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Grid Architecture Mapping to Understand Transformation (GAMUT)

Concept Definition

July 2025

Jaime T Kolln
Artis Riepnieks

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Jaime T Kolln
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Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Abstract

The electric power system is undergoing significant transformation driven by changes in the generation mix, increasing reliance on information and communication technologies, evolving customer expectations, growing demand, and a dynamic cyber-physical environment. To address these challenges, substantial investments will be made over the next decade to create a flexible, affordable, secure, reliable, and resilient electric system. In response, the U.S. Department of Energy's (DOE) Office of Electricity (OE) is developing knowledge management tools aimed at systematically documenting technology pilots and demonstration projects. This initiative seeks to improve understanding of operating contexts, planning steps, and integration requirements for innovative grid technologies.

OE's project leverages Grid Architecture principles to collect and organize insights into the interdependencies, requirements, and capabilities of various grid solutions. By employing a systematic approach, the project aims to perform a feasibility study for the development of a software tool that will support stakeholders, including regulators, transmission and distribution system operators, aggregators, and technology providers. By offering a systematic, software-based framework to document technologies, understand their benefits and impacts, and inform deployment strategies, the proposed Grid Architecture Mapping to Understand Transformation (GAMUT) Tool is intended to reduce costs, enhance decision-making, and facilitate scaling and effective deployment of new technologies. The feasibility study will evaluate the technical and financial viability of the GAMUT Tool, identifying stakeholder needs and assessing risks and mitigation strategies. Ultimately, the GAMUT team aims to develop an initial minimal viable product, followed by staged improvements, to aid in the modernization and transformation of the U.S. electric grid.

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1.0 Introduction

The electric power system is undergoing a significant transformation, characterized by changes in the generation mix, increased reliance on information and communication technologies, new customer expectations, and a changing cyber-physical environment. Government entities, the electricity industry, and other stakeholders are projected to invest billions, if not trillions, of dollars over the next decade to meet rising electricity demand with a flexible and affordable electricity delivery system that is secure, reliable, and resilient.

To support decision-making and the cost-effective adoption of innovative grid technologies, the U.S. Department of Energy's (DOE) Office of Electricity (OE) has called for the development of knowledge management tools. These tools are intended to assist in systematically documenting technology pilots and demonstration projects to improve understanding of the operating context, planning steps, and integration requirements to adopt innovative grid technologies. A systematic and standardized approach to analysis, using a software-based evaluation tool, can help inform grid stakeholders of potential benefits of advanced technologies and facilitate their scaling, extension, and replication.

By applying Grid Architecture principles and conducting structural assessments of pilot and demonstration projects, information can be systematically collected and organized. This approach allows insights into requirements, dependencies, and capabilities to be queried and reviewed by stakeholders. Consequently, it increases the awareness and understanding of various components, software, and processes vital to technology integration and adoption, thereby informing better decision-making and reducing costs and barriers associated with the transformation of the electricity delivery system.

1.1 Grid Architecture and Industry Structures

System architecture provides the conceptual framework that outlines the structure, behavior, and key constraints of a system. It aims to facilitate the understanding of the system's overall configuration, attributes, and the interactions among its components. System architectures are typically documented and specified in a formal manner. The discipline of systems engineering includes core principles and methodologies for the Grid Architecture development process.

Grid Architecture¹, developed under prior DOE projects, is the application of system architecture principles, network theory, and control theory to the electric power grid. It represents a high-level description of the entire power system, spanning multiple interdependent networks of structures serving as a crucial tool to comprehend and define the complex interactions. Grid Architecture provides methods to document and specify the highest level of the grid's architecture, allowing for systematic analysis of the complex interactions across the current and evolving grid. These interactions include the electrical infrastructure itself, supporting infrastructures, and other financial, jurisdictional, and regulatory dependencies. Figure 1 provides examples of what is included in the Grid Architecture structures.

