good Practices" in research projects. This includes, amongst others, providing descriptions of successful research projects, providing information on standardized scenarios and benchmarks, showing examples of data management in large research projects, and provide additional information on specific examples. Thought most of these requirements are oriented towards the scientific community, they must be also developed with different users under consideration (industrial partners, decision-makers, citizens).

To this goal, two main subelements are presented. The first one, namely “Best Practices in Research”, is oriented towards giving an overview of research projects, their experiences, and their examples for different stages of the research cycle. The second one is to introduce the use of the research and transfer platform during the different stages of the research lifecycle, as to include relevant information required for the exploitation of the platform capabilities.

Subelement: Best Practices in Research

This subelement is strongly linked with *Transparency*. Based on the research lifecycle, the goal is to provide a Search Engine that allows presentation of research guidelines (“How To…”), with inclusion of examples on project (and application) formulation, scientific project management, scientific research methods and modelling in energy research, information and examples on data management (DBMS, data protection, licenses, FAIR data principles), information and examples on data analysis (statistical analysis methods, text analysis, analysis tools, uncertainty quantification) and guidelines for publications and listings (with links) of themed conferences or journals. The goal is to cover comprehensively the different stages of research. A first view of what is desired may be reflected in existing initiatives and communities for energy system modelling and simulation platforms, such as openmod[5], oemof[6], or Open Science Framework[7]. The recommendation should use as many defined words from the ontologies in *Core* as possible.

Subelement: Introduction to the use of the research and transfer Platform

This subelement is linked with the rest of the platform. Based on the different stages of the research lifecycle, the use of the different elements of the platform is introduced here. Introductory explanations are here showcased with demonstrative examples with consideration of user profiles

[5] openmod-initiative.org/

[6] oemof.org/

[7] osf.io/

and degree of expertise. Examples for proper use of the online *Simulation* tool, *Competence* search functionalities, and *Transparency* element are to be here showcased.

Interaction with the other Elements

Core

Introduction, examples for linking with research partners and research institutes

Competence

Link to concrete projects or profiles (competence). A search machine that allows searching for specific examples related to projects is desired. Links to existing profiles for related research.

Repository

Introduction to the component. A search machine that allows a link to existing repositories, project results, model artifacts and databases

Simulation

Introduction to the component. A set of tutorials for different expertise levels that allow using the different element features. Basic tutorials may include notebooks and video demonstrators. Advanced tutorials for developing independent models and contributing to the open-source projects also are included.

Transparency

Introduction. Linkage to the component through a wiki-style page for search and find of previous projects and their key findings and specific success stories. Thematic search for projects.

Repository

Goals of the Element

The goal of *Repository* is to make data, models and scenarios in the energy domain more findable, accessible, interoperable and reusable (FAIR, [5]). Besides making these artifacts available, *Repository* should include information about artifacts which can be made available on request. Also, a limited access to artifacts, e.g. behind authentication, should be also supported.

Harmonized interfaces should be supported by *Repository* by labeling and describing them, therefore increasing their visibility. In general, a good filter functionality is required to improve the search results, offered via *Core*. Also, the information attached to the artifacts should contain precise details.

Functionalities for the Element

Repository focuses on three main classes of artifacts: data, models and scenarios. The functionalities can be separated in front-end and back-end functionalities. The backend consists of metadata schemas and of databases. Metadata can be used to describe the artifacts. By standardizing these descriptions into schemas, the description can be better compared and integrated into other functionalities, such as the search function. The databases are required to store metadata of different artifacts and to store datasets, if required.

The front-end of the platform consists of three parts. The “Add” functionality allows to aggregate additional artifacts or at least a description about artifacts to the platform. It should be easy to add artifacts, so more artifacts will be added. The required descriptions of the artifacts are based on the metadata schemas. The second functionality is search. The search functions, including filters, is required to find artifacts and accesses the databases and will be offered via an API to *Core* to be usable from the whole platform. The third part of the front-end is the representation of an artifact based on the stored information.

Subelement: Metadata Schemas

Metadata can be used as the ontological description of the different artifacts. By using semantic web resources, the quality of the metadata can be increased [6]. A metadata schema or standard is used to predefine the different elements needed to describe and categorize a certain artifact. Besides the different categories, called elements, the schema also defines if for a certain element a free value is allowed or the use of a controlled vocabulary is required. A limited vocabulary increases the comparability of the metadata. Instead of a free value, a link to a semantic web resource is also possible.

For *Repository*, metadata schemas for data, models and scenarios are required. These metadata schema should share some common elements, while some elements will differ. *Repository* will build on and extend existing metadata standards to increase interoperability. In general, the metadata schema should include:

- Links to a paper, project, other relevant artifacts
- Information about who is allowed to access the artifact
- Quality of the artifact, e.g., where is the data from, is coded reviewed and tested, how often is the data or code already reused in other studies
- Information as authors etc., which could be inherited from DCAT[8]
- A PID, which will be created by the *Core* element

[8] https://www.w3.org/TR/vocab-dcat-2/

For datasets, the metadata schema should include whether the data is real or artificial. The Open Energy Platform[9] already introduced a metadata schema for datasets in the energy domain, which can be used as a starting point. The metadata schema for the models should include programming language and used libraries. CodeMeta[10] is a common metadata schema for research software and can be used as a foundation. The metadata schema for the scenarios should be used as base for *Simulation* as well. To enable this, semantic web technologies are also required [7].

To increase the interoperability of the domain-specific description of the artifacts, domain-specific ontologies provided by the *Core* can be used as controlled vocabularies.

Subelement: Databases

Repository requires two types of databases. For all artifacts, *Repository* needs to store the metadata based on predefined schemas.

For datasets, *Repository* should also be able to store datasets, which should be accessible via an API, like the functionality of the Open Energy Platform. Additionally, metadata on these datasets is required, and stored as well.

Subelement: Add

The add functionality enables users to add new artifacts, which can either be the artifacts itself, e.g., a dataset, or a description of an artifact including a link, e.g., a model in gitlab. For adding new artifacts, an interactive formula should be provided to add the information. The questions should be based on the right metadata schema, so the given answers can be linked to the elements of the schema. The add functionality should be able to automatically collect relevant information, e.g., programming languages from a from an online repository (e.g. gitlab). If possible, new information should link to entities in other elements (e.g. projects in *Transparency*) or semantic web resources (e.g. by using an ontology for programming languages) by presenting suggestions, when input is typed. The collected information on the artifacts will be stored into the appropriate databases (registries).

Subelement: Search

The search functionality of *Repository* should be developed in accordance with the search API of *Core*. All registries should be searched for relevant entries. It should be possible to filter the results according to different elements of the metadata schema.

Additional to the basic search functionality, a graphical overview of the artifacts should enable a faster start into the *Registry* element.

Subelement: View

For all artifacts, an overview page should be created. This overview page lists the most important information from the related metadata and links to other relevant resources. For datasets, a preview of the data and a graphical visualization should be included into the overview page, similar to data platforms like Kaggle[11] or bio.tools[12][8]. Also, on the overview page, it should be possible to download the data in different formats and time resolutions. For scenarios, it should be possible to directly important them into *Simulation*.

Besides the overview page of one artifact, a comparison page enables to compare different types of a certain artifact, e.g., different datasets.

---

[9] https://openenergy-platform.org

[10] https://codemeta.github.io/

[11] https://www.kaggle.com/datasets

[12] https://bio.tools

Interaction with the other Elements

There are two principal ways how *Repository* interacts with other elements: Link to other information and let other information link to the information in *Repository*. Based on the general PIDs, as introduced in *Core* linking between entities in the different elements becomes possible.

