



INTEROPERABILITY MATURITY ROADMAP

IEEE Std 2030.5

Authored by
IEEE 2030.5 Ecosystem Steering Committee (ESC)

Interoperability Maturity Roadmap

IEEE Std 2030.5

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Executive Summary

Interoperability in the context of this document is a quality of information and communications technology interfaces that enables two or more devices or systems to connect and successfully interact. Achieving interoperability in an environment of mass deployments, by various purchasers and solution providers is a multi-faceted, complex topic that requires the alignment of all stakeholders involved in the development, integration, and operation of the related technologies. These stakeholders form an ecosystem, or community, of organizations with the desire to codify agreements on the things necessary to make integration of the devices and systems simple and reliable.

The IEEE 2030.5 Ecosystem Steering Committee (ESC) was formed to review the state of interoperability for the application of IEEE Std 2030.5 and determine a path forward (a roadmap) for enhancing interoperability for the ecosystem emerging around the standard. As interoperability involves agreements, processes, and supporting material in many areas, the ESC roadmap development process was facilitated by United States Department of Energy (DOE) national laboratory staff who used an interoperability maturity model tool and roadmap methodology developed under the DOE's Grid Modernization Initiative. The roadmap development process was conducted in a series of meetings that spanned roughly a year. Those meetings identified gaps and challenges confronting the IEEE 2030.5 ecosystem in several areas, but particularly in the coordination of efforts that span various implementation areas of IEEE Std 2030.5. That includes testing and certification, education, branding and marketing of interoperable technology, a management framework for cryptographic keys to support secure communications, and templates for creating implementation profiles, among several other items.

The process of developing the roadmap revealed the complex nature of the organizations using IEEE Std 2030.5 and how the landscape changes depending upon the electricity responsive resources being integrated. For example, significant attention has been given to integrating smart inverters for photovoltaic distributed generation in California. In this case, organizations have come together to put in place an implementation profile that specifies requirements that can be tested and certified for supporting interoperable deployments. The maturity level exemplified in this situation is quite different from the emerging applications of IEEE Std 2030.5 for electric vehicle service equipment, where a different implementation profile is being developed. It is different again from new activities evolving in the coordination of demand responsive resources.

The IEEE 2030.5 ESC acknowledges the various technology types that can be integrated with IEEE Std 2030.5 and desires to reflect in the roadmap a vision where there is commonality of approach and supporting processes and material to advance interoperability based on this technical standard across the many types of implementations. While the group recognizes that IEEE Std 2030.5 is also applicable to gas, water, and other types of infrastructure, for the purposes of this roadmap, the scope of activities was focused on the integration of electric system responsive resources.

Lastly, the ESC realizes that this is a roadmap that relies on the goodwill of ecosystem members to consider and take up the cause of the documented actions. As progress is made and the landscape shifts with time, the high-level plans represented here deserve to be revisited and shaped accordingly.

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Introduction

The development of operationally flexible electricity resources at the grid edge and associated communication technologies is transforming power system operations. This transformation challenges the current operation as diverse types of responsive electric equipment need to function together in a safe, effective, and reliable manner. This IEEE 2030.5 Ecosystem Steering Committee (ESC) document proposes a roadmap about the integration of responsive distributed generation, energy storage, and loads (responsive resources) using IEEE Std 2030.5 and supporting material.

This document uses the terms interoperability and integration ecosystem (or community) as defined in the Interoperability Strategic Vision whitepaper.¹ Interoperability is “the ability of two or more systems or components to exchange information and to use the information that has been exchanged.”² For the purposes of this document, the term refers to the process to achieve interoperability and is focused on the integration experience required to make two or more systems connect and interoperate. Integration ecosystems refers to, “A community of participating organizations collaborating to address one or more business or social objectives that concern interoperability and ease the deployment of specific technologies. The participants in such communities represent many types of organizations that are needed to support integration objectives. These include asset managers/owners/users, technology suppliers, service providers, distribution system operators, regulatory and government agencies, consortia and trade associations, and testing and certification bodies. They have an established convening body with champions who drive the group toward alignment in achieving their shared objectives.”

The responsive resources involved in this roadmap, named assets, are classified based on their nature and capabilities. To effectively advance simple and reliable integration of those assets, the stakeholders need to agree on technical standards envisioning the ease of integration and interaction. To describe the scope of the roadmap effort, this document identifies the different actors involved in the coordination of the operation of the assets. Some of these actors are directly participating in the interaction of the assets, while others significantly influence the ability for these interactions to take place.