¹ <https://gridarchitecture.pnnl.gov>

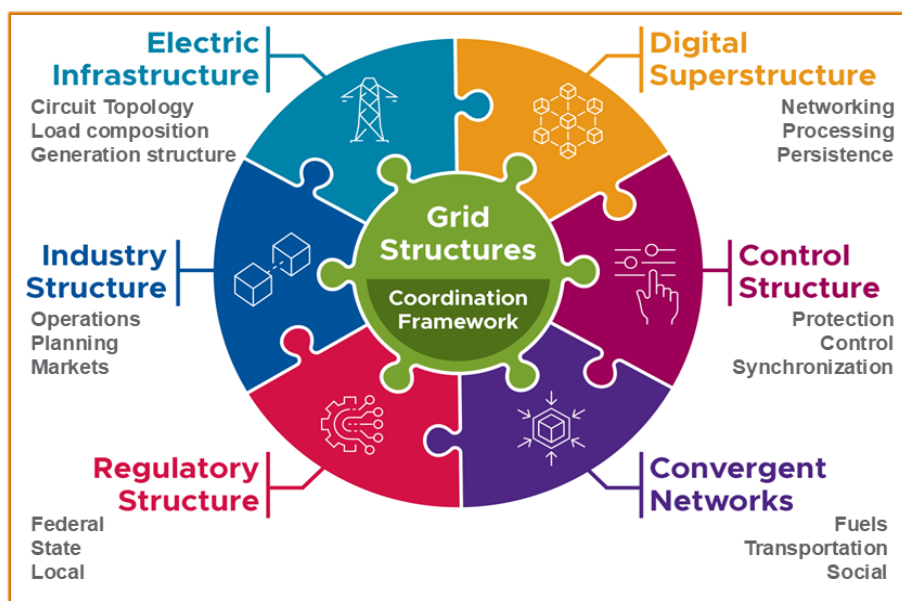


Figure 1. Grid Architecture network of structures.¹

This top-down approach provides a foundation for analyzing broad grid challenges, documenting, and specifying architectural structural requirements to guide grid transformation strategy and plans. By identifying dependencies between structures, informed design decisions can be enabled that will reduce barriers to adoption and broad deployment of new technologies. The architecture establishes the bounds for specific solution designs, and it has been utilized to inform policy makers as well as other DOE research and development projects. However, there has not been a similar methodology established to evaluate how specific technology solutions fit into a Grid Architecture vision. Further, consistent tools do not exist to easily link technology solutions to the Grid Architecture structures that would be suitable for broad application by DOE, researchers, industry, and other stakeholders. The GAMUT project will address this gap by providing structured information collection, technology solution identification, and knowledge management frameworks that can be applied to software-based solutions.

1.2 Data and Knowledge Management

Knowledge Management is a well-established discipline to facilitate the collection, organization, sharing, and analysis of knowledge. The Grid Architecture Mapping to Understand Transformation (GAMUT) Tool will leverage the existing developments in software tools as well as the developed knowledge/information that's available through Grid Architecture, technology standards, and other materials. The choice of knowledge management approach and tools will dictate the information organization within the GAMUT Tool. The actual approach will be determined as part of the feasibility study and will include an assessment of multiple use cases to evaluate various engineering tradeoffs associated with these approaches.

One of the examples is graph-based knowledge management approaches that offer beneficial outcomes to managing information and making it accessible to GAMUT's users. Knowledge graphs organize and store information/knowledge in a graph structure where nodes represent

¹ Pal, Seemita, and Wollman, David, "A Practical Introduction to Common Grid Architecture Techniques," (2024), <https://doi.org/10.2172/2342144>

entities and edges represent relationships between them. Graph-based knowledge management offers good capabilities to illustrate connections/interdependencies between data points, integrate diverse data types, and potentially offers a potentially good starting point for automatic software tool integration (e.g., large language model training datasets).

2.0 Project Overview

The GAMUT project aims to establish feasibility and, with approval, deliver a minimum-viable-product for an approach for systematically documenting and understanding the operating context, specifications, processes, benefits, and impacts of various technologies and solutions to support grid modernization. Grid Architecture fundamental concepts will be applied in a systematic way to analyze and understand the various components, interdependent systems, and interactions of new technology, including hardware, software, and processes, being deployed in the electric system. This methodology also will enable stakeholders to measure the effectiveness of different technology deployment scenarios in relation to a future grid vision and how these solutions can be more easily scaled and implemented across jurisdictions. A framework for systematic application of Grid Architecture techniques and structural assessments will support collecting and organizing information, providing insights into requirements, dependencies, and capabilities.

2.1 Project Process Structure

The project structure was developed with the objective of a feasibility study for the development of a software tool (the GAMUT Tool) to enhance understanding of technologies that will aid in cost-effective transformation of the electric system. As is typical with software and systems design endeavors, the project team must first understand the objective and constraints to develop a list of requirements. The stakeholders at DOE Office of Electricity worked with the Pacific Northwest National Laboratory team to draft the initial set of requirements included in this document. These requirements will inform the initial information collection process.

As Grid Architecture is a complex process spanning the seven structures shown in Figure 1, context will be needed to define the intent for each topic's information request from stakeholder groups. The information collection process draft will provide the project team an opportunity to work with technology developers and users to refine the questions as well as the context and other guidance that the GAMUT Tool will eventually use. As an iterative process, there will be multiple rounds of review with various technologies to broadly cover all the Grid Architecture topics. The various iterative process components are shown in Figure 2.