Core

Repository uses the PID service of *Core*. Also, it includes users, as introduced in the user management of *Core*. The description of the different artifacts in *Repository* uses ontologies provided by the ontology function of *Core*. The search within *Repository* is integrated in the federated search of *Core*.

Competence

The description of artifacts in *Repository* can include links to institutions in *Competence*. Therefore, it also possible to list the artifacts within the description of the institutions.

Best Practices

Best Practices includes a guideline how to use *Repository* including information on anonymization of data, and detailed description of the metadata schemas.

Simulation

It should be possible to automatically import scenarios stored in *Repository* into *Simulation*. Also, the data and models described in *Repository* can be used within scenarios in *Simulation*. Data and scenarios created within *Simulation* can be stored within *Repository*. *Simulation* creates metadata about the scenarios and data based on the schema used in *Repository*.

Transparency

The description of artifacts in *Repository* include links to projects in *Transparency*. Therefore, it also possible to list the artifacts within the description of the projects. Also, discussion on artifacts in the forum within *Transparency* should link to the specific artifact.

Simulation

Goals of the Element

The platform component *Simulation* supports the coupling and reusability of different simulation tools and models to enable co-simulation of various scenarios by addressing typical use cases in interdisciplinary research. The element extends co-simulation frameworks like mosaik[13] by adding assistance to build complex scenarios including the artifacts from *Repository*. The focus lies on the combination of different domain-specific simulation tools and modeling approaches as well as on the integration of laboratory infrastructure into the co-simulation [9].

Functionalities for the Element

The main goal of *Simulation* is to provide a co-simulation platform to couple different tools and models, which are stored in *Repository*. Thus, the metadata schemas for data, models and scenarios are required and used as a foundation for *Simulation* to list and connect compatible artifacts within the co-simulation platform [7].

The co-simulation platform consists of three parts: *create*, *run and analyze*. The *create* functionality allows to extend scenarios from *Repository* and to create user-defined scenarios. It should be possible to parametrize the simulation models to provide different configurations for the scenarios. The *run* functionality includes the execution of the scenario and visualization during runtime. The last part of the co-simulation platform is the analysis of the simulation results, including data visualization.

Subelement: Create

Reference scenarios are prepared for different target groups (starters, advanced users, experts) and made available in *Repository*. It should be possible to import and edit these scenarios directly in *Simulation* with a user-friendly web interface.

Repository defines common interfaces between models and data. Models and data compatible with these interfaces are listed in *Simulation* and can be connected within the co-simulation platform to create user-defined scenarios. In this regard, an approach presented by Schwarz et. al [7] can be used to assist in the planning of co-simulation based on semantic knowledge representation. It will be aligned with the energy ontologies provided by *Core*.

The configuration phase of a scenario includes the selection of the appropriate model depth, width and scope. The following simulation specifications and constraints should be considered:

- Size of a plant, selectable time period, accuracy of input parameters, characteristic values to be calculated, Key Performance Indicators (KPIs)
- Addressed problems (transformation paths, schedule optimization, etc.)
- Evaluation of input data (red: is not compatible, yellow: is not completely suitable [e.g. reference year is not correct], green: compatible)

Via the user authentication function of the platform element *Core*, it should be possible to save scenarios within the user profile and access it anytime. In addition, it should be ensured that during the editing process, the scenario is automatically saved at regular intervals, so that no work gets lost.

[13] https://mosaik.offis.de

Subelement: Run

It should be possible to initialize and run the simulation directly over the platform as well as locally.

The co-simulation platform should have a user-friendly interface for a simple scenario assembly and configuration. In addition, it should be possible to set breakpoints in the configuration phase and adjust the simulation speed at runtime. The visualization should include:

- A progress bar to visualize the current simulation state
- A node diagram with color-coded nodes for violations and failures (e.g., voltage levels, bottlenecks) to display the current grid state

For the local execution, a configuration file (ontology-based) is provided via the platform. This file enables the automated creation and configuration of scenarios.

Subelement: Analyze

The last part of *Simulation* includes the analysis of the simulation results.

When the simulation is finished, the simulation results should be displayed via a dashboard (e.g. via Grafana[14]). This includes the presentation of selected parameters, KPIs and optimized results (e.g., primary and secondary energy, energy production from renewable energy sources, local consumption). It should be possible to filter and sort the data (e.g., by month, year). In addition, the visualization of data should include both tabular and graphical presentation (e.g., graphs, plots). Furthermore, a benchmark comparison of scenarios should be included to compare relevant characteristics.

Apart from that, it should be possible to save the simulation results in the user profile as well as locally via download. This includes the following functionalities:

- Possibility to delete data within the user profile
- Creation of an ID for sharing a link to the scenario
- Possibility to save user-defined scenarios and simulation results in *Repository*

  Possibility to save raw data (e.g., csv format) as well as tabular and graphical presentations (e.g., graphs, plots)

Interaction with the other Elements

The artifacts, which are stored in *Repository*, are mandatory for *Simulation* in order to create and run scenarios for the analysis of complex energy systems.

Core

The user registration and authentication function of the platform element *Core* is needed to save scenarios within the user profile and to access them at any time. Also, all scenarios get unique PID from the PID service.

Competence

In *Competence*, a linkage to research projects, in which the same or similar scenarios are simulated, is to be shown.

Best Practices

Best Practice should include instructions for setting up the tools and infrastructure needed for the co-simulations.

[14] https://grafana.com

Repository

It should be possible to import scenarios stored in *Repository* into *Simulation*. In addition, the data and models described in *Repository* should be usable within scenarios in Simulation. Data and scenarios created within *Simulation* can be stored within *Repository*. *Simulation* creates metadata about the scenarios and data based on the schema used in *Repository*.

Transparency

Transparency should enable information exchange on existing scenarios, models, and data and highlight current activities in research projects on similar simulation objectives and data analysis.

Transparency

Goals of the Element

The main goal of the platform element *Transparency* is to process, publish and communicate research and development content to promote a broader and interdisciplinary discussion among all respected types of stakeholders. In addition, it serves as a foundation to use these processed results in research-oriented teaching and education. Thus, the element represents the platform and prospectively the whole energy research sector towards the society and industry. Furthermore, it serves as the communication channel for distributing this information.

Functionalities and important considerations for the Element

The stakeholders of the platform, i.e. researchers, practitioners from various domains, political decision makers, local authorities, citizens and students, are distinguishable in terms of characteristics such as their knowledge base and intended purpose to use the platform. Hence, it is vital for the success of this element to offer the contents presented on the platform and their delivery channel in a stakeholder specific manner. For this reason, content of the element should be processed in multiple ways, e.g. advanced content or easy-to-understand content in simple language, for different groups of stakeholders, where appropriate. For other content and intended stakeholders, a single way of presentation for all stakeholders is sufficient.

When choosing which content to present in which format, it must be evaluated if a certain content should be produced within the current project ZLE or if it is more reasonable to link to external websites.

Transparency consists of several subelements to reach the above stated goal. For all subelements, the quality, correctness and neutrality of the content has to be ensured as well as the up-to-dateness of the information.

Following the goal of the element of reaching a broader part of the society, the platform should be promoted towards the (mass) media and local authorities.

