Pacific Northwest
NATIONAL LABORATORY

ARCHITECTING THE GRID EDGE

ENSURING RELIABILITY AND RESILIENCE

DISCLAIMER

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operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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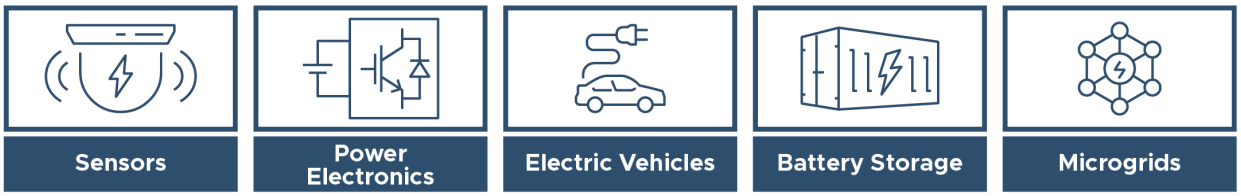
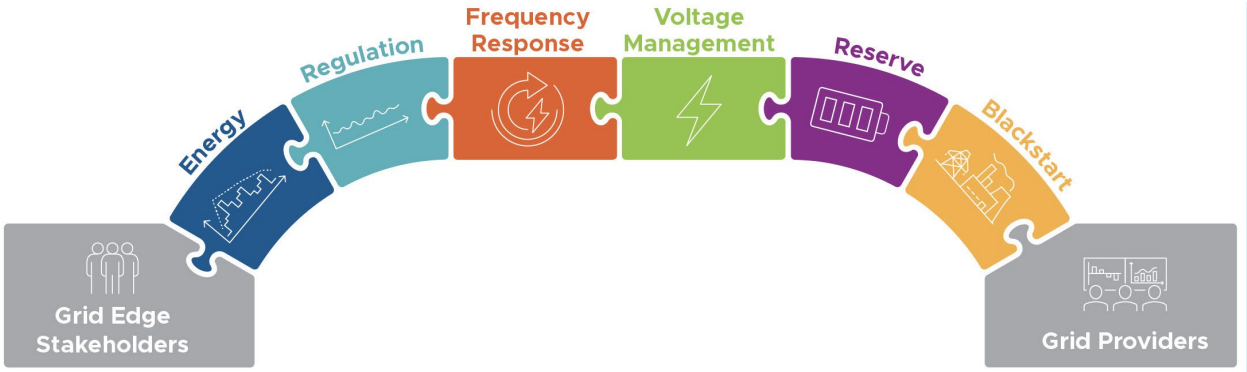
SUMMARY

ENGAGING THE GRID EDGE AT A GLANCE

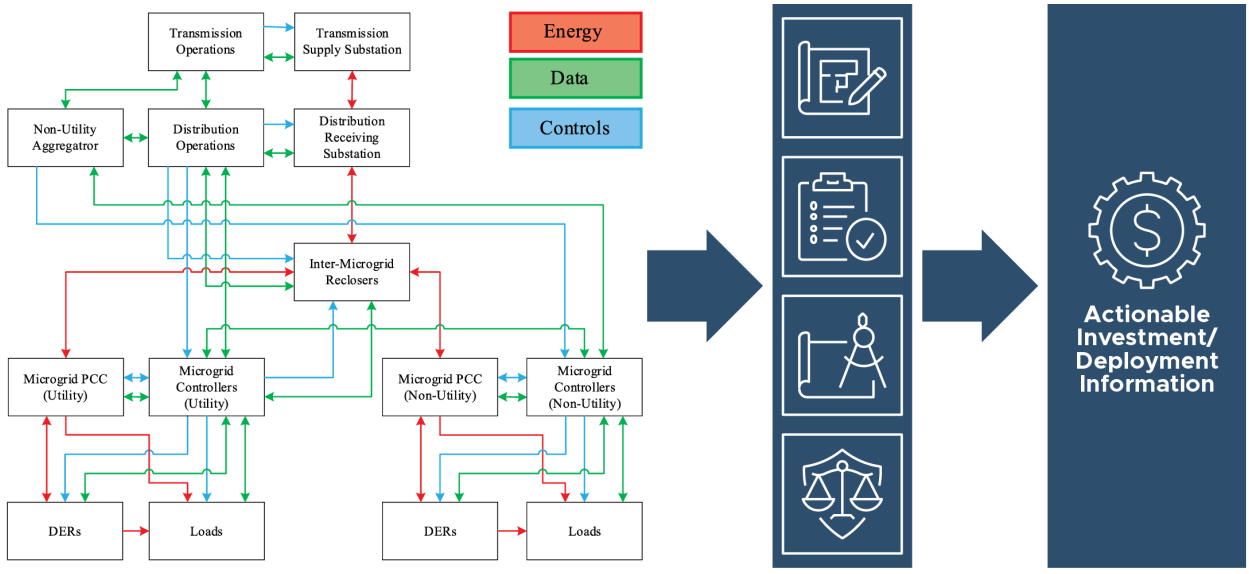
Grid edge solutions are at the center of a grid revolution - an emerging resource that will transform the nation's electricity infrastructure, markets, and the relationship with the end-users.