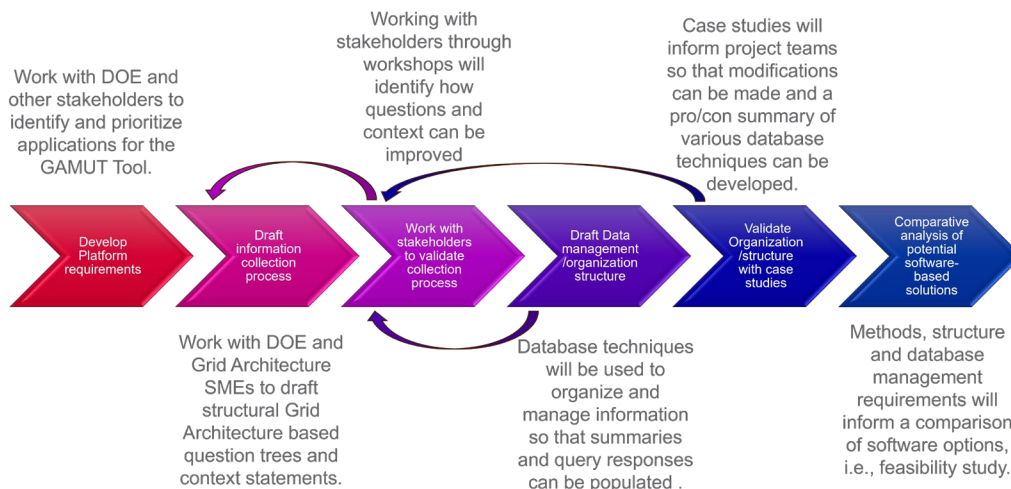


Figure 2. GAMUT project approach to software development feasibility.

Once a general information collection process is agreed upon, the information collected through the validation process will be used to understand how it should be organized. The knowledge organization database will need to be able to associate topics and enable a variety of queries, as well as provide an overview summary of the technology. This will be organized according to the Grid Architecture-based structural attributes and other details related to advanced technology pilots and demonstrations. Once again, this process will be iterative and require validation with stakeholders, including the technology developers, project sponsors, partners, and utility partners who would provide inputs and benefit from outputs.

The feasibility study will include a discussion of technical and financial feasibility aspects, with details related to risks and their mitigations. Tool development recommendations will include advantages and disadvantages of available knowledge management methodologies, including a discussion of input ingestion, output association, and database management alternatives. It is expected that both the technical assessment and stakeholder review recommendations will lead to a go/no-go decision and a report, including selection of the recommended potential solutions.

2.2 GAMUT Stakeholder Perspectives

The GAMUT Tool is designed to support a variety of stakeholders at different interaction points. Those providing input will include a diverse set of stakeholders such as technology developers, technology pilot project managers, contractors, utilities, and other jurisdictional entities. These users will not only contribute information but will also benefit from understanding gaps in their knowledge about dependencies and implications.

As this scope is limited to a feasibility assessment, the subset of users, both input and output stakeholders, will be constrained to a manageable number within a few key technology domains. For the feasibility study, a set of projects will be engaged to validate the interrogation process. The projects cover topics such as distribution control schemes, dynamic line ratings, and other innovative technologies.

The GAMUT Tool is expected to facilitate advanced technology development and deployment and identify associated gaps or challenges. One of the key benefits of Grid Architecture is its ability to highlight interdependencies or systemic issues. For example, technology developers may not be fully aware of regulatory constraints or market-related benefits.

While Grid Architecture offers a comprehensive approach to designing, operating, and optimizing electrical grids, it is not expected that all users will be experts on the subject. Therefore, stakeholder expectation of the GAMUT Tool is to interact with standardized inputs, where appropriate. The structures from Grid Architecture can help to streamline and facilitate the data collection process, without requiring specialized in-depth guidance to understand the context of the input.

Due to intellectual property and electric power system security constraints, user roles and associated access privileges will also need to be defined to manage access by sub-populations within the stakeholder community.

2.2.1 Information Provider Perspective

It is assumed that the information provider will need guidance related to Grid Architecture and its structures. Relevant context will be provided to them to help inform the information they provide. This will include a general description of the type of information required and its intended use.

This guidance benefits the input provider by helping them identify topics for further exploration, such as markets, regulatory environment, or hidden coupling among industry structures. This allows for a more holistic understanding of the technology without requiring the input provider to become a Grid Architecture expert.

Similar to other software “wizard”-type guidance, a user may need to return to the tool at a later date, or another information provider may be asked to provide input on a specific topic. For example, a project performer might provide details about a technology, while a partner utility might provide system or jurisdictional details.

The user interface should cater to this variability in input providers through lookup mechanisms. Examples include a protected link for adding certain information or a feature for inviting or requesting access. To encourage maximum participation, every effort should be made to identify and protect sensitive information and intellectual property.

2.2.2 Output User Perspective

Like the information provider, the output user will also need guidance on the various topics available for query. In addition to queries, the output user will also benefit from a technology summary or a technology deployment playbook (i.e., CliffsNotes). This summary should be able to give an overview of all Grid Architecture network structure topics as they are requested.