Subelement: Energy Research Roadmap and Trend Cloud

To gain a comprehensive overview over the past and future research in the energy sector, an energy research roadmap can be established. Here, two ways of presentation might be reasonable. On the one hand, for researchers, students and practitioners that are experienced in the domain, a scientific presentation is beneficial. On the other hand, there should be a less complicated presentation for citizens and practitioners that are less experienced, but interested, in the domain of the energy sector. The former approach could be supported by using text in an easy-to-understand language, implementing clear graphics and possibly videos. A quick overview over trending topics in the energy sector can also be provided by implementing a word cloud. Word clouds will be generated through the usage of functionalities provided by the core element.

Subelement: Summaries, Recordings and Social Media Embedding

While scientific papers are likely comprehensible for more experienced stakeholders in their published form, they can be processed into brief summaries to promote the tangibility and clarity of energy research for less experienced stakeholders. If existent, recordings of conference speeches can be published for the same reasons. Also, social media content of researchers could be embedded on the platform. Besides papers, brief summaries can also be produced for research projects to make the information more transparent for both more and less experienced stakeholders.

Subelement: Presentation of energy research projects

Regarding research projects, platform users can be given the possibility to present their own projects. Following this approach, the platform would work as a substitute for separate project websites.

Subelement: Use Cases

Within the presentation of certain research topics, their practical relevance can be illustrated by realizing use cases. For example, certain simulations and their results can be demonstrated. The usage of anonymized profiles of districts or energy communities, including their boundary conditions, can be linked. As another aspect of practical relevance, the presented content might contain implications for practical or private decisions.

Subelement: Educational Content

Educational content such as lecture slides, laboratory experiments and lecture recordings can be shared via the platform to be utilized for private educational purposes or for teaching in schools and universities. With this approach, a teaching and learning network such as ATLANTIS[15] could be established. Therefore, the results of the workshops within the project ZLE could also be employed. In order to promote public courses, a reminder function could be implemented, which notifies the users about these events upon registration. Practitioners might be more interested in application-oriented educational content which can be provided by processing certain existing educational content.

Subelement: Public Forum

In order to promote a dialogue within the platform's community and the communication between researchers and other stakeholders, particularly citizens, a public forum can be implemented. In this forum, users can ask questions towards researchers or discuss certain topics publicly. It remains to be evaluated to what extent a registration of users is reasonable or necessary here as well as if there should be a separate forum only accessible by researchers besides the public forum.

Subelement: Further Content

Besides research and development content, further content such as regulatory content, news, norms or prospective changes in the energy sector could be provided on the platform. It remains to be evaluated if this approach is reasonable or applicable.

Interaction with the other Elements

Core

The user management system of *Core* is vital for *Transparency* especially in terms of user generated content such as partners sharing information about projects as well as users posting content into the user forum. *Transparency* also benefits from the general search function in terms of supporting users in finding and filtering for the information they want to retrieve. To enable the interaction between entities within the element and towards entities from other elements, *Transparency* also employs the PID service.

Competence

Research results and information about projects of partners from *Competence* can be processed and presented via *Transparency*. The *Competence* profiles of institutions involved can be linked in the respective content presented in *Transparency*. Public Courses, lecture slides, and other material will also be displayed in the linked profile of the *Competence* element. Furthermore, activities in the public forum are also displayed with a linkage of the profiles in *Competence*.

Best Practices

Best Practices can be published and linked via the content, delivered through *Transparency*.

Repository

Artifacts from *Repository* used for the production of content presented via *Transparency* such as the underlying data or simulation models of a certain paper can be linked.

[15] https://www.elan-ev.de/projekte_atlantis.php

2.3 Concept for a Prototype of an Open Digital Platform for Interdisciplinary Energy Research and Transfer

Based on the broad concept, we define relevant functionalities for a first prototype within this work. A functionality presents a technical module which has well defined interfaces to the user and other functionalities. For each functionality, we determine a priority level, see Table 1 for an overview of these levels. For all high prioritized functionalities, we present first ideas for the technical realization using existing frameworks and approaches. The prototype will be implemented as demonstration of the general concept in the next work package (AP2.3) within the ZLE project.

Table 1 Overview of priority levels

Priority level	Description	When to be implemented
Base	A definitive required functionality for a working element	First
Prioritized	A highly relevant functionality for our stakeholders	After base functionalities
Simplified	A relevant functionality simplified to be implemented with reduced effort	After base functionalities
Bonus	A nice to have functionality	At the end if time remains
Not-in-prototype	A not required functionality which will not be included in the prototype	No implementation

Core

Goals of the Element

The *Core* element supports the other elements with basic functionalities, which are needed within multiple elements, e.g., an user management. *Core* is not specific for the energy domain, but it delivers essential functionalities as base for multiple features within the other element to achieve a coherent and working platform.

Functionalities for the Element

Core defines the technical backbone, including corporate design and interoperability requirements. It includes user management, a federated search and a PID service. Also, within *Core* the website structure and some general pages (e.g., about us page) are defined. With these functionalities, *Core* supports the other elements.

Table 2 Relevant functionalities of Core

Functionality	Priority Level	Depends on (within the same element)	Depends on (within other elements)
Technical Process	Base		
Technical Backbone	Base	Technical Process	
General Pages	Base	Technical Process, Technical Backbone	
Federated Search	Base	Technical Process, Technical Backbone	
User Management	Simplified	Technical Process, Technical Backbone	
Energy Ontologies	Simplified		
Word Cloud for Search	Bonus	Technical Process, Technical Backbone, Federated Search	
PID Service	Not-in-prototype	Technical Process, Technical Backbone	

Subelement: Technical Process

Since all functionalities should be hosted within one platform, a common development process needs to be defined. This includes the development and deployment process, as well as the corporate design and the definition of general APIs between functionalities. The corporate design, based on the design of the ZDIN[16] including colors, default pages and logos, will be created to be used within all elements. Therefore, the **Technical Process** is a prerequisite for all functionalities.

Subelement: Technical Backbone

All elements should run within one platform. The server for the platform will be hosted by OFFIS. Also, a general landing page is defined within the technical backbone. Therefore, the **Technical Backbone** is a perquisite for all functionalities.

Subelement: General Pages

Core will include some **General Pages** needed for the platform. “About us” gives on overview ofthe history and latest developments of the platform and over the involved institutions. “Privacy policy” includes the privacy policy, required for European Websites. “Error page” is required if a page is not found.

Subelement: Federated Search

There needs to be one search engine over the whole platform, which is integrated into *Core*. To enable this search, a search API will be defined and used by the other elements. The API includes a definition, how a search request can be sent to the elements. Also, it enables to important possible filters from the different elements like categories or artifact type to narrow the results. Using this API, *Core* can access the information in the other platform elements.

Subelement: User management

Core will involve the **User Management** which includes functions like authentication, login and registration forms for the platform. It should be possible to create and change user accounts. Linking the user accounts to other accounts, e.g., ORCID[17], gitlab[18], should not be part of the prototype. The user can be added to different groups with different rights depending on the platform elements. *Core* will define three global groups: administrators, moderators and general users. If possible, external accounts can be used for authentication like ORCID-Accounts.

Subelement: Energy Ontologies

In different elements of the platform, especially in competence, repository and simulation, words from an ontology can be used to improve machine readability. For the best interoperability within the platform, the same ontologies should be used for all elements of the platform. Therefore, *Core* offers a central service for these ontologies. The services will be based on the terminology service of the TIB[19] and similar ontologies as in NFDI4Ing will be used as a starting point[20].

Subelement: Word Cloud for Search

Core will include a word cloud, as in Mentimeter[21], based on past search queries to give an overview about search trends. The word cloud can be used as inspiration for users of the platform.