Interoperability is addressed not only by the definition of a standard but by the development of Implementation profiles and guides, the interconnection requirements, and procedures for testing and certification. Those elements are considered critical for the success of an ecosystem encouraging a business, economic, and regulatory policy environment that aligns technology solutions with viable business value propositions to drive the need to simplify interoperability and advance future standardization.

The IEEE 2030.5 ESC interoperability roadmap outlines activities to advance the interoperability dimensions related to responsive resource integration starting with the present state of IEEE Std 2030.5, supporting material, and related efforts. While the image of a plug and play standard is attractive, the roadmap acknowledges the complex responsive resource integration landscape and aims to describe practical steps that can lead to a simple, streamlined, and largely automated process.

¹ “Interoperability Strategic Vision,” GMLC 1.2.2 White Paper, PNNL-27320, March 2018. Accessed November 2018 at <https://gridmod.labworks.org/sites/default/files/resources/InteropStrategicVisionPaper2018-03-29.pdf>

² Definition taken from ISO/IEC/IEEE 24765.

1. Roadmap Scope

IEEE Std 2030.5 is designed to support many different application domains. Arguably the greatest area of application interest emerging in technology deployments using IEEE Std 2030.5 is in the distributed energy resource area, specifically in distributed solar and wind systems using smart inverters. Government policies are being enacted in states such as California and Hawaii that require coordination of these responsive resource systems in order to address system operational concerns in regions with high penetrations of these resources.

Attention to these issues encourages stakeholders to come together to seek alignment on standards, guides, and policies that address interoperability and the ease of integrating these systems. Close behind this immediate driver is community interest to address the coordinated operation of storage systems, electric vehicle charging, and demand response. While this attention should not diminish the application of IEEE Std 2030.5 to other integration scenarios, a set of priority responsive resource assets brings focus and substance to the scope of the roadmap effort. In addition, interactions between transmission level operations and distribution system operations has great influence on how customer-oriented assets are engaged in operation. This effort recognizes the importance that aggregated distribution level resources has with the transmission level interactions.

While IEEE Std 2030.5 may be applied to other utility services such as water and gas, the scope of this roadmap focuses on electric system interactions. The following sections summarize the priority assets of attention, the actors involved in the integration and operation scenarios related to these assets, and a conceptualization of the points of integration and interfaces for communication between the actors that help bound the scope of this roadmap.

1.1 Assets

Assets are the communicating energy resources that are being integrated for coordination with electric system operations.

- PV/Wind: The energy generated by these assets are integrated into the electric system using power electronic inverters. Automated control and communications capabilities installed with the inverters provide mechanisms for coordinated operations with the power system.
- Battery: These energy storage devices (whether electrochemical, electromechanical, or thermal) are presumed to reside in a stationary location. They can run in both charge and discharge mode and may be able to regulate the rate of charging and discharging. They use power electronic inverter technology with automated control and communications capabilities to provide a mechanism for coordinated operations with the power system.
- EVSE (electric vehicle supply equipment): These charging systems for electric vehicles (EVs) also use power electronics to regulate the charging current of vehicle batteries. They can also regulate discharge back into the power system. They may use power electronic inverter technology with automated control and communications capabilities to provide mechanisms for coordinated operations with the power system as an alternative path of communication with the EV. The mobile nature of the resource and transportation objectives make these assets different from stationary batteries.
- Responsive load: These assets use electricity to perform work or services, and are automated to regulate their operation, usually within some operational constraints. These resources may be associated with industrial, commercial, and residential facilities (as opposed to large

manufacturing and processing plants). Homes tend to have unitary devices; however, in large, commercial buildings and small industrial plants, the equipment's operation may be part of an interrelated set of processes that use a facility management system. Such facilities may also include other assets, including PV/Wind, batteries, and EVs. The facility management system may coordinate the operation of the devices within the premises to shape the overall facility load and make it responsive for interaction with the electric system. Alternatively, each unitary device within a facility may have its own interface and metering to the electric system for coordinating operations.

- **Meter (measurement metrology):** This asset class refers to the measurement parts of an electric meter and its communications interface and is not an energy resource per se. The capabilities within a meter enclosure may perform many different functions beyond the basics of power and energy metrology, including device and facility management functions. Where these additional functions are designed and located are a matter of packaging. To clarify the concepts in the scope of concerns, the meter asset in this document refers strictly to the metrology of the meter and its communications interface.