For the feasibility study, the initial output user will be considered as DOE technology experts looking to better understand pilot projects or demonstrations that are nearing readiness for large-scale deployment. Use cases may include their impact, best practices, lessons learned, challenges, and any jurisdictional or systemic issues that were discovered during a pilot or similar demonstration. While this is the initial intent, all considerations should be given to making the output user base and objectives flexible and extensible. Additional examples of users include planners, engineers, regulators, and others that provide critical feedback during usability studies, procurements, and other approvals.

There are a variety of opportunities to benefit from knowledge of advanced grid technologies, ranging from simple time-saving reviews and comparisons to queries that are yet to be developed. In this way, queries should be categorized and dynamic, perhaps using keyword searches and topical searches for the feasibility study, but with consideration of how this may be extended beyond to use machine learning and artificial intelligence based searches.

2.3 Develop Software Tool Suite Requirements

The requirements specification will define the functionalities and capabilities required for the software tools, ensuring that the tools can effectively support the documentation, analysis, and comparative assessment of grid solutions. Additionally, a feasibility evaluation will assess the practicality and feasibility of developing the proposed software tool suite, evaluating technical challenges, resource requirements, and potential benefits.

Software tools that manage databases and resources already exist, including artificial intelligence tools that can provide interpretations and responses. As part of the feasibility assessment, Pacific Northwest National Laboratory will provide recommendations relating to the level of complexity, steps that should be taken, and timeline for the program project to provide the most useful resource that can be reasonably provided. An example of a basic reference tool is the SEPA Catalog of Standards¹, while a complex large language model tool such as ChatGPT can provide reasonable summaries of complicated documents or topics. Risk management associated with improper application of large language models and the false information (hallucination) issue also needs to be considered.

2.4 Information Collection and Management Structure

The information collection process will be set up to be information carrier type agnostic. Initial collection efforts will be carried out with the guidance and contribution from DOE and technology development project teams (including case studies). At the initial stage of the project, the collection process is envisioned to be explorative and qualitative rather than quantitative and rigorous. Comprehensive information collection and processing approaches are planned to be part of the overall feasibility assessment.

The main sources of information are documentation and written artifacts (including Grid Architecture materials, standards, reports, diagrams, etc.), including the documents provided by technology project participant teams (technology descriptions, lessons learned, reports, etc.). Another significant part of the information source will be case studies and interactions with providers of the specific grid solutions. This means capturing narratives and information that are not well documented or even defined, for example, lessons learned, anecdotal/systemic issues, as well as subject matter expert interviews. For the collection process, we envision using the structured Grid Architecture framework, as well as developing a methodology that's a good fit for any chosen knowledge management solution.

The information inputs will have to be decomposed into their relevant elements, according to Grid Architecture structures and consistent with the knowledge management framework. The decomposition process will be qualitative at first to understand the feasibility of potential use of machine learning tools to reliably perform this task. Information that is decomposed can later be retrieved through queries that might not come from the initial context, enabling the overall solution to be a lot more future-proof and manageable for GAMUT users.

All information contained in GAMUT will need to be managed to ensure their security, privacy, and availability. Information management is a cross-cutting process that will be applied throughout the collection, processing, analysis, presentation, and other steps in the information lifecycle throughout the GAMUT project. Access to information needs to be controlled, especially when information is obtained through a non-disclosure agreement or other process that limits proliferation. The project team acknowledges that there will be many potentially complex information management decisions that are not obvious at the moment. Feasibility assessment will include assessment of the main decisions (e.g., information use under non-disclosure agreements, business sensitive, intellectual property, etc.) that will have an impact on the overall feasibility.

¹ SEPA Catalog of Standards, <https://sepapower.org/knowledge/catalog-of-standards/>

2.5 Case Studies

To validate and demonstrate the proposed methodology, the project will conduct a series of case studies. Specific grid solutions will be selected, and the documentation and assessment methodology will be applied to analyze the design, implementation, and integration of these solutions within the Grid Architecture. These case studies will be performed in partnership with technology solution development teams and those who were involved in the deployment. It is likely that the discussions will be staged, with introductory meetings, working sessions, and unsupervised use by stakeholders. All stages would collect feedback and likely require iterative refinement. The case studies will demonstrate the practical application and effectiveness of the methodology, highlighting the benefits and insights gained from this structured approach.

2.6 Feasibility Study

Ultimately, the project will determine if knowledge management software tools, information sources and approaches are practical to be developed to support this application of the Grid Architecture concepts in the GAMUT Tool. If feasible, the tool(s) would be beneficial for developing insights and supporting decision-making for various stakeholders, including funding sources, technology developers, grid operators, engineers, and policymakers. These tools would be expected to aid in the identification of interdependencies in the structural relationships (shown in Figure 1); dependencies between different grid components (e.g., generation, transmission, distribution); scalability to ensure that the technology can support and be integrated with current and future capacity, loads, and technologies; security, to improve any solution default security posture at any project stage; and resilience to withstand and recover from adverse conditions.