---

[16] https://zdin.de/ , accessed 17.01.2022

[17] https://orcid.org/

[18] https://about.gitlab.com/

[19] https://service.tib.eu/ts4tib/index

[20] https://terminology.nfdi4ing.de/ts4ing/index

[21] https://www.mentimeter.com/features/word-cloud

Competence

Goals of the Element

The *Competence* element presents and describes the multi-layered proficiencies and skills of the registered workgroups within the research network on the ZLE platform considering:

- Subject-specific and user-oriented presentation of competences
- Easy and multi-sided access to competences
- Multiple functions enhancing an effective use of competences (see functionalities)
- Fast and easy updating of competences with options for automation
- Information transfer via API

The central element and function of *Competence* is the **Profile** which allows a proper presentation of the workgroups' proficiencies. Among the ZLE platform the *Competence* profiles provide linkage to the research elements stored in *Repository* and *Simulation* by the corresponding workgroup. The research clusters that emerge from these profiles provide a connecting point for new researchers and enable the research network on the ZLE platform to grow steadily.

Each interested stakeholder is able to create a new **Profile** by a) following a questionnaire or b) filling out prescribed answer boxes. Both ways are provided by the function input mask (see subelement: input mask). The possibility of completing a pre-created and already semi-filled profile, which lists user's data and research from data crawling will not be implemented in the prototype.

Each **Profile** will get a unique PID enabling a persistent linking over all platform elements. The level of detail respectively identification for each scientific **Profile** will be workgroup-level (e.g. workgroup "Energy Systems" at elenia Institute for High Voltage Technologies and Power Systems). Higher level of detail or person-specific profiles are not intended as they will drastically increase the amount of needed profiles. High numbers of profiles solely representing one user increases the risk of many similar profiles and at the same time the risk of inactivity among the profiles. Starting points for the development of the **Profile** function can be TIB VIVO[22], but with a reduction of the personal dissolution to workgroup level.

Functionalities for the Element

The *Competence* element consists of multiple functions to enable an intuitive input, adequately presentation and information transfer of the competences of users on the ZLE platform. The functionalities and properties differ in their focus on presentation of competences, their accessibility and their aggregation.

Table 3 Relevant functionalities of Competence

Functionality	Priority Level	Depends on (within the same element)	Depends on (within other elements)
Profile Information	Base		User Management
Input Mask	Base	Profile Information	
Quality Management	Prioritized	Profile	User Management
Competence Taxonomy	Prioritized	Profile Information, Input Mask	Energy Ontology
Research Cluster	Simplified	Profile	User Management
Deadman's handle	Simplified	Profile	
Competence Access Privileges of	Simplified	Profile	User Management

[22] https://vivo.tib.eu/fis/

Federated Search			
Updating Literature References	Simplified	Profile	
Research Map	Bonus	Profile	User Management
Enabling of Information Transfer	Bonus	Profile	User Management
Anonymized rating of profiles	Not-in-prototype		
Automatized Competence Crawling	Not-in-prototype		
Suggestion of profiles	Not-in-prototype		

Subelement: Profile Information

The **Profile Information** includes all necessary content to describe one *Competence* **Profile**. The **Profile Information** consists of basic information about the stakeholder (e.g. institution, address), a representative (e.g. for elenia Institute's workgroup "Energy Systems" – Prof. Bernd Engel) and a contact person (e.g. for elenia Institute's workgroup "Energy Systems" – Henrik Wagner project employee for ZLE). The contact person should alsobe in charge of maintaining the profile. The representative and the contact person do not need to be different persons but it is recommended as representatives tend to be too occupied than to maintain the profiles.

The research focus, research projects and current publications (including papers, data and simulation models) will be listed together with the membership in other research networks. The information and competences listed in the profiles are accessible by the *Core* elements search engine. For adequate search results, a common keyword scheme (see subelement competence taxonomy) can be used as assistance in in filling out the profile. The **Profile Information,** especially the basic information, will be explained in further detail in future prototype versions.

Subelement: Input Mask

The **Input Mask** provides two different ways of to enter information for the **Profile** creation. The a) questionnaire uses an interview-based format which leads through the **Profile** creation process by questioning the needed information (e.g. "What is the shortcut of your research institute?" – elenia). The questions will follow one after another and often include some useful hints and examples. This provides an interactive way which may reduce abortions of the **Profile** creation process. In addition, the Input Masks provides b) prescribed answer boxes (e.g. "Shortcut (if existing): [elenia]). The hints will be displayed when clicking on a small "?" right next to the prescribed answer boxes. The implementation could be based on the Open Source Inputmask from Robin Herbots[23] or the Vanilla Masker[24].

Subelement: Quality Management

The automated competence and information gathering can lead to list false information in profiles on the research and transfer platform. Therefore, the implementation of an efficient **Quality Management** with a short update interval is required to avoid an "information laundering". Moreover, privacy rules are applied to protect the personal data of the user of the research and transfer platform.

Subelement: Competence Taxonomy

The *Competence* element will provide a **Competence Taxonomy** which unifies and simplifies filling out the entries in the profiles. This enables describing the same competences with the same definition, reducing imprecise descriptions and enabling the formation of competence clusters as well as displaying them, e.g., in the form of a word cloud. The **Competence Taxonomy** will be extracted from a suitable source (e.g., an open science ontology for energy research).

[23] https://robinherbots.github.io/Inputmask

[24] https://vanilla-masker.github.io/vanilla-masker/demo.html

Subelement: Research Cluster

The functionality of **Research Clusters** allows grouping of competences based on a common research focus (e.g., co-simulation of energy systems) or membership by extracting this information from the profiles. This grouping or clustering helps to synthesize groups of researchers which may not belong to the same institution or research project but still focus on the same topic. Other than that, the word cloud provides inspiration for new platform users. To create a research cluster, all entries listed in the profiles under the term "Research Cluster" are collected and serve as an input for the Word Cloud. When clicking on a term respectively a research cluster in the Word Cloud, a list will be displayed including all profiles which have named this Research Cluster as their competence. Moreover, the affiliation of the profiles to a research network may also be shown. The **Research Clusters** will be implemented based on the word cloud function from *Core* but as its set on bonus priority and the Research Cluster of *Competence* on prioritized it might also be an own development of the element. Nevertheless, Mentimeter[25] or a simple python-based approach such as from Amo Mueller[26] or based on JavaScript from Tim Dream[27] could be starting point of implementation of this word cloud.

Subelement: Deadman's Handle

Profiles which did not update their information (e.g., literature references) or logged-in for a set amount of time are flagged as inactive to guarantee up-to-date profiles. This increases the incentive to maintain the profiles as well as showing the active participation in the community of the research platform.

Subelement: Competence Access Privileges of Federated Search

The database of Profiles can be searched via an API, so that Information can be accessed by the Core's **Federated Search** allowing a platform-wide access of information.

Subelement: Updating Literature References

The *Competence* profiles allow updating the profiles literature reference by uploading BibTex files which vastly reduces handling time.

Subelement: Research Map

Within the **Research Map** all registered user profiles will be displayed on an interactive map. The map includes sorting functions (based on address, perimeter, cluster), allowing filtering for certain research focuses. Network representation of **Research Clusters** can also be selected showing the geographical spread of in terms of clusters connected profiles. The Research Map is set to priority level bonus to avoid the ZDIN's research map being cannibalized by the *Competence* ones. The ZDIN's research map[28] is also basis of development for the *Competence* research map which is based on Google Maps.