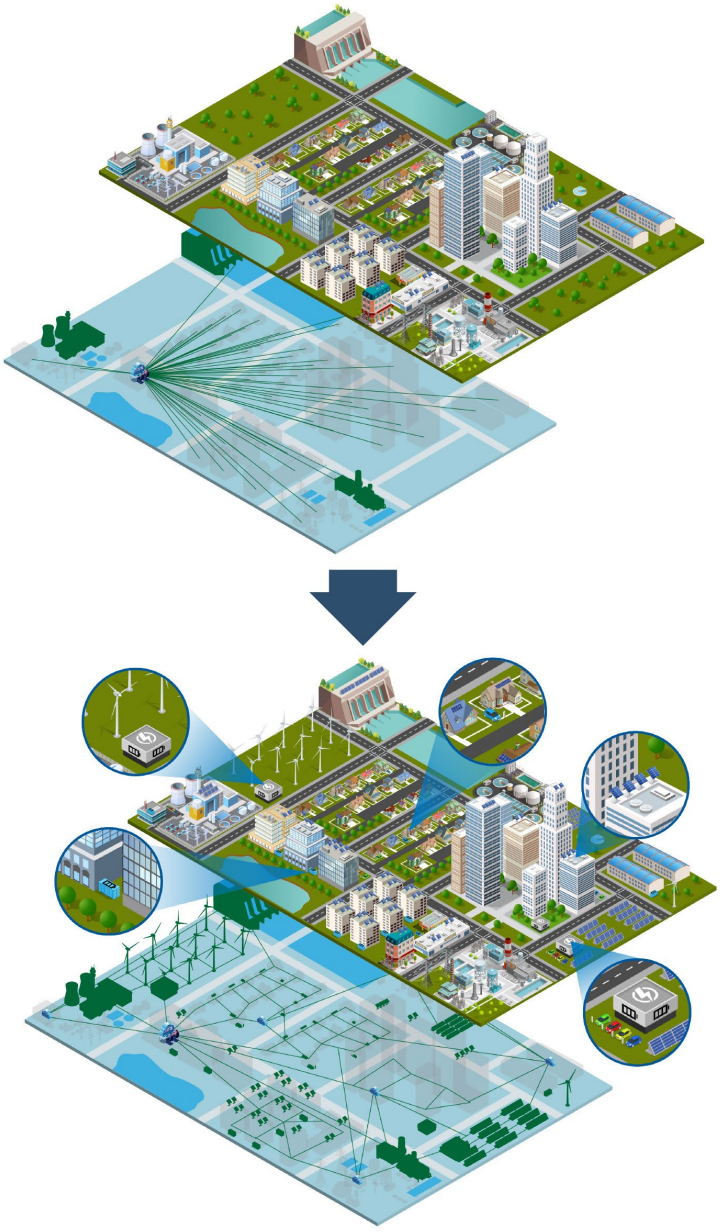
Grid services can act as a bridge between the centralized systems and the grid edge, to ensure local benefit as well as system level operating requirements.