The feasibility study should include:

- technical feasibility for the specific application of Grid Architecture
- results of stakeholder workshops and discussions
- database techniques
- a financial assessment that includes a cost analysis and budget planning for certain solutions
- risk identification and mitigation recommendations
- case study-based assessment of the knowledge management strategy.

Development recommendations should include:

- methods, structure, and database management requirements
- a detailed assessment of compared software options
- actionable recommendations based on the feasibility study
- the preferred technology stack, estimated budget, project timelines, and suggested features to be prioritized.

The feasibility study will provide an assessment of multiple solution domain architecture tradeoffs, case study experience, and requirements verification/validation. By taking a holistic approach to the software tooling feasibility study, proposed structures and capabilities for a software tool development that complies with identified and validated requirements can be offered. This feasibility study will include a minimum-viable-product and additional capabilities

for consideration as future capabilities. This could be considered a staged approach to GAMUT Tool development.

3.0 GAMUT Tool

3.1 Systematic Approach to Knowledge Management

During project planning and execution, the team will adopt an informal systems engineering lifecycle process to ensure a systematic approach and mitigate project risks. Initially, information on requirements, needs, and expectations will be gathered to fully comprehend the problem domain before finalizing the solution architecture for GAMUT.

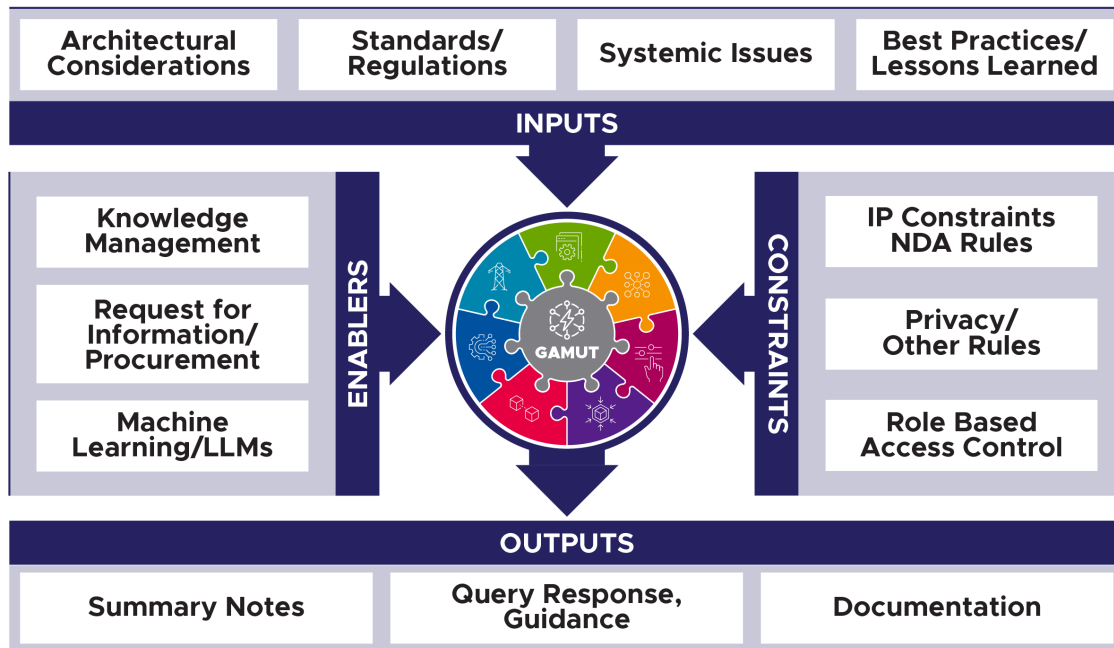


Figure 3. General approach to “GAMUT System”

The individual components of inputs and outputs will be described in more detail in the next document chapters. The “Inputs” section covers any information that needs to be processed by the GAMUT Tool. We also include any potential tool use or applied external methodologies/approaches to enable “input” as a functionality. Defining and capturing information for the “Outputs” section ensures that the GAMUT Tool produces the necessary information/artifacts to satisfy stakeholder expectations/needs. “Enabler” and “Constraint” sections will be part of the solution space documentation to capture relevant information from adjacent systems that can either enable additional functionality/opportunities or limit GAMUT Tool operations (e.g., legal or regulatory requirements). This approach helps capture the entire system considerations for GAMUT and avoid silos. Refinements are expected to be continuous throughout the project lifecycle, as more information becomes available.

The information related to innovative grid technologies and their deployment will be captured with guidance related to Grid Architecture structures and principles and preferred formats for documentation. Additionally, the prompts to provide input will aid in identifying gaps or missing information. This iterative process is depicted in Figure 4.