Subelement: Enabling of Information Transfer

As a bonus functionality, the *Competence* element will provide an **API** for the gathered competences in the field of energy research in the **Profiles** for other researchers. Information can only be accessed with the permission of the respected profile maintainer to ensure data protection.

[25] https://www.mentimeter.com/

[26] http://amueller.github.io/word_cloud/

[27] https://wordcloud2-js.timdream.org/#love

[28] https://zdin.de/zukunftslabore/energie

Methods (for Open Energy Research)

This element was renamed from “Best Practices” after receiving feedback about the unclarity of the significance of the name and intentions of the element.

Goals of the Element

The *Methods* element has two broad objectives:

- First, general research guidelines for conducting energy research within the Open Science practices are to be presented, gathered from successful experiences from research projects. Best Practices and standards for cooperative project development, scenario modeling, data management are here required, to deliver ideas to structure cooperative research.
- Second, an introduction for the use of the different elements of the platform is required, as to provide an introduction for the use of the website, and thus maximize the usability of its elements.

Functional requirements are oriented towards the stakeholders. Based on the analysis of interview results (see [2] for details), the application of this element is oriented mostly towards the research community. The key use of this element is to provide an overview of scientific method during the different stages of the research lifecycle. For this purpose, Wiki styled pages are to be developed to provide quick access to read and write information on web pages. The Wiki engine allows collaborative development and expansion of content.

Functionalities for the Element

The main functionality of this element is to give a methodological overview of "Good Practices" in research projects. This includes, amongst others, providing descriptions of successful research projects, providing information on standardized scenarios and benchmarks, showing examples of data management in large research projects, and provide additional information on specific examples. Though most of these requirements are oriented towards the scientific community, they must be also developed with different users under consideration (industrial partners, decision-makers, citizens).

To this goal, two main subelements are presented. The first one, namely “Methods for Open Energy Research”, is oriented towards giving an overview of research projects, their experiences, and their examples for methods in different stages of the research cycle. The second one introduces the use of the research and transfer platform during the different stages of the research lifecycle, as to include relevant information required for the exploitation of the platform capabilities.

Subelement: Methods for Open Energy Research

This subelement is strongly linked with **Transparency**. Based on the research lifecycle, the goal is to provide a Search Engine that allows presentation of research guidelines (“How To…”), with inclusion of examples on project (and application) formulation, scientific project management; scientific research methods and modelling in energy research; information and examples on data management (DBMS, data protection, licenses, FAIR data principles); information and examples on statistical analysis methods, text analysis, analysis tools, uncertainty quantification; and guidelines for publications, listing (or links) to themed conferences or journals. The goal is to cover comprehensively methods for the different stages of research. A first view of what is desired may be reflected in existing initiatives and communities for energy system modelling and simulation platforms, such as openmod[29], oemof[30], or Open Science Framework[31]. The recommendation should use as many defined words from

[29] openmod-initiative.org/

[30] oemof.org/

[31] osf.io/

the ontologies in *Core* as possible. To this purpose, a dedicated Wiki site for Methodologies on Energy Research oriented to Open Science is to be developed. This will allow:

- Creation of documentation
- Access and restriction through authentication
- Attachment of media through uploading or embedding (videos, social media content)
- Topical association
- Creation and editing through Web browser

Following functionalities for a Wiki-Style site are then required:

a) **Create:** This feature allows creation of documentation, preferably using a Web-Style formatting. It shall allow writing in plain text directly in a browser, embedding of external documentation (Media hosted in other public platforms, embedding of social media content) and uploading own media.
b) **Edit:** A feature (also dependent on authentication for locked content) that allows editing of content. A page can also be locked to prevent further editing from non-authors or non-authenticated users.
c) **Revert:** Feature that allows authenticated users to revert changes to previous versions.
d) **Link:** This shall allow linking between pages within the platform, as well as external wiki. Preferable using markdown style.
e) **Hierarchical Structuring**: A hierarchical structure shall allow creation of categories, child categories, and child pages. This structuring is to be done on synergy with the Energy Ontologies and the general structure of the Platform.
f) **Search:** In connection with the Core Search API, this will allow searching for entries in the wiki and to present content from other elements.
g) **Tracking:** Allows keeping a backlog of the wiki page, search its editing history, and reverse changes (via Authentication)
h) **Tagging:** Allows labeling a wiki page with specific tags (also from Energy Ontologies) for a topical search.
i) **Export:** Functionality to export the content of a wiki page to a PDF (or similar) document.
j) **Authentication:** Functionality to enable privileges to users for creation/editing/reverting of restricted pages. Linked to the Core “User Management” feature.

Table 4 Relevant functionalities of Methods

Functionality	Priority Level	Depends on (within the same element)	Depends on (within other elements)
Create	Base		
Link	Base	Create	
Search	Base		Core: Federated Search
Hierarchical Structuring	Base	Create	
Authentication	Base	Create, Edit, Revert	Core: User Management
Edit	Prioritized	Create, Authentication	
Tracking	Prioritized	Create, Edit	
Revert	Prioritized	Create, Edit, Tracking, Authentication	
Tagging	Simplified	Search	Core: Energy Ontologies
Export	Bonus		

Table 5 Example Content for Methods for Open Energy Research

Content	Priority Level	Related to (other elements)
FAIR Data Principles	Base	Transparency, Repository
Versioning and GIT	Base	Repository
Licenses and Copyright	Base	Transparency
Guidelines for Visualization and Results Presentation	Prioritized	Repository, Transparency
Modelling and Simulation in Energy Research	Prioritized	Simulation
Proposal Guidelines	Prioritized	Transparency
Principles for Open Science	Prioritized	Transparency
Publishing Guidelines	Prioritized	Transparency
Statistical Methods	Simplified	Repository
Funding Application	Simplified	Transparency
Research Project Management Tools	Simplified	Transparency
Methods for Energy Research	Simplified	Transparency
Forming Research Consortia	Bonus	Competence
Trending research methods	Bonus	Competence
Data and results quality evaluation	Bonus	Repository
Data Structures and DBMS	Bonus	Repository, Transparency
Where to publish? Use of Keywords	Bonus	Transparency

Subelement: Introduction to the use of the research and transfer Platform

This subelement is linked with the rest of the platform. Based on the different stages of the research lifecycle, the use of the different elements of the platform is introduced here. Introductory explanations are here showcased with demonstrative examples with consideration of user profiles and degree of expertise. Examples for proper use of the online **Simulation** tool, **Competence** search functionalities and **Transparency** element are to be here showcased. Similar to the proposed Wiki for "Methods", a Wiki-Stile "Introduction to the use of the Platform" site must be developed, with the same functionalities as in

Table 4.

Table 6 Example content for introduction to platform

Content	Priority Level	Depends on (within other elements)
Search Syntaxis Examples	Prioritized	Core
Glossary of Terms	Prioritized	
Wizard: User Profile Creation	Not-in-prototype	
How to: Specific project search	Prioritized	Competence
Wizard: Create Project Profiles	Bonus	
Wizard: Create Project Profiles	Bonus	
How to: Add Artifacts and DB	Prioritized	Repository
How to: Use Git with the Platform	Simplified	
How to: Previsualize Data	Bonus	
“Create Simulation” Tutorial	Base	Simulation
“Run Sim” Tutorial	Base	
“Analyze Sim” Tutorial	Base	
Basic Jupyter Notebooks for Sim	Simplified	
Advanced User Tutorials	Bonus	
How to: Search for projects and related artifacts	Prioritized	Transparency
How to: Find current Trends in Research	Simplified	
How to: Content for different Stakeholders	Bonus	

Repository

Goals of the Element

The goal of *Repository* is to make data, models and scenarios in the energy domain more findable, accessible, interoperable and reusable (FAIR, [5]). Besides making these artifacts available, *Repository* should include information about artifacts, which can be made available on request. Also, a limited access, e.g., behind authentication, to artifacts should be supported as well.