1.2 Actors

The actors are the responsible parties or their agents that are interacting to coordinate the operation of responsive resources with electric system operations.

- **Regulator:** Regulators are responsible for establishing and monitoring the policies or rules of engagement for responsive resource interactions with the electric system within their jurisdictional authority. They do not participate directly in the interactions, but their policies and decisions guide the nature and performance requirements of the interactions. This may include protocol selection.
- **Transmission System Operator (TSO):** This class of actors include independent system operators and regional transmission authorities (ISO/RTOs), wholesale market operators, and the parts of utilities that have similar responsibilities for coordinating operations of the bulk electric power system and its associated markets. The way this level of the system is organized and managed as well as the terms used is varied. To focus the scope of this roadmap, this class of actors do not participate directly in the interactions with responsive resources but depend upon distribution system operators and service providers to interact with responsive resource assets and present an aggregated set of responsive resources at the transmission system level. The policies and interaction rules of engagement they put in place with the distribution system operator and service provider guide the nature and performance requirements of the interactions with the responsive resource assets.
- **Distribution System Operator (DSO):** This actor is responsible for the safe, effective, reliable, and efficient operation of the distribution system infrastructure. It represents the distribution system operations parts of utilities. It may interact with a Service Provider who aggregates the responsive behavior of responsive resources to ensure safe and reliable operations. It may also interact directly with a Responsive Resource Facility Operator who supervises a set of responsive resource assets within the facility or it may interact directly with the local intelligence.
- **Service Provider (Aggregator):** The Service Provider is an aggregator of responsive resource assets for coordination with a DSO and potentially with a TSO. For the sake of this roadmap, the Service Provider may use IEEE Std 2030.5 and associated material to interact with the DSO. It also interacts directly with a Responsive Resource Facility Operator who supervises a set of responsive resource assets within the facility or it may interact directly with the local intelligence.

- **Responsive Resource Facility Operator:** This actor represents the customer who is using electricity in a facility or the customer's agent who is responsible for operating the facility. The facility may include something as large as the premises of a building or compound, in which case it will likely have a management function that supervises the operation of several responsive resource assets each with its own local device manager. It may also be as small as an intelligent responsive resource asset itself with its local device manager. The Facility Operator interacts with the Service Provider in its role to aggregate the behavior of responsive resources and it may interact with the DSO for safe and reliable operation of the distribution system. The Facility Operator may be the customer or a third-party operator (local or remote) who is acting on the customer's behalf.
- **Responsive Resource Asset Manager:** Each responsive asset has intelligence to manage its operation. The Responsive Resource Asset Manager has direct control of the asset and interacts with the facility's management function to coordinate its operation within the facility. It might also interact directly with other Responsive Resource Asset Managers in the facility or with the DSO and/or the Service Provider. Examples of a Responsive Resource Asset Manager include a smart thermostat for heating and cooling systems, a building management system, a smart inverter controller, or a microgrid controller.

1.3 Interfaces

Figure 1 depicts a simplified view of the actors, assets, and interfaces of interest that link the actors. This landscape helps focus the scope of discussion for the roadmap. It shows the regulator and the TSO as important players that influence the specification of the interfaces shown in red, but the direct interacting actors are the DSO, Service Provider, Responsive Resource Facility Operator, and the Responsive Resource Asset Managers. The role of the Management Function in the figure is to represent three types of IEEE Std 2030.5 use cases for integration.

1. The first represents the IEEE 2030.5 interface of an individual responsive resource asset communicating directly with the DSO and/or Service Provider plus the meter. In this case, the Management Function box degenerates into a direct connection to the local asset manager.
2. The second case represents the Management Function as a coordinator of one or more responsive resource assets within a facility. In this case, the DSO and Service provider plus the meter use IEEE Std 2030.5 to interact with something like a building or home management system, which internally interacts with the responsive resource assets and hides the details of the internal interactions from the external parties.
3. The third case represents the use of IEEE Std 2030.5 for interacting between the Management Function with one or more responsive resource assets inside the facility.

Each of these actors might have an interface to the Meter to access the measurement of electricity use. This is also included in the scope of IEEE Std 2030.5 and the roadmap.