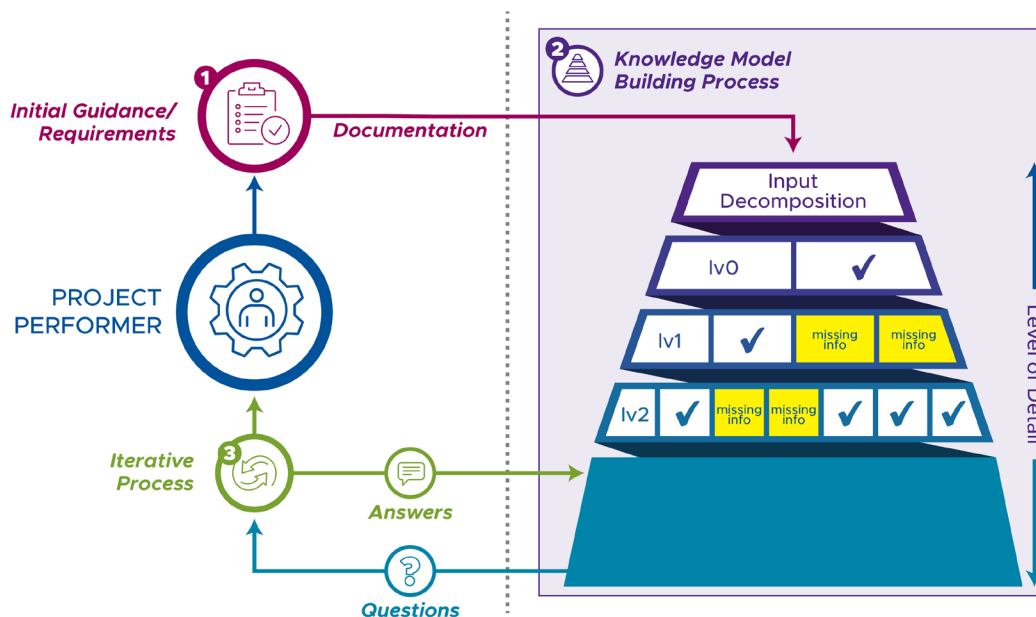


Figure 4. Information provider (here Project Performer) user interaction process.

The first step guides an information provider through the preparation of available documentation for a given technology, pilot, or demonstration. The second series of interactions are interactions with the GAMUT Tool (guided at first) to capture and decompose the relevant information. The second step decomposes and organizes the information from inputs and documentation to fill necessary topic areas and identify any gaps and missing information. These gaps may be addressed by engaging with information providers with specific queries at step three. Step three serves as the feedback loop with the GAMUT Tool user.

3.2 System Requirements

The following sections discuss some of the requirements that have been identified through initial conversations. These should be considered draft requirements for the purpose of providing an understanding to potential stakeholders who will collaborate with the GAMUT project team for feasibility and development.

3.2.1 Input Requirements

Input requirements support the data collection process. This includes guidance related to Grid Architecture and the information request process, what information needs to be collected, and context around why the information is useful.

IR 01 - Inputs and input requests shall be comprehensible by a human user (human readable language).

IR 02 - The GAMUT Tool shall have a machine-readable input interface for knowledge and data management (including information update processes).

IR 03 - The GAMUT Tool shall collect characteristics/parameters/statistics and other ordered information of technology pilots, demonstrations, and deployments. Examples include details

about results from experiments and pilot deployments, jurisdictions where it was deployed, feedback from stakeholders, etc.

IR 04 - The GAMUT Tool shall collect information about Grid Architecture structural dependencies. Examples include regulatory, electric infrastructure, market, etc. (see Figure 1) requirements and constraints.

IR 05 - The GAMUT Tool shall collect information about the supporting technology composition. This would include requirements for hardware, software, or integration that would be necessary for deployment.

IR 06 - The GAMUT Tool should require users to provide evidence supporting the use of relevant standards that support the integration requirement of the technology.

IR 07 - The GAMUT Tool should require users to provide evidence that relevant regulatory or policy requirements have been addressed.

IR 08 - Inputs may include keywords or phrases.

IR 09 - The input method should provide an option to specify/categorize business sensitive verses publicly accessible information.

3.2.2 General Capability Requirements

These general capability requirements are capabilities related to the GAMUT software tools' capabilities to support information collection, organize the information, and access the information.

GCR 01 - The GAMUT Tool shall be structured based on Grid Architecture concepts, including interdependencies with other domains, i.e., regulatory structure, digital structure, control structure, and electricity infrastructure.

GCR 02 - The GAMUT Tool shall organize and categorize documentation.

GCR 03 - The GAMUT Tool shall provide necessary relevant context to support the user interaction. This includes guidance and examples of regulation, market, and standardization, and other Grid Architecture structure information that will aid technology deployment replicability.