Harmonized interfaces should be supported by *Repository* by labeling and describing them, therefore increasing their visibility. In general, a good search and filter functionality is required to improve the search results, offered via *Core*. Also, the information attached to the artifacts should contain a lot of precise details, like authors, examples of use, programming language.

Functionalities for the Element

Repository focuses on three main classes of artifacts: data, models and scenarios. The functionalities can be separated in front-end and backend functionalities. The backend consists of **Metadata Schemas** and of databases (including their management system, **Metadata Registry**). Metadata can be used to describe the artifacts. By standardizing these descriptions into schemas, the description can be better compared and integrated into other functionalities, such as the search function. The databases must store metadata of different artifacts and store datasets if required.

The front-end of the platform consists of three parts. The **Interactive Form** allows to add description about artifacts to the platform. A straightforward process should all an effective addition of more artifacts for all researchers. The required descriptions of the artifacts are based on the **Metadata schemas** including a brief description. The second functionality is search. The search functions, including filters, are needed to find artifacts and access the databases, and will be offered via an API to *Core* to be usable from the whole platform (**Basic Search)**. The third part of the frontend is the representation of an artifact based on the stored information (**Artifact Overview Page**).

Table 7 Relevant functionalities of Repository

Functionality	Priority Level	Depends on (within the same element)	Depends on (within other elements)
Metadata Schemas	Base		Energy Ontologies
Metadata Registry	Base	Metadata Schemas	PID Service
Artifact Overview Page	Base	Metadata Schemas	
Interactive Form	Prioritized	Metadata Schemas, Data upload	User Management, PID Service, Energy Ontologies
Basic Search	Prioritized	Metadata Registry, Metadata Schemas	Federated Search
Limited Access	Simplified		
Data upload	Simplified		
Graphical Search	Bonus	Metadata Registry	Federated Search
Comparison of Artifacts	Bonus	Metadata Schemas, Metadata Registry	
Small Visualization	Bonus	Metadata Schemas, Artifact Overview Page	
Recommendation of Similar Artifacts	Not-in-prototype		
Download in Different Formats	Not-in-prototype		

Subelement: Metadata Schemas

Metadata can be used as the ontological description of the different artifacts. By using semantic web resources, the quality of the metadata can be increased [6]. A metadata schema or standard is used to predefine the different elements needed to describe and categorize a certain artifact. Besides the different categories, called elements, the schema also defines if for a certain element a free value is allowed or the use of a controlled vocabulary is required. A limited vocabulary increases the comparability of the metadata. Instead of a free value, a link to a semantic web resource is also possible.

For *Repository*, metadata schemas for data, models and scenarios are required. These metadata schemas should share some common elements, while some elements will differ. In general, the metadata schema should include:

- Links to a paper, project, other relevant artifacts
- Information about who is allowed to access the artifact
- Quality of the artifact, e.g., where is the data from, is coded reviewed and tested, how often is the data or code already reused in other studies
- Information as authors etc., which could be inherited from DCAT[32]
- A PID, which will be created by the *Core* element

To increase the interoperability of the domain-specific description of the artifacts, domain-specific ontologies provided by **Energy Ontologies** in *Core* can be used as controlled value vocabularies, where possible.

For the description of data, *Repository* will reuse and extend the metadata schema of the Open Energy Platform (OEmetadata[33]). This also enables interoperability to the Open Energy Platform[34].

For the description of models, a new metadata schema should be developed for *Repository*. It should include relevant elements from CodeMeta[35], a common metadata schema for research software, and other relevant existing metadata schemas.

The description of scenarios needs to be synchronized with the developments in simulation. The metadata schema should be based the scenario description of the Open Energy Platform[36] and the ontology-based scenario description developed by Schwarz and Lehnhoff [7].

Subelement: Metadata Registry

Within *Repository*, metadata of data, models and scenarios will be stored, made available and searchable. Within the registry metadata for the different artifacts based on the according **Metadata Schemas** will be stored. The registry will be based on ckan[37].

Subelement: Interactive Form

The interactive form enables users to add new artifacts, which can either be the artifacts itself, e.g., a dataset, or a description of an artifact including a link, e.g., a model in an online repository (like gitlab). Adding datasets should be implemented by using the **Data Upload**. The questions within the form should be based on the right metadata schema, so the given answers can be linked to the elements of the schema. The add functionality should be able to automatically collect relevant information, e.g.,

[32] https://www.w3.org/TR/vocab-dcat-2/

[33] https://github.com/OpenEnergyPlatform/oemetadata

[34] https://openenergy-platform.org

[35] https://codemeta.github.io/

[36] https://openenergy-platform.org/factsheets/scenarios/

[37] https://ckan.org/

programming languages from a gitlab link. If possible, new information should link to entities in other elements (e.g. projects in *Transparency*) or semantic web resources (e.g. by using the ontologies from **Energy Ontologies** in *Core*) by presenting suggestions, when input is typed. The collected information on the artifacts will be stored into the appropriate registries.

Subelement: Limited Access

The **Metadata Schemas** will include an element availability, where available on request is an allowed approach. In this way, the limited access is implemented in a simplified way.

Subelement: Data upload

Repository will not offer a database for data. Instead, an upload to the Open Energy Platform using their API[38] will be enabled. This removes the requirement of offering data hosting, but still make it possible to upload data to a known data platform for energy research. Before adding data, users will be informed that the data is upload to a third party.

Subelement: Basic Search

The search functionality of *Repository* should be developed in accordance with the **Federated Search** of *Core*. All registries should be searched for relevant entries. It should be possible to filter the results according to different elements of the **Metadata schemas**.

Additional to the basic search functionality, an overview of latest searched artifacts should enable a faster start into the *Registry* element.

Subelement: Graphical Search

As bonus a graphical overview of the different artifacts should simplify the search for new artifacts. It should also be connected to the **Federated Search**.

Subelement: Artifact Overview Page

For all artifacts, an overview page should be created based on the **Metadata Schemas**. This overview page lists the most important information in a comprehensive way from the related metadata and links to other relevant resources like on bio.tools[39] [8]. For scenarios, it should be possible to directly important them into *Simulation*.

Subelement: Comparison of Artifacts

Within each category of artifacts, e.g. in scenarios, a comparison of artifacts is possible. In this way, it is easier to find the right artifact. The ORKG already enables certain comparisons[40], which should be used as starting point.

Subelement: Small Visualization

The data of datasets should be visualized as a preview on the artifact overview page. Grafana[41] is a commonly used tool for data visualization and, therefore, can be integrated for that purpose.

[38] https://oep-data-interface.readthedocs.io/en/latest/api/how_to.html

[39] https://bio.tools

[40] https://www.orkg.org/orkg/comparison/R113171

[41] https://grafana.com/

Simulation

Goals of the Element

The platform component *Simulation* supports the coupling and reusability of different simulation tools and models to enable co-simulation of various scenarios by addressing typical use cases in interdisciplinary research. The element extends co-simulation frameworks, such as mosaik[42], by adding assistance to build complex scenarios including the **Artifacts** from *Repository*. The focus lies on the combination of different domain-specific simulation tools and modeling approaches [9].