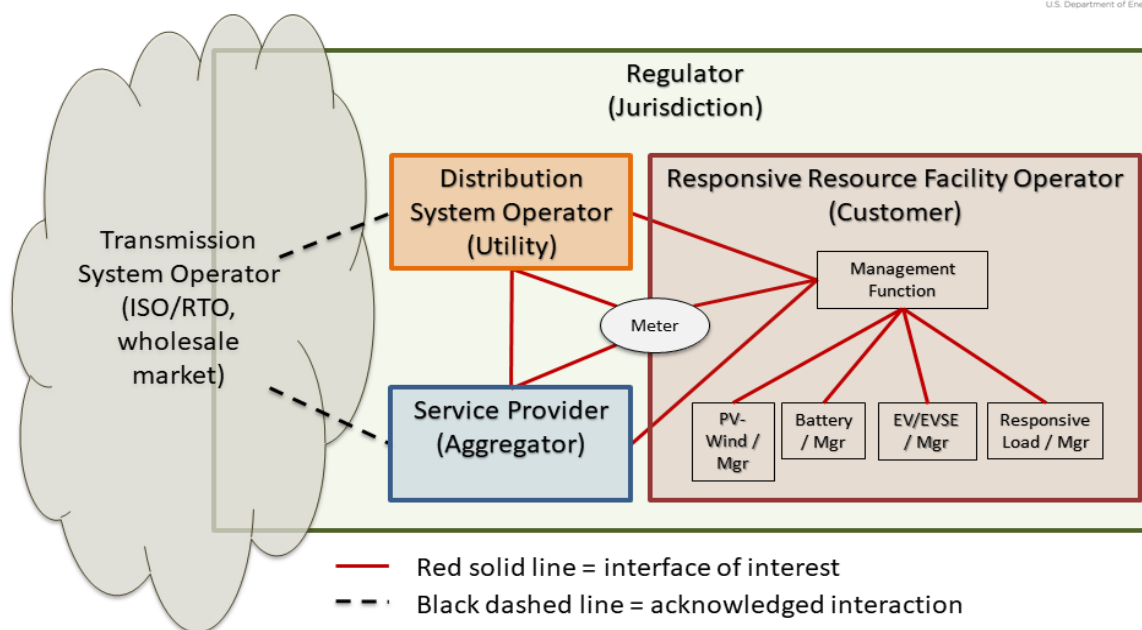


Figure 1—Interfaces of interest conceptual diagram

1.4 Time Horizon

The general period considered in developing the roadmap is from the present to 5 years out. This allows for the description of near-term actions within the roadmap while also considering some steps that may take somewhat longer to implement but help move the ecosystem toward the visionary goals in a reasonable time period.

1.5 Marketplace Business Drivers

A major business objective that has driven the adoption of IEEE Std 2030.5 and helped spawn a community of stakeholders to put in place supporting documents and practices is the integration of PV systems with smart inverters in California and Hawaii. Besides these regional marketplaces, many states of the United States and Ontario, Canada are discussing responsive resource integration and the use of IEEE Std 2030.5. In addition, Korea is participating in IEEE 2030.5 standards efforts and deployments.

These areas represent the main contributors to the IEEE 2030.5 interoperability roadmap effort; however, interest is also being shown in other parts of the world. For example, Africa is looking at using IEEE Std 2030.5, but from a different use case direction. Their implementations consider microgrid or small community electric systems where they would like to have common interface specifications so that these small electric systems can be integrated into a larger, national system as the infrastructure matures.

While the roadmap needs to acknowledge the initial marketplaces influencing this work, it also should consider how other, emerging marketplaces can be informed of roadmap efforts that advance interoperability using IEEE Std 2030.5 and associated material so that the ecosystem grows and becomes even more valuable. The roadmap needs to reflect a vision that supports a common technical standard with rules and best practices for specializing support of different applications (i.e., responsive resource technologies being integrated and their coordination frameworks).

2. Acronyms and Abbreviations

CSIP	common smart inverter profile
DER	distributed energy resources
DR	demand response
ESC	IEEE 2030.4 interoperability ecosystem steering committee
EV	electric vehicle
EVSE	electric vehicle supply equipment
GMLC	Grid Modernization Lab Consortium
IEEE	Institute of Electrical and Electronics Engineers
OpenADR	Open Automated Demand Response
PICS	profile implementation conformance statements
PKI	Public Key Infrastructure
PV	photovoltaics
SAE	Society of Automotive Engineers

3. Roadmap Vision

The following sections summarize a vision for interoperability that IEEE Std 2030.5 will enable in the future. The vision intends to align stakeholders on a direction from which action steps can be derived. Discussing the vision requires an understanding of the tangible elements that capture the agreements necessary to advance interoperability.