GCR 04 - The GAMUT Tool shall guide users through the information collection process of providing documentation and details associated with the technology under consideration. This process includes guidance for users who may not be subject matter experts in Grid Architecture and all aspects of the information and capabilities associated with the Tool.

GCR 05 - The GAMUT Tool should support technology interoperability assessment by allowing for queries based on previously developed interoperability requirements (Interoperability

Maturity Model¹, GridWise Architecture Council – “GWAC Stack”², Reference Interoperability Procurement Language³).

GCR 06 - The GAMUT Tool should request additional input based on provided information such as keywords, phrases, and/or technology parameters.

GCR 07 - The GAMUT Tool should support a systematic way to ingest input queries and perform input decomposition, applying data management standards whenever possible.

GCR 08 - The GAMUT Tool should have a standardized way to process data updates and perform knowledge management.

GCR 08 - The GAMUT Tool should provide an indication of missing information and/or associated documentation.

GCR 09 - The GAMUT Tool may provide feedback based on input or lack thereof.

GCR 10 - The GAMUT Tool shall keep all necessary information about data sources and provide it upon user request.

GCR 11 - The GAMUT Tool shall provide necessary security solutions to ensure data security, including access management techniques like role-based access control. (also see IR 09)

3.2.3 Output Requirements

These output requirements address the needs of output users, those stakeholders that would benefit from pilot, demonstration, and deployment insights. The output requirements cover how documentation is provided and the interaction requirements between the output user and the GAMUT Tool.

OR 01 - The GAMUT Tool shall provide summary output, describing the technology and associated documentation as high-level “Cliff notes.”

OR 02 - The GAMUT Tool shall provide results based on queries of topics including solution space, Grid Architecture structure, keywords, standards, policies, etc.

OR 03 - The GAMUT Tool shall constrain output based on privacy and sensitive information but provide a description of how to obtain permission to access that information, e.g., authorization request.

OR 04 - The GAMUT Tool should identify systemic issues such as restrictive regulatory, policy or structural constraints.

OR 05 - The GAMUT Tool should provide technology deployment best practices, considerations, and common issues.

¹ Knight, Mark R., Kolln, Jaime T., Widergren, Steven E., et al., "Interoperability Maturity Model," (2020), <https://doi.org/10.2172/1804457>

² Widergren, Steven E, Hardin, Dave, Ambrosio, Ron, et al., "Interoperability Context-Setting Framework," (2007)

³ Kolln, Jaime T., Widergren, Steven E., Nguyen, Cuong, et al., "Reference Interoperability Procurement Language," (2020), <https://doi.org/10.2172/1607494>

OR 06 - Output shall be comprehensible by a human user (natural language/diagrams).

OR 07 - The GAMUT Tool shall provide all metadata about source information used in output (upon request).

3.3 Concept of Operation

Figure 5 depicts a potential interaction format for the scope of a specific technology pilot demonstration deployment assessment. This description provides an insight into how the GAMUT Tool could be used by a user (not how the GAMUT Tool itself works). The GAMUT Tool output user in Figure 5 is providing initial questions about a specific or generic topic. In the most minimalistic approach, the input provider may use the GAMUT Tool to improve project technology documentation without oversight from the GAMUT Tool output user (e.g., DOE) and can provide the outcomes directly to stakeholders. In this case, an information provider user interacts with the GAMUT Tool to prepare the information and improve documentation by providing questions, clarifications, and addressing gaps. An output user may also be part of the process as a reviewer of the documentation.

In a more involved use case, an output user may utilize the GAMUT Tool to interact with an information provider user (e.g., a project performer) and request to provide information considered input for the GAMUT Tool. The project performer is interacting with the GAMUT Tool directly and is subject to identified input requirements that are defined by the GAMUT Tool interface. This means that the user needs to submit the necessary information according to the GAMUT Tool information structure (influenced by the implemented knowledge management approach). Then the GAMUT Tool ingests the information and provides the output user with available notes, feedback, information gaps, or suggestions for further actions. Since the information circulation permits question/answer structure on all user interfaces, it is possible that the output user can generate requests for additional details to an information provider through the GAMUT Tool. The main benefits from utilizing GAMUT Tool versus a direct communication would be the structured and systemic approach to addressing the missing information and providing the necessary context to avoid potential misunderstanding. The process is iterative, and in each step the GAMUT Tool may be used to provide relevant context or missing information, clarification, or guidance for a more comprehensive approach to both the output user and the information provider. The outcome of this use case is improved quality of technology documentation and reduced technology deployment risk for the output user.