Functionalities for the Element

The main goal of *Simulation* is to provide a co-simulation platform to couple different tools and models, which are stored in *Repository* (**Artifact Overview Page**). Thus, the **Metadata Schemas** for data, models and scenarios are required and used as a foundation for *Simulation* to list and connect compatible artifacts within the co-simulation platform [7].

The co-simulation platform should allow to extend scenarios from *Repository* and to create user-defined scenarios. It should be possible to parametrize the simulation models to provide different boundary conditions for the scenarios. It also includes the execution of the scenario and visualization during runtime. The last part of the co-simulation platform is the analysis of the simulation results, including data visualization.

Table 6 Relevant functionalities of Simulation

Functionality	Priority Level	Depends on (within the same element)	Depends on (within other elements)
Reference Scenarios	Base		
Artifact List	Base		Basic Search, Metadata Schemas, Artifact Overview Page
Running the Simulation directly over the Platform (web-based)	Prioritized	Reference Scenarios, User-defined Scenarios	
Saving the Simulation Results locally	Prioritized	Running the Simulation directly over the Platform	
Creation of User-defined Scenarios	Simplified	Artifact list	Metadata Schemas
Simulation Configuration	Simplified	Reference Scenarios, User-defined Scenarios	
Visualization of the Simulation State on the Platform (during runtime)	Simplified	Running the Simulation directly over the Platform	
Save Scenarios within the User Profile	Bonus	Reference Scenarios, User-defined Scenarios, Simulation Configuration	User Management, PID Service
Local Execution	Bonus	Reference Scenarios, User-defined Scenarios	
Visualization of Simulation Data and Results on the Platform	Bonus	Running the Simulation directly over the Platform	
Creation of Hardware-In-The-Loop Scenarios	Not-in-prototype		
Laboratory Coupling	Not-in-prototype		
Saving the Simulation Results within the User-Profile	Not-in-prototype		

[42] https://mosaik.offis.de

Benchmark-Comparison of the Scenarios	Not-in-prototype

Subelement: Reference Scenarios

Reference scenarios are prepared for different target groups (starters, advanced users, experts) and made available in *Repository*. It should be possible to import and edit these scenarios directly in *Simulation* with a user-friendly web interface.

Subelement: Artifact List

Repository defines common interfaces (via the **Basic Search**) between models and data. Models and data compatible with these interfaces are listed in *Simulation*.

Subelement: Creation of User-defined Scenarios

The Artifact List is used to create user-defined scenarios. In this regard, an approach presented by Schwarz et. al [7] can be used to assist in the planning of co-simulation based on semantic knowledge representation. It will be aligned with the **Energy Ontology** provided by *Core*.

Subelement: Simulation Configuration

The configuration phase of a scenario includes a simplified selection of the appropriate model depth, width and scope. The following simulation specifications and constraints should be considered: size of a plant, selectable time period, characteristic values to be calculated, Key Performance Indicators (KPIs).

Subelement: Running the Simulation directly over the Platform (web-based)

It should be possible to initialize and run the simulation directly over the platform. The co-simulation platform should have a user-friendly web-based interface for a simple scenario assembly and configuration, like the *open_plan* tool[43]. In addition, the *Maverig*[44] tool from *mosaik*, which is a graphical user interface for creating and visualizing smart grid simulations, can be used as a reference for the co-simulation platform.

Subelement: Visualization of the Simulation State on the Platform (during runtime)

The visualization should include the log prints of the co-simulation framework *mosaik* and a simple progress bar to visualize the current simulation state.

Subelement: Local Execution

For the local execution with *mosaik*, an automated generated scenario python script or configuration file (ontology-based) is provided via the platform. This file enables the automated creation and configuration of scenarios.

Subelement: Visualization of Simulation Data and Results on the Platform

When the simulation is finished, the simulation results should be displayed via a dashboard (e.g., via Grafana[45]). This includes the presentation of selected parameters, KPIs and optimized results (e.g., primary and secondary energy, energy production from renewable energy sources, local consumption). It should be possible to filter and sort the data (e.g., by month, year). In addition, the visualization of data should include both tabular and graphical presentation (e.g., graphs, plots).

[43] https://open-plan.rl-institut.de/de/

[44] https://gitlab.com/mosaik/tools/maverig

[45] https://grafana.com

Subelement: Saving the Simulation Results locally

It should be possible to save the simulation results locally via download. This includes the functionality to save raw data (e.g., csv format) as well as tabular and graphical presentations (e.g., graphs, plots).

Transparency

Goals of the Element

The main goal of the platform element *Transparency* is to process, publish and communicate research and development content to promote a broader and interdisciplinary discussion among all respected types of stakeholders. In addition, it serves as a foundation to use these processed results in research-oriented teaching and education. Thus, the element represents the platform and prospectively the whole energy research sector towards society, politics and industry. Furthermore, it serves as the communication channel for distributing this information.

Functionalities and important considerations for the Element

The stakeholders of the platform, i.e. researchers, practitioners from various domains, political decision makers, local authorities, citizens and students, are distinguishable in terms of characteristics such as their knowledge base and intended purpose to use the platform. Hence, it is vital for the success of this element to offer the contents presented on the platform and their delivery channel in a stakeholder specific manner. For this reason, content of the element should be processed in multiple ways, e.g., advanced content or easy-to-understand content in simple language, for different groups of stakeholders, where appropriate. For other content and intended stakeholders, a single way of presentation for all stakeholders is sufficient.

When choosing which content to present in which format, it must be evaluated if a certain content should be produced within the current project ZLE or if it is more reasonable to link to external websites.

Transparency consists of several subelements to reach the above stated goal. For all subelements, the quality, correctness and neutrality of the content has to be ensured as well as up-to-dateness of the information.

Following the goal of the element of reaching a broader part of the society, the platform should be promoted towards the (mass) media and local authorities.

Table 8 Relevant functionalities of Transparency

Functionality	Priority Level	Depends on (within the same element)	Depends on (within other elements)
Input Masks	Base	Summaries of Papers and Projects, Presentation of Energy Research Projects, Event Calendar, Educational Content	Core
Summaries of Papers and Energy Research Projects	Base	Input Masks, Trend Clouds, Presentation of Energy Research Projects	All
Public Forum and Chat	Simplified	Input Masks, Trend Clouds	Core, Competence
Event Calendar	Simplified	Input Masks	Competence
Educational Content	Simplified	Input Masks	All
Energy Research Roadmap	Bonus	Summaries of Papers and Projects, Presentation of Energy Research Projects	All
Trend Clouds	Bonus	Summaries of Papers and Projects, Presentation of Energy Research Projects, Public Forum, Educational Content	Core
Funding Calls	Bonus	Input Masks	Core

Subelement: Input Masks

To reduce the complexity of creating or uploading content in general, **input masks** are provided for standardized content (e.g., for brief summaries of scientific papers) and for non-standardized content (e.g., for presenting board games). Additionally, these masks ensure the standardization of similar content in terms of format besides ensuring data integrity which facilitates further processing and error prevention. There are several existing solutions for implementing input masks such as the JavaScript libraries Cleave.js[46] or VanillaMasker[47]. The choice of a specific solution depends on other solutions and programming languages chosen for other parts of the platform and on the requirements in terms of content structure which are to be evaluated.