3.1 Elements of Agreement for Interoperability

The roadmap references a few enabling elements that are critical for the sustained success of the ecosystem. These elements are as follows:

1. IEEE Std 2030.5—Containing the technical requirements for interoperability and curated by a committed group of industry experts to ensure its currency, applicability, usability, and relevance.
2. Implementation Profiles—Containing the specific parameters required to meet particular application deployments (e.g., CSIP – Common Smart Inverter Profile that was developed for PV smart inverter deployments). These implementation profiles may be created by collaborative stakeholders or mandated by authorities and will specify which sections of IEEE Std 2030.5 are required to be supported to achieve interoperability for the specified application. California’s Rule 21 policy references the CSIP for the California investor owned utilities.
3. Interconnection Requirements—Containing the regulatory and technical requirements (grid codes) for interconnection of responsive resources to the electric power system (e.g., IEEE Std 1547, CA Rule 21, HI 14H).

4. Testing and Certification Procedures—Containing the test specification (consistent with the standard and implementation profile), and test and certification process and requirements with an aim to drive transparency, consistency, reproducibility and repeatability between testing and certification bodies.

3.2 Vision Statements

IEEE Std 2030.5 Vision

IEEE Std 2030.5 will be the leading technical standard for responsive resource asset integration. As the top technical standard, IEEE Std 2030.5 will be the first choice of producers, users, regulators and other stakeholders when identifying the technical requirements for interoperability of responsive resource assets. The standard applies to all known responsive resource assets, though some assets may reflect a higher priority of attention due to real-life scenarios (e.g., inverter-based responsive resources in California). The standard will also be maintained to proactively address new responsive resource applications and technologies as needed, to stay current with the evolution of the ecosystem.

The standard will be maintained in a clear, concise manner, reducing ambiguity and interpretation, and enabling the ecosystem to drive toward a plug-and-play future that maximizes commonality for all responsive resource assets, while maintaining necessary differences between different types of responsive resource assets. The standard will also facilitate the development of implementation profiles where needed but will preferably evolve to eliminate or reduce the need for implementation specialization.

In this regard, IEEE Std 2030.5 is a critical element of reducing the effort for integration of responsive resource assets.

IEEE 2030.5 Implementation Profile Vision

IEEE Std 2030.5 will be maintained in a manner to reduce the need for specialization via implementation profiles. However, there will be stakeholders who want to define implementation profiles based on IEEE Std 2030.5 for specific deployment applications. Such documents describe deployment specifics, such as security encryption key management or regulatory requirements that may be outside the scope of IEEE Std 2030.5. To facilitate this process, the ecosystem will maintain a proven template for the creation of new profiles and curate an openly accessible community library for refactoring existing implementation profiles to new implementations where applicable. Stakeholders will use a common feedback mechanism to propose revisions to IEEE Std 2030.5 to reduce or eliminate the need to develop new implementation profiles, and commit to implementing implementation profiles that do not create new or different requirements than those specified in IEEE Std 2030.5, but rather to only specify the application of the requirements (e.g., make an optional feature mandatory).

In this regard, implementation profiles are a critical element of reducing the effort for integration of responsive resource assets.

Interconnection Requirements Vision

The regulatory and technical requirements for interconnecting responsive resource assets to the electric power system will clearly specify the functionality that an implementation profile of IEEE Std 2030.5 must support, and that the responsive resource assets must include to achieve interoperability. These requirements will apply to the integration of all responsive assets, but we acknowledge that most

jurisdictions (and associated ecosystem stakeholders) will define these in a priority order as dictated by real-life scenarios. We encourage and will facilitate the adoption of common elements across different jurisdictions to reduce the amount of specialization and specification development effort.

In this regard, Interconnection Requirements are a critical element of reducing the effort for integration of responsive resource assets.