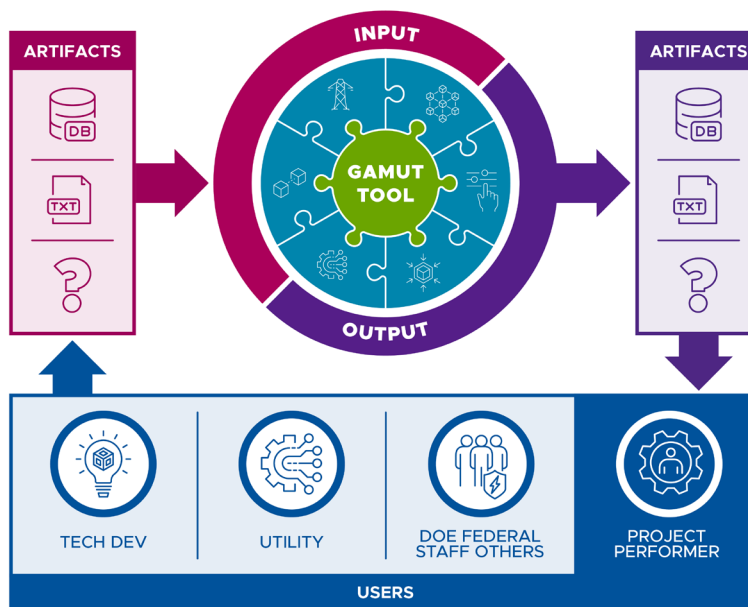


Figure 5. User's potential interaction flow with GAMUT.

Potential future use may include other user groups (e.g., utility partners and other stakeholders) and their specific use cases. For example, a utility GAMUT Tool user could be interested in:

- Identifying suitable technology from the integrated resource plan and/or other planning phases of project development.
- Best practices and field deployment experience lessons learned.
- Supporting information associated with requests for information, requests for procurement, and other activities that would develop requirements and challenges.
- Ensuring systemic approaches to identify hidden dependencies (coupling), regulatory, market, or other systemic issues as part of technology evaluation.

Any user can use the GAMUT Tool to establish and explore scope/context for inquiries for information providers to aid question preparation and evaluate answers for completeness and context match for identifying gaps in answers.

4.0 Conclusion and Next Steps

The electric power system is experiencing significant changes, driven by a changing generation mix, increased reliance on information and communication technologies, new customer demands, growing load, and an ever-changing threat landscape. To meet these challenges, stakeholders are poised to make substantial investments in innovative grid technologies to ensure a flexible, reliable, and resilient electricity delivery system.

DOE aims to support this transformation through the development of knowledge management tools, such as the GAMUT Tool, based on Grid Architecture principles. These tools will facilitate the systematic documentation, understanding, and deployment of innovative grid technologies. By improving our grasp of dependencies, interactions, and systemic issues, these tools will aid stakeholders in making informed decisions and optimizing technology integration.

Initial phases of this project focus on a feasibility study to evaluate the development of a software tool suite that organizes and manages information related to various grid technologies. By involving a diverse group of stakeholders—ranging from technology developers to utility operators—the project aims to create a comprehensive framework for the effective documentation and analysis of technology pilots, demonstrations, and deployments.

Once validated, the GAMUT Tool will provide significant benefits, including identifying gaps and challenges, offering insights into best practices, and facilitating knowledge sharing among stakeholders. Additionally, it will cater to multiple stakeholder perspectives, ensuring broad utility and engagement.

4.1 Next Steps

The project team will finalize the requirements gathering process, bounded by the limits of a feasibility study. Any future requirements identified will appear in an appendix to the feasibility study, retained for future development. This process includes engaging with stakeholders to refine and confirm the initial set of tool requirements through workshops and interviews to collect their input. This input will also help the project team to establish guidance and educational materials to help stakeholders understand and effectively use the tool.

We will then draft the GAMUT Tool structure, which will require iterative development of information collection processes. This includes developing and testing the initial information collection process with a select group of technology developers and users. The project team will refine the process based on feedback and expand to cover more Grid Architecture topics.

The feasibility study will then assess technical and financial feasibility, potential risks, and mitigation strategies. The project team will utilize the case studies to validate the proposed methodology and demonstrate practical applications. This will lead to tool development recommendations, focusing on key features, technology stacks, and timelines. It will also include a summary of an evaluation of different knowledge management methodologies and recommend the most suitable ones for implementation.

4.2 Future Work

Stakeholder engagement will continue to be an important component of the GAMUT Tool development. This will aid in the identification and definition of additional roles, capabilities, and

requirements. Defining user roles and access privileges will ensure the protection of sensitive information and intellectual property. Implementation and testing will also be important when developing the GAMUT Tool. The project team would begin the development of a minimal viable product based on the validated requirements and recommendations. This would be followed by pilot tests to gather user feedback and make necessary adjustments.

If the tool receives approval after minimum-viable-product development, the team will follow on with full deployment and continuous improvement, including rolling out the GAMUT Tool to a wider audience after successful pilot testing, continuously gathering feedback, and updating the tool to address emerging needs and technologies.

By following these steps, we aim to ensure that the GAMUT Tool effectively supports the modernization and resilience of the electric power system, ultimately contributing to a more reliable, affordable, and secure energy future.

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