Subelement: Summaries of Papers and Energy Research Projects

Following the main goal of the element, the most important subelement of *Transparency* is to create **brief summaries of scientific papers and research projects**. Since scientific papers are likely comprehensible for more experienced stakeholders in their published form and also usually already provide a summary in form of an abstract, they are only processed into brief summaries for less experienced stakeholders in order to promote the tangibility and clarity of energy research. Easy-to-understand language and graphics and possibly explanatory videos should be used here. If existent, recordings of conference speeches might be embedded as a bonus. Brief summaries of research projects on the other hand are relevant for experienced stakeholders as well. The platform also provides an overview of all projects stating their topics and participating members. As a result, **projects** are summarized in two ways of presentation: A scientific presentation for experienced stakeholders and a less advanced presentation for less experienced stakeholders.

Summaries of papers and projects will be realized through standardized **input masks**, filled out by the users. Besides members of the ZLE, external partners from *Competence* are also given the possibility to summarize their papers and projects. In this case, the content must be reviewed by a ZLE member before publication on the platform. The categorization of research projects follows a keyword-based approach.

To highlight the practical relevance of papers and projects, their implications for private and practical decisions shall be pointed out where applicable. Besides these implications, use cases, such as the demonstration of a co-simulation and its results, should be employed here as well.

Subelement: Public Forum and Chat

To promote a dialogue within the platform's community and the communication between researchers and other stakeholders, particularly citizens, **a public forum** will be implemented. In this forum users can ask questions towards researchers or discuss certain topics publicly. The content of the forum is organized by using sub-forums for the different domains in energy research. While reading the content posted in the forum is possible for every user, only registered users can contribute here. Therefore, an authentication function is implemented representing an interface to the partner profiles from *Competency* employing the **User Management** of *Core*. The forum also contains a chat function to send private direct messages to another user for which prior registration is also required. Moderation of the content posted in the user forum is necessary to filter out undesirable content and to ensure answers by experts in a reasonable amount of time. There are several free solutions, such as phpBB[48] or Simple Machines[49], and commercial solutions, such as WoltLab Suite[50] or Vanilla Forums[51], providing these functionalities. The choice of a solution depends on several objectives such as its cost structure,

[46] https://github.com/nosir/cleave.js

[47] https://github.com/vanilla-masker/vanilla-masker

[48] https://www.phpbb.de/

[49] https://www.simplemachines.org/

[50] https://www.woltlab.com/de/

[51] https://vanillaforums.com/en/

its licensing model, its compatibility with mobile devices, its levels of developer and community support and if it supports SEO optimization just to mention a few.

Subelement: Event Calendar

To promote **public educational events,** such as lecture series or workshops, the platform contains a **calendar** of these events. Partners from *Competence* can declare their attendance to events so that other platform users are able to see which partners attend a certain event. Their profiles from *Competence* are linked here. A reminder function is employed to notify users about these events upon registration. These functionalities might be based on the Google Calendar API[52] as it provides different types of reminders and notifications via pop-up or e-mail.

Subelement: Educational Content

Educational content, such as lecture slides, laboratory setups and lecture recordings**,** might be shared via the platform to be utilized for private educational purposes or for teaching in schools and universities. The results of the ZLE workshops might be employed here as well. Since the main goals of *Transparency* are covered by other subelements and for reasons of expected effort, an extensive processing of existing educational content for different types of stakeholders is not planned. Therefore, only those educational artefacts which require a low effort in terms of processing are provided on the platform.

Subelement: Energy Research Roadmap

To gain a comprehensive overview over the past and future research in the energy sector, an **energy research roadmap** will be established. Here, two ways of presentation are reasonable. On the one hand, researchers, students and practitioners that are experienced in the domain, a scientific presentation is beneficial. On the other hand, there should be a less advanced presentation for citizens and practitioners that are less experienced, but interested, in the domain of the energy sector. The less advanced presentation should be supported by using text in an easy-to-understand language, implementing clear graphics and possibly videos. The roadmap can be implemented based on several commercial solutions such as ITONICS Roadmap[53] which is also used by Bayern Innovativ[54].

Subelement: Trend Clouds

A quick overview over trending topics and content in *Transparency* is provided by implementing **word clouds** for different subelements of *Transparency* including an own word cloud each for the domains of the paper and project summaries viewed the most, for the domains discussed in the forum the most and for the topics of educational content viewed the most. These clouds are generated based on past search queries as in Mentimeter which is already described in *Core***.**

Subelement: Funding Calls

Transparency also provides a textual overview over third party funding calls in energy research. The funding calls are linked and described briefly stating the most important information. The categorization of these calls follows a keyword-based approach. For instance, the 7th energy research program of the German federal government[55] could be contained here.

---

[52] https://developers.google.com/calendar

[53] https://www.itonics-innovation.com/roadmap-software

[54] https://www.bayern-innovativ.de/seite/roadmapping

[55] https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/7th-energy-research-programme-of-the-federal-government.html

3 (Geplante) Veröffentlichungen

Konferenz/ Journalname	Datum der Veröffentlichung	Autorenschaft	Ggf. Link zum Dokument
"Towards a Concept for an Open Digital Platform to Support Interdisciplinary Energy Research" 11th DACH+ Conference on Energy Informatics 2022	Geplant September 2022	Ferenz; Ofenloch; Penaherrera; Wagner; Werth; Breitner; Engel; Lehnhoff; Nieße	

4 Literaturverzeichnis

[1] S. Ferenz *et al.*, “ZLE Open Science Declaration,” Aug. 2021, doi: 10.5281/zenodo.5221234.

[2] O. Werth, S. Ferenz, and A. Nieße, “Requirements for an Open Digital Platform for Interdisciplinary Energy Research and Practice,” presented at the 17th International Conference on Wirtschaftsinformatik, Nürnberg, Feb. 2022. [Online]. Available: https://aisel.aisnet.org/wi2022/sustainable_it/sustainable_it/2/

[3] M. Booshehri *et al.*, “Introducing the Open Energy Ontology: Enhancing data interpretation and interfacing in energy systems analysis,” *Energy AI*, vol. 5, p. 100074, Sep. 2021, doi: 10.1016/j.egyai.2021.100074.

[4] M. Uslar, M. Specht, S. Rohjans, J. Trefke, and J. M. Vasquez González, “The IEC Common Information Model,” in *The Common Information Model CIM: IEC 61968/61970 and 62325 - A practical introduction to the CIM*, M. Uslar, M. Specht, S. Rohjans, J. Trefke, and J. M. Vasquez Gonzalez, Eds. Berlin, Heidelberg: Springer, 2012, pp. 75–106. doi: 10.1007/978-3-642-25215-0_3.

[5] M. D. Wilkinson *et al.*, “The FAIR Guiding Principles for scientific data management and stewardship,” *Sci. Data*, vol. 3, no. 1, Art. no. 1, Mar. 2016, doi: 10.1038/sdata.2016.18.

[6] M. L. Zeng and J. Qin, *Metadata*, Second. London: fp, facet publishing, 2016.

[7] J. Schwarz and S. Lehnhoff, “Ontological Integration of Semantics and Domain Knowledge in Energy Scenario Co-simulation,” in *Proceedings of the 11th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management*, Vienna, Austria, 2019, pp. 127–136. doi: 10.5220/0008069801270136.

[8] J. Ison *et al.*, “The bio.tools registry of software tools and data resources for the life sciences,” *Genome Biol.*, vol. 20, no. 1, p. 164, Aug. 2019, doi: 10.1186/s13059-019-1772-6.

[9] C. Steinbrink *et al.*, “CPES Testing with mosaik: Co-Simulation Planning, Execution and Analysis,” *Appl. Sci.*, vol. 9, no. 5, Art. no. 5, Jan. 2019, doi: 10.3390/app9050923.