Grid architecture can be used as a tool to navigate the wide range of options for how to implement grid services, ensuring improved reliability, resiliency, security, and affordability.



PROLOGUE: THE EVOLVING GRID EDGE



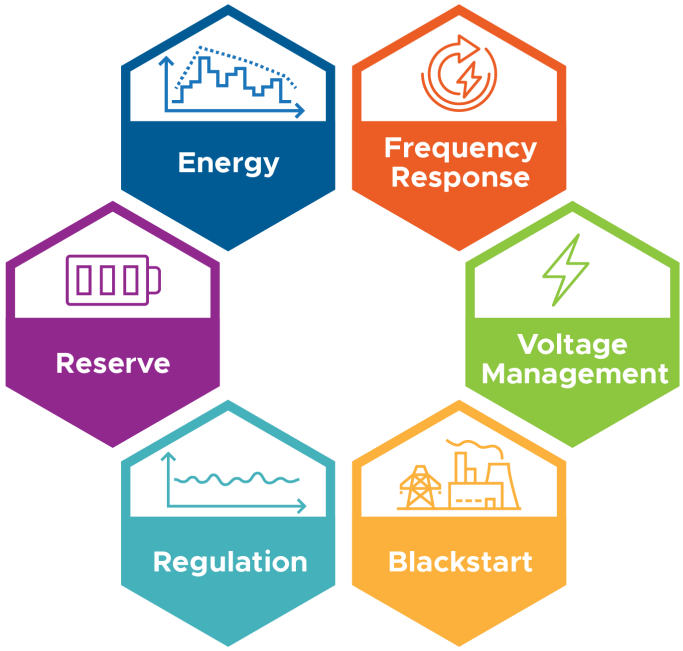
The nations electrical infrastructure has been continually evolving since Thomas Edison placed his first commercial central power plant in operation in 1882. Since then, changes in technology, customer needs, and regulatory policy have driven transformation, resulting in the continent spanning interconnected system that is operated today. The same forces that resulted in the current electrical infrastructure continue to drive change. This change is occurring the fastest at the "grid edge", where once passive actors who simply consumed electricity are actively engaging with emerging new stakeholders to achieve a range of new goals, moving beyond simply producing electricity locally.

The grid edge is a concept, and not a single piece or portion of the nation's electric infrastructure. While it is often associated with behind the meter technologies, it is much more than that. In addition to the systems and capabilities that a utility may deploy at the feeder and/or substation level, the grid edge also includes all of the devices and systems that might be deployed by customers, communities, aggregators, and an increasing array of new stakeholders. And beyond the devices and systems being deployed at the grid edge, is the relationships between those devices and the people/organizations/communities that deploy them.

The deployment of new devices and systems represents a massive new technical potential, especially with respect to the ability to produce electricity near the end-use consumer. Despite the benefits of increased electricity production at the grid edge, a reliable and resilient electrical infrastructure has operational requirements beyond simple electricity production. While this is not a problem when there are relatively few grid edge devices, as they proliferate, they will begin to replace the capacity of traditional centralized assets that provide energy along with other essential services. The challenge that lies ahead is how to enable new stakeholders to operate their new grid edge devices and systems to achieve their local goals, while at the same time ensuring that they contribute to, and improve, the overall system reliability, resiliency, security, and affordability. Grid services offer a structure to make this connection.

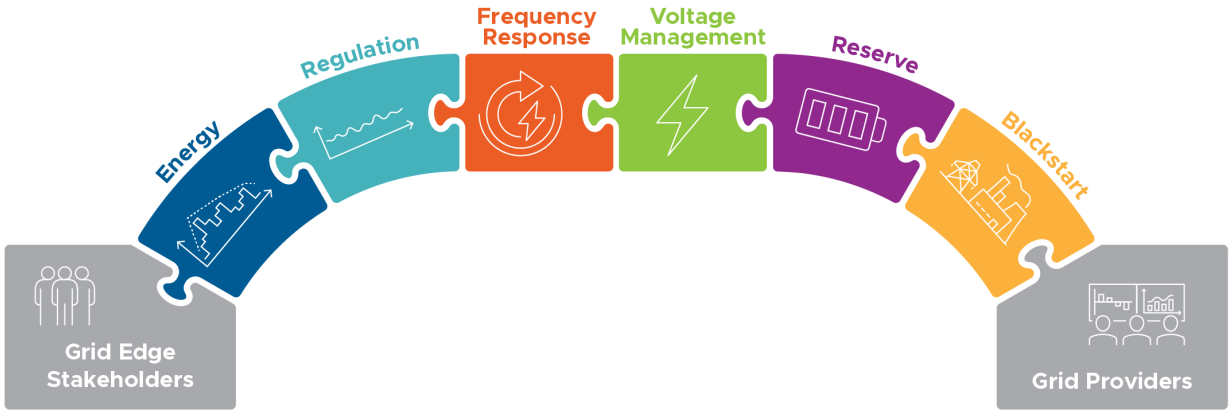
GRID SERVICES

To achieve the goal of orchestrating the devices and systems being deployed at the grid edge, it is necessary to have a structure to connect them. Currently, there are mechanisms for grid edge devices to engage with the bulk power system, but these interactions are based on the historic bilateral relationship between utilities and customers. What is needed is a generalized structure that describes the "services" that the electrical infrastructure requires. The concept of grid services can be used to bridge between the capabilities of grid edge devices and what the bulk power system needs to operate.

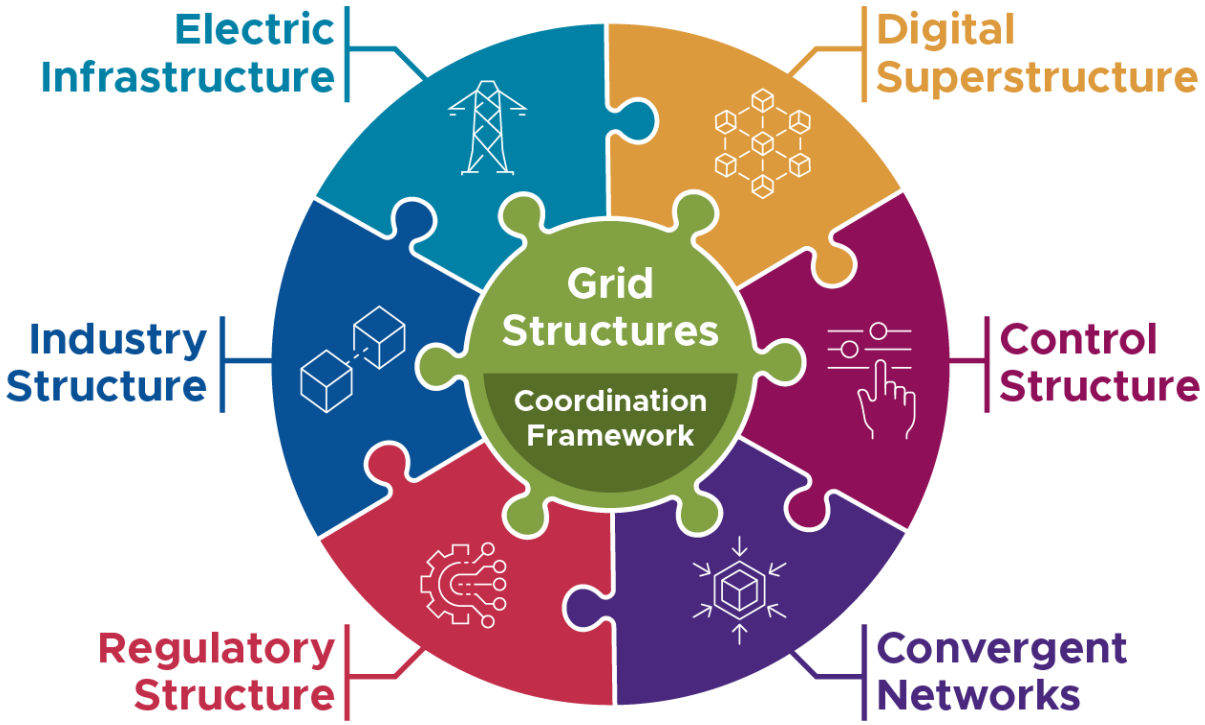


Grid services are defined as the basic functions that an electrical power system must have to ensure reliability and resiliency. The six key services include Energy, Reserve, Regulation, Frequency Response, Voltage management, and Blackstart. These services are fundamental to a power system and are applicable regardless of size or era of the power system. However, how the services are provided can vary significantly. For example, spinning reserve could be obtained directly from large central generators, or indirectly from controllable end-use loads; distribution level voltage could be controlled directly by voltage regulators and shunt capacitors, or indirectly via incentive signals sent to customer-owned inverters. So, while the services must be obtained for reliable and resilient operations, determining how the services are obtained is a decision that the system operator must make based on their willingness to trade-off the cost and benefits of direct vs. indirect methods of obtaining the needed services.

Because of the complexity of the decisions to be made, new tools and approaches are necessary. The concepts of grid architecture provide a framework for determining how to best obtain the necessary grid services for a specific stakeholder.



GRID ARCHITECTURE TO ENGAGE THE GRID EDGE



When making planning and operational decisions on how to obtain the necessary grid services, there is rarely a single “correct” choice. Instead, there are trade-offs between an array of choices that must balance a number of different considerations. For example, a utility determining which services it will serve with assets they own, and which services they will serve with non-utility assets. Similarly, owners/operators of grid edge devices and systems need to determine if providing one or more grid services is well aligned with their technical capabilities and business/regulatory models. Deciding the best mix of resources to provide the needed resources is a complex process that extends well beyond purely technical considerations.

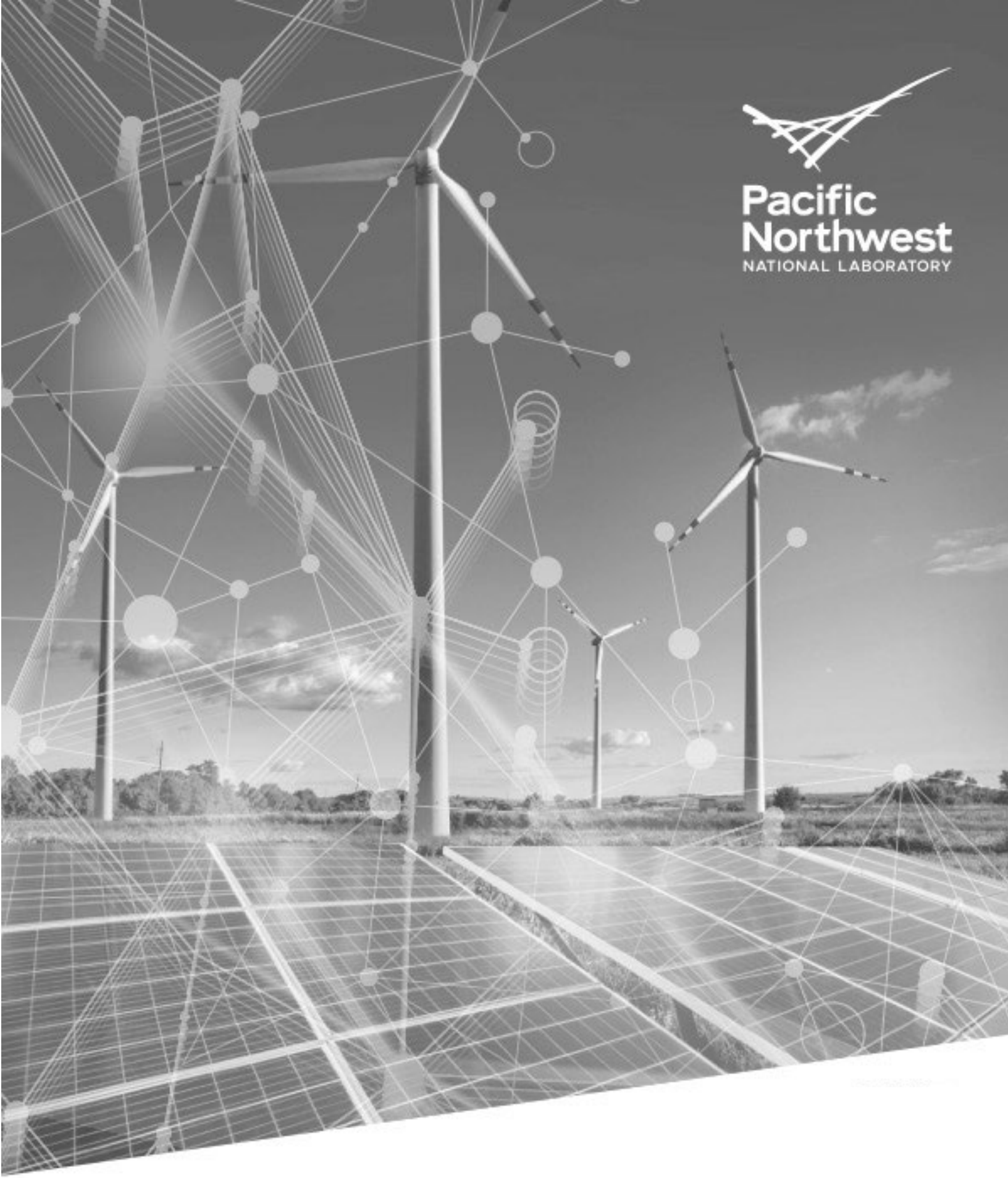
Grid architecture is a tool that can be used to help manage complexity and risk, including how to engage grid edge devices as elements of the six essential grid services. For the grid edge stakeholder, they need to determine if participating in one or more grid services is possible with their devices and/or systems capabilities, and if it is well aligned with their business and operational goals. These decisions need to be made on both the operational and planning time frames. For a utility it means that they have to have an operational plan in the near-term for obtaining the services necessary for anticipated conditions. In the planning timeframe, the utility must make mid- and long-term determinations if they will invest in the capital projects necessary to provide all of the anticipated services they will need, or if they will only secure a portion and plan on engaging grid edge stakeholders for the rest.

Grid architecture is a tool that can help to manage the complexity of these decisions, yielding actionable information to inform the decisions made by the various stakeholders.

OUTCOMES

Grid services and grid architecture can be used as tools to ensure that reliability, resiliency, security, and affordability are maintained as the grid edge continues to evolve. This includes addressing not only the range of new devices and systems that are being deployed, but also the relations and interactions between them. In order to mature the structure and use of grid services and grid architecture, work in the following areas in needed.

- Categorize the new stakeholders/actors that are interacting with the grid edge, including individual types and classes.
- Define grid services and their specifications. This includes an evaluation if the current list is sufficient and how to address uncertainty in service procurement.
- Identify locational elements of various grid services, such as voltage control and black start.
- Define how to qualify resources as a grid service, including quantification of certainty.
- Define how to contract for grid services, and how to quantify value. Both from the utility and grid edge stake holder perspectives.
- Develop a framework for how to map various devices and systems to individual grid services they could support.
- Make grid architecture more accessible for evaluating direct and indirect evaluation options. Extend the work being done on grid services and contracts and include use-cases that directly address common utility challenges.
- Develop/extend the simulation and analysis tools and capabilities to evaluate the impacts of grid edge devices supplying essential services, under normal and abnormal conditions.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