Test and Certification Procedures Vision

The widespread integration of responsive resource assets is founded on trust. Trust from producers, users, regulators and all other stakeholders that the assets will work as intended and expected once deployed and integrated into system operation. Testing and certification procedures are a critical element in establishing this trust. Their development requires clarity of specification in IEEE Std 2030.5, and the appropriate implementation profile and interconnection requirements. Testing and certification procedures will be documented, publicly available and consistent with the other critical elements. All ecosystem stakeholders recognize the certification brand and trust certified products and services will integrate easily and reliably. Many IEEE Std 2030.5-based products and services will be available and certified to work based on regional jurisdictions, and there will be ready access to publicly available lists of certified products for the ecosystem stakeholders to reference. As experience grows testing should scale and become more comprehensive, efficient and cost-effective. Also, differences in implementation profiles and interconnection requirements in different jurisdictions should reduce overtime, the commonality between the corresponding test procedures should also be enhanced.

In this regard, Test and Certification Procedures are a critical element of reducing the effort for integration of responsive resource assets.

4. Roadmap Development

The methodology used to develop this roadmap concentrated on the process to develop high-level, strategically oriented steps to advancing interoperability in a specific technology integration area. It was designed with a heavy emphasis on understanding the ecosystem of businesses and related stakeholders and the key drivers that make interoperability a worthwhile topic to invest their time and effort. Such motivation is necessary to garner participation in developing a roadmap, and more importantly, in taking ownership to make progress.

Linked closely with the roadmap methodology is the Interoperability Maturity Model (IMM) tool. The IMM provided a structured way to explore the state of interoperability, which has many complex dimensions. It also served to identify gaps and helped those participating in the roadmap process to define their desired goals and prioritize the areas that need attention to achieve them.



"SIMPLY WRITING A ROADMAP IS NOT ENOUGH — THE TRUE MEASURE OF SUCCESS IS WHETHER OR NOT THE ROADMAP IS IMPLEMENTED AND ACHIEVES THE ORGANISATION'S DESIRED OUTCOME."

*IEA Energy Technology Roadmaps:
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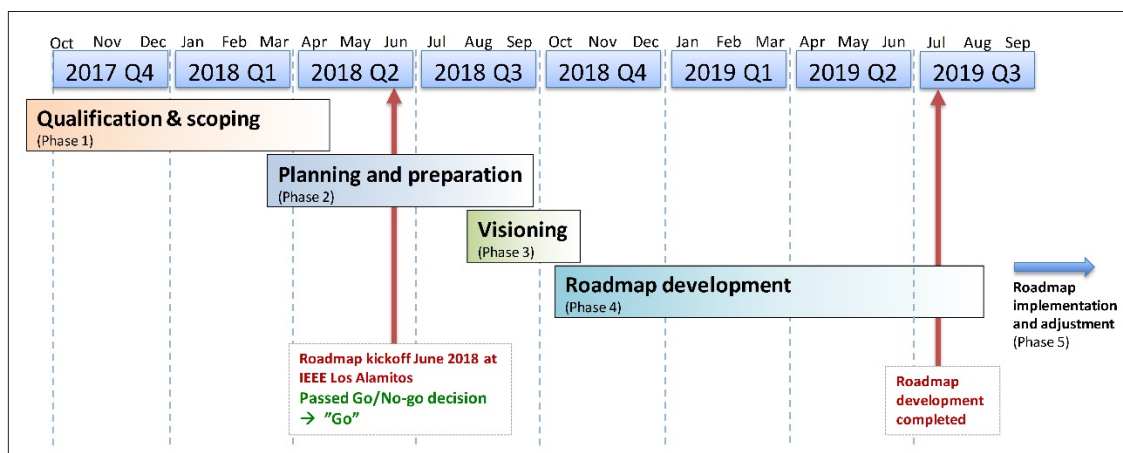


Figure 2—Roadmap Development Process Timeline

In this way, the roadmap combined process-related concerns as well as evaluation of the criteria associated with achieving interoperability.

The core roadmap development process was completed over a twelve-month period (additional detail is shown in Figure 2). In creating the initial interoperability roadmap methodology, the project team reviewed several technology roadmap processes and found one that fit well with the objectives of the overall interoperability effort. The IEA's *Energy Technology Roadmaps: A Guide to Development and Implementation*³ document offered a process for creating roadmaps that fit well with the needs for building consensus among the various parties with interest in technology integration and enabling field deployments through standardized agreements. The approach was adapted to the specific needs of electric power system interoperability and then further modified to apply to IEEE Std 2030.5.

³ IEA—International Energy Agency. 2014. *Energy Technology Roadmaps: A Guide to Development and Implementation*. Accessed February 2017 at <https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapAguidetodevelopmentandimplementation.pdf>.