EPRI

Interoperability Maturity Model

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One of the key characteristics of the energy transition is true integration of distributed resources, customer energy use, and community energy management with the planning and operation of the electric power system. This also means coordination across different energy sectors, such as gas, water, heat, and transport. All of these requirements associated with the energy transition involve extensive collaboration among various stakeholders. It is acknowledged that collaboration is essential not only across organizations, but also within technology. Complicating matters is the long-life span of components within the energy grid, necessitating innovation that can seamlessly interact with older technologies from diverse vendors—a call for interoperable solutions.

Regrettably, the term "interoperable" lacks a precise definition and is poorly understood. It suggests the idea that two technologies can effortlessly cooperate in a plug-and-play manner, a concept often recognized more intuitively than defined explicitly. A prime example of interoperability is the universal use of the same type of wall plug within most European countries. Conversely, instant messaging, while seemingly interoperable, often fails, as applications may be incompatible between Android and iPhone. This lack of true interoperability also manifests in workplace collaborations, where choosing a collaboration platform involves navigating through contracts and approvals from different software vendors.

Similar challenges are encountered in the energy transition. For instance, determining the platform for residential homes to participate in a demand response program or identifying the technology for creating virtual power plants poses dilemmas. Given the centrality of electrical power in society, introducing a tech giant into the space to manage necessary information exchanges is often viewed unfavorably. A decentralized approach is deemed more appropriate, creating more opportunities for innovation. However, the diversification of technological development to facilitate innovation creates even more challenges for interoperability. Established technology development methods tend to assume a hierarchical approach, requiring a paradigm shift for the diverse yet collaborative nature of technology development for the energy transition.

This paper argues for the foundational role of interoperability at the community level in developing solutions for the energy transition and emphasizes the importance for industry leaders to invest in the maturity and stability of these interoperability communities. The paper introduces the concept of an interoperability maturity model and assessment tool (EMINENT—**E**valuating the **M**aturity of **I**nteroperability for the **EN**ergy **T**ransition) that is being developed and applied as part of the int:net Horizon Europe project (https://intnet.eu/) to help organizations and interoperability communities evaluate and enhance their interoperability maturity.

Section 1 discusses the nature of interoperability, aiming to clarify its definition. Section 2 develops a capability model to describe the components of this skill. In Section 3, different dimensions are discussed to evaluate proficiency in this skill, examining how organizations, communities, or industries typically evolve in this regard. The final section discusses next steps in application of the maturity model and the opportunity for coordination across the industry.

DEFINING INTEROPERABILITY

Before diving into interoperability maturity models, it is important to define what is meant by interoperability. The definition will be contextualized by disambiguating the term "interoperability" from "standardization." Then, a deep dive into the different ways and places that interoperability needs to be manifested will be discussed.

Interoperability and Standardization

The concepts of interoperability and standardization are distinct but are closely related and easily confused. For the purpose of this paper, the definition of "standard" from the Dublin Core Metadata Initiative is used:

> "A reference point against which other things can be evaluated or compared."[1]

Interoperability is defined by Merriam-Webster as:

> "Ability of a system … to work with or use the parts or equipment of another system."[2]

Considering these two definitions, it is fair to say that standards and standardization are necessary to achieve interoperability, but interoperability requires a degree of collaborative adoption and convergence, as well as the operational decision making to allow (at a policy or regulation level) for those systems to in fact make use of those "parts or equipment".

Manifesting Interoperability

In the introduction, interoperability was defined as being plug-and-play collaboration of technology. The Merriam-Webster definition also speaks of "systems", "parts", and "equipment". But interoperability goes beyond just technology. It also involves aligned operational practices, goals, and principles. For this article, we rely on the Smart Grid Architectural Model (SGAM) interoperability framework.[3] A complete overview of this framework can be found in Figure 1.

1 Dublin Core, https://www.dublincore.org/specifications/dublin-core/dcmi-terms/#http://purl.org/dc/terms/Standard

2 Merriam-Webster, https://www.merriam-webster.com/dictionary/interoperability#:~:text=noun,or%20equipment%20of%20another%20system.

3 For those familiar with the GridWise Architecture Council (GWAC) Stack, multiple studies, including one at https://syc-se.iec.ch/deliverables/sgam-basics/, have noted how these two models are compatible with each other.

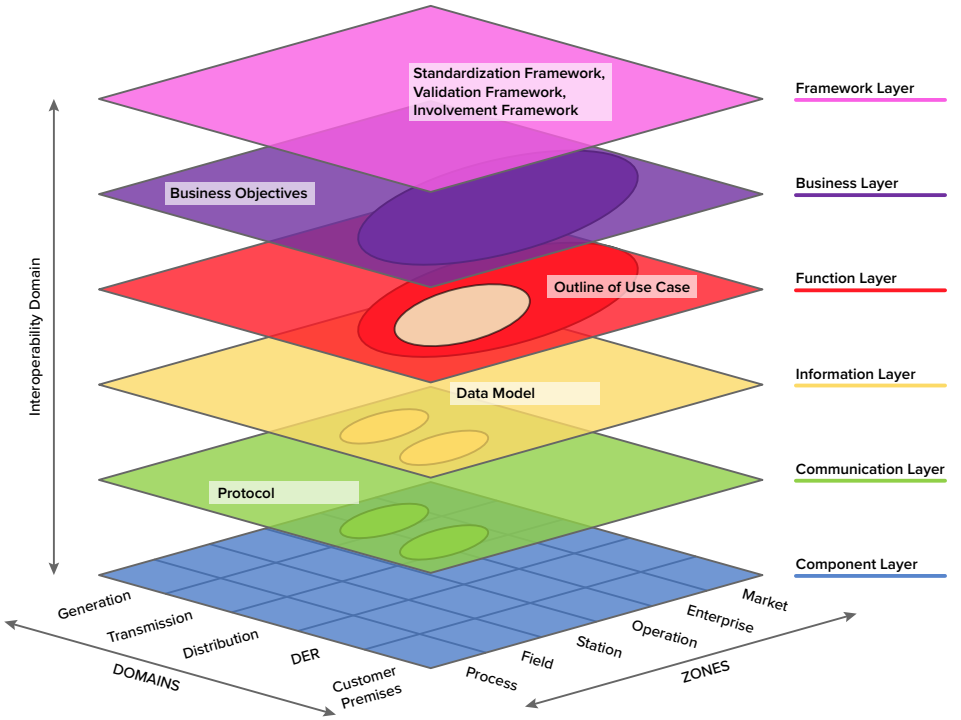

Figure 1. *The 6-layer SGAM model.*

This SGAM model describes six layers of interoperability.[4] At the bottom we have the component layer. **The first layer** describes the need for the physical components to physically fit together. A good example is how plugs and wall sockets fit together (if one stays within a certain region, of course), or how USB A plugs and USB A ports physically fit together. An example of failing interoperability was the period when every (smart) phone company used its own chargers until the EU mandated a single charging port specification to be used for all devices and the industry settled on USB C,[5] with Apple joining the ranks most recently.[6]

The second layer from the bottom covers the protocols with which physical components and software communicate with one another. Protocol, in this technical context, refers to the system of rules with which different components communicate with each other. Components may support multiple protocols simultaneously, but at least one must be in common between two components for them to have a chance to be interoperable. A good example of such a protocol would be IEC 61850 for substation automation or TCP/IP for communication over the internet. A more analog example of such a protocol would be the meter pulse signal that utilities used to send out to switch between meter registers on analog meters.

The third layer, the information layer, describes the need to harmonize information and data, specifically their meaning and interpretation, across components and users. Examples of standardized information include information exchanges based on the IEC-CIM (the International Electrotechnical Commission Common Information Model), Inspire (the EU geospatial data standard), or any of the many World Wide Web Consortium (W3C) standards for metadata. Examples of failed interoperability include any utility's experience trying to integrate its geographic information system (GIS) from vendor A with its energy management system/supervisory control and data acquisition (EMS/SCADA) system from vendor B, or any organization attempting an upgrade to its human resources, enterprise resource planning (ERP), or outage management system (OMS) to one from a different vendor. The need for semantic interoperability has become increasingly evident as our industry is going through a digital transformation.

The fourth layer governs alignment in business functions. The idea is that if two organizations have adopted incom-

4 As part of the int:net project, a sixth layer (the framework layer) was added to the original five of the SGAM model.

5 European Union Council, https://data.consilium.europa.eu/doc/document/ST-10713-2022-INIT/x/pdf [in French].

6 BBC, "New iPhone, New Charger: Apple bends to EU rules," https://www.bbc.com/news/technology-66708571.

patible processes, collaboration is at best an exception and at worst impossible. Examples of aligned business functions would be the coordinated security analysis across transmission system operators (TSOs) in Europe. Examples of failed alignment include migrants/expats coming to a new country, needing a bank account in that country to be able to rent a residence, but finding out that banks require them to have a domestic address before they can open a bank account (which requires them to have a residence, which requires them to have a bank account, and so on). A current development that exemplifies the importance of aligned business functions occurs when a large industry gets a flexible load contract as a prerequisite for a new grid connection. When that happens, it is important that both the transmission and distribution system operators can limit the capacity that this connection can take from and feed onto the grid, as well as the industry having the processes to anticipate the flexibility requirements and continue the adjusted operation.

The fifth layer is the business layer. This layer addresses the notion that businesses need to have aligned goals and strategies for interoperability to be possible. For example, consider the situation in which a chemical plant has the desire to become net-zero, but the gas grid from which they receive natural gas has the strategy to use fossil sources for as long as possible. Even if the technology they use is currently plug-and-play, in the long run this collaboration will end because the strategies of the two parties are incompatible.

The sixth layer describes that the legal and regulatory frameworks within which this interoperability occurs need to be aligned. For example, consider an EU-based company that would like to make use of a U.S.-based software as a service (SAAS) offer, and this service involves personally identifiable information. If this service cannot comply with the right to be forgotten, then the EU-based company is in violation of the laws of its jurisdiction. Another example would be if a software development team wishes to use a GPL-licensed (GNU General Public License) software library as part of a commercial offering. In these cases, the legal frameworks are not aligned and will therefore inhibit interoperability.

Interoperability and Communities

One of the fundamental conclusions of this work is the observation that interoperability is a quality not just of a technical system, but also of the organizational participants in that system. Whether they are manufacturers of computer parts adopting standards such as USB, PCI-e, or SATA, or substation automation vendors offering sensors, actuators, and remote terminal units (RTUs) using the IEC 61850 protocol, this level of interoperability requires both vendors to create the products and clients/customers/consumers (whether they are large-scale computer manufacturers or consumers building their own computers in the computer part example, or utilities and/or generators in the IEC 61850 example) to purchase those compliant products and implement them in their systems. Furthermore, vendors and clients need to collaborate with vendors and manufacturers to make sure that the standards meet the needs of the clients and the systems they build and/or operate. Interoperability requires a community of organizations, invested in the same problem space, to collaborate. This establishes an *interoperability community*.

Is it possible, strictly speaking, for an interoperable system to be produced by a single entity? Yes. For example, because many businesses use MS Office for writing documents, managing data in spreadsheets, and creating slideshows, there is a sense of interoperability. However, this form of interoperability often goes hand in hand with a sense of monopoly and antitrust concerns. Furthermore, businesses that wish to make use of an alternative office suite find themselves struggling to collaborate with businesses that use MS Office. Developers of those alternative office suites find that they have a relatively small influence in how their innovations affect the standard that is often owned by a single company. The role that the energy system—and, specifically, its infrastructure—plays in society makes it problematic to introduce such single-vendor interoperability solutions.

Interoperability in the World

A good example of interoperability limitations between organizations involves smart phone texting. Take the example of Apple iMessage. If both parties are texting with Apple devices, the text appears as a blue text bubble. If someone with an Android device is texting, the text appears as a

green text bubble. It is a visual illustration of the problems that Android and iPhone users have when trying to text each other. Here's a good Wall Street Journal (WSJ) has a podcast that describes the tangible consequences when interoperability fails in the telecommunication domain, in the case of Android–iPhone messaging.[7] And yes, the WSJ calls interoperability a "wonky concept".

DEFINING THE CAPABILITIES THAT SUPPORT INTEROPERABILITY

Interoperability exists between at least two components, parts, and/or systems. It is about interaction and collaboration. For this reason, we look at interoperability through the lens of a community of organizations and individuals that collaborate around interoperable solutions. These communities include those who create the standards, as well as those who adopt these standards in their solutions.

As it turns out, this perspective and approach to developing solutions is neither new nor unique to the interoperability/standardization space: The world of open-source software (or hardware) development deals with many similar issues. Based on experiences and articles from that community, we developed a capability model with three high-level capabilities and 10 sub-capabilities (Figure 2).

Community Facilitation

The community includes the people and organizations who invest their knowledge, time, and other resources into the creation and/or implementation of interoperable systems. Within any individual organization, decision making, work assignment, and conflict resolution are typically organized through the organizational hierarchy, in which the ultimate decision power lies with the directors. Communities that grow around interoperability do not have this kind of institutional power. These communities are built on voluntary participation: Anyone can just walk out and not participate if the direction of the standards and solutions that are being developed does not fit their needs, does not address their concerns, or worse, violates their interests. Decision making in these collaborations happens through consensus making.

The ability to create and maintain this much more fluid community is therefore vital to the continued development and use of interoperable solutions.

The following three sub-capabilities that support this effort:

1. Community growth: The ability to attract new participants (and replace old ones).

2. Knowledge retention: The ability to share and pass on both institutional and technical knowledge of how the standards and solutions address the problem that they aim to solve.

3. Maintaining diversity of perspectives: Interoperability is, by definition, an interdisciplinary effort. A multitude of expertise and perspectives needs to come together to produce the interoperable outcomes that we are (more

7 "One Company's Quest to Burst Apple's Blue Bubble Texts," https://www.wsj.com/podcasts/the-journal/one-companys-quest-to-burst-apples-blue-bubble-texts/E10958FA-D44F-406C-B344-111502EFCC07.

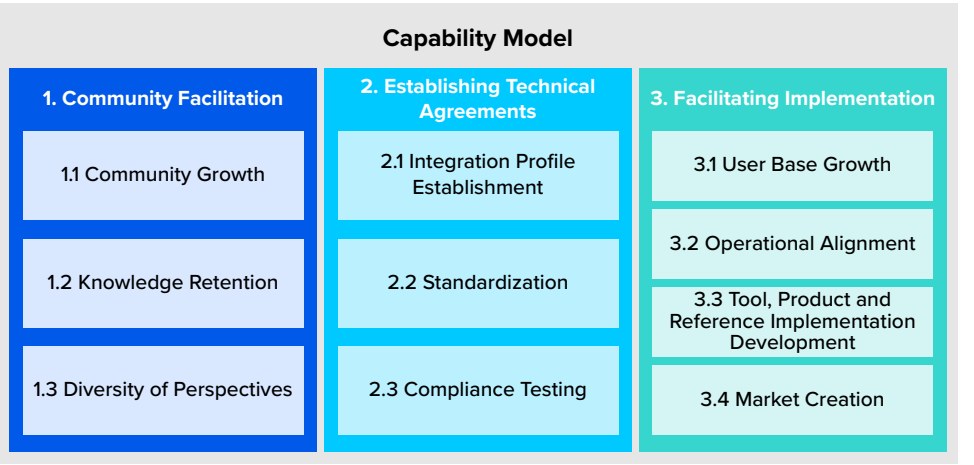

Figure 2. *The Interoperability Capability Model developed in the int:net Project.*

and more desperately) looking for. Within the utility space, which is so embedded in society, the solutions that are developed at times also require the perspectives of the communities in which they will be implemented. Ensuring that all these perspectives are represented will greatly improve the quality of the solutions that are being developed, as well as ease adoption.

Establishing Technical Agreements

The second capability concerns the ability to make technical agreements. We already addressed the importance of standardization; this is the capability that supports it. It is divided into three sub-capabilities, as follows:

1. Profile establishment (or integration profile establishment): This concerns the ability to come to an agreement about which problem is being solved. This can also be thought of as creating consensus about the requirements for the interoperable system. This often involves utilization of the "use case methodology" originally developed in the EPRI Intelligrid Initiative and adopted in the IEC as standard IEC 62559 (https://syc-se.iec.ch/deliveries/iec-62559-use-cases/).

2. Standardization: The ability of the community to establish the technical, organizational, and legal specifications for the interoperable system(s).

3. Compliance testing: The ability of the community to test—or even certify—that a given implementation or solution complies to the specifications laid out in the standard(s).

Facilitating Implementation

The third capability of interoperability communities' concerns is facilitating implementation. After all, if no one adopts implementations of the standards in their operation, then the standards are just a stack of paper, and the community is just a professional friend group. The "ability of a system […] to work with or use the parts or equipment of another system," as Merriam-Webster defined interoperability, fundamentally depends on those other systems, parts, or equipment to exist, and be used in the first place.

Facilitating implementation is supported by the following four sub-capabilities:

1. User base growth: This capability is about as straightforward as it can get. The more users of the technology the better. Specifically in the utility space where the challenge of distributed energy resources (DER) or electric vehicles (EVs) is in the numbers. The more EVs that adopt a standardized charging protocol, the more impact that fleet can have on congestion management. The more, the merrier.

2. Operational alignment: This capability recognizes that the equipment and systems do not just need to be there; they also need permission to make use of each other. We do not want utilities to just charge privately owned batteries at will; the owner and the utility need to make agreements about how, when, and what kind of compensation are used and how conflicts are resolved.

3. Tool, product, and reference implementation development: A standard means very little if it is not implemented. The interoperability community has a large role to play when it comes to proving that the standards work by developing reference implementations and encouraging vendors and manufacturers to adopt the interoperability frameworks that it has been developing.

4. Market creation: Ultimately, any technology or standard will survive only if there is a market for it. The developers and suppliers of the products and services need to have a positive business case. Ultimately, a healthy market will also ensure continued investment in the standards and the community developing them.

Defining Organizational Maturity

With an established understanding of interoperability, it becomes clear that there is a need for a maturity assessment of the various capabilities. Understanding the current state of these capabilities is essential for identifying strengths, pinpointing weaknesses, and strategically planning enhancements. By evaluating the maturity levels, stakeholders gain valuable insights that guide resource allocation and enable the alignment of capabilities with evolving standards and technologies.

Organizational maturity refers to the level of development, capability, and effectiveness that an organization has achieved in various aspects of its operations, processes, and functions. It encompasses the organization's ability to manage and adapt to change, implement best practices, and continuously improve its performance over time.

Using EPRI's capability-based maturity model, the interoperability capabilities across four dimensions can be evaluated [8,9]:

- Process: the processes that are in place to take the actions required for the capability.
- People and organization: members of the community having the right knowledge, skill set, and community culture to support the capability.
- Information: the information and data that are required to perform or improve upon the capability.
- Resources: finances, time, facilities, and other types of resources, both their availability and the continuity of the investments being made.

Six levels of maturity, ranging from "nonexistent" to what amounts to "industry leading", are also defined. The descriptions of what is expected to be observed if a given dimension has reached a given maturity level are called characteristics. How this all fits together can be seen in Figure 3.

Examples of these descriptions can be found in the Appendix. The characteristics are at the heart of the maturity model, as they form the point of comparison (a "standard", if you will) that allows us to look at different communities and establish their interoperability maturity.

8 In EPRI's reference maturity model, "Technology" is modeled as a fifth dimension; however, for the subject of "supporting the development of interoperable solutions", this dimension was found to be less insightful, consisting primarily of file-sharing technologies and proper version control. When technology is specifically relevant for interoperability communities, it is modeled under the "Resources" dimension.

9 For very mature interoperability communities, or very complex standards, like the IEC-CIM, it might be relevant to reintroduce this dimension as part of an evaluation.

INTEROPERABILITY MATURITY ASSESSMENT

With the interoperability maturity model in hand, the maturity of interoperability communities can be assessed and managed. To this end, the EMINENT (**E**valuating the **M**aturity of **I**nteroperability for the **EN**ergy Transition) maturity assessment tool has been developed. The interoperability maturity assessment comprises a survey[10] and a tool that generates a maturity report based on the responses.

Why We Need This

Understanding interoperability has become an urgent necessity in our current landscape, particularly as the energy sector undergoes a significant transition. Many solutions devised to address this shift, ranging from DER and EVs to demand response mechanisms, hinge heavily on interoperability. This extends beyond the realm of electricity, encompassing the need for seamless interaction between various energy markets and infrastructure, including natural gas, hydrogen, and heating systems. Although pockets of interoperability exist, the industry lacks a comprehensive understanding of how they evolved and, more importantly, the means to consistently replicate their success. The introduction of an interoperability maturity model offers insights into the intricate business and organizational contexts necessary for fostering the development of interoperable solutions. By addressing these critical aspects, the way can be paved for a more interconnected and efficient energy landscape that can navigate the complexities of the ever-evolving energy ecosystem.

10 The survey can be found at https://ec.europa.eu/eusurvey/runner/Eminent.

Maturity level > dimension v	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Process	Characteristic p0	Characteristic p1	Characteristic p2	Characteristic p2	Characteristic p3	Characteristic p5
People and organization	Characteristic po0	Characteristic po1	Characteristic po2	Characteristic po3	Characteristic po4	Characteristic po5
Information	Characteristic i0	Characteristic i1	Characteristic i2	Characteristic i3	Characteristic i4	Characteristic i5
Resources	Characteristic r0	Characteristic r1	Characteristic r2	Characteristic r3	Characteristic r4	Characteristic r5

Figure 3. *Defining maturity levels across the different dimensions of maturity: overview of dimensions, maturity levels, and characteristics (p = process; po = people and organization; i = information; r = resources).*

Status of Applying the Maturity Model

Within the int:net project, we have tested the assessment using the project community itself. For illustration purposes: Members of the project community completed the questionnaire, and the answers were aggregated across the dimensions for each sub-capability. This resulted in the maturity scores seen in Figure 4.

A report for each of the high-level capabilities was generated, showing the scores for each of the dimensions (for example, see Figure 5).

An example of a lesson learned in this assessment is that there are many resources available for knowledge (1.2.r, with an average score of 3.1) but this has not translated into the community knowing where to find the information (1.2.i, with an average score of 1.4). This could cause the project to pay extra attention to communicating which information resources are available, and where they can be found.

A keen eye will also observe that the scores for "diversity of perspectives" (1.3.*) are all relatively low. This can be explained by the fact that this is a Horizon Europe research project, with participation mostly by research institutes. It is in the nature of this collaboration structure that this diversity is limited. The contractual nature of the grant agreement also does not leave much room for this to change. Consequently, the project community concluded that although this is a point of learning for future collaborations, it will not prioritize improving this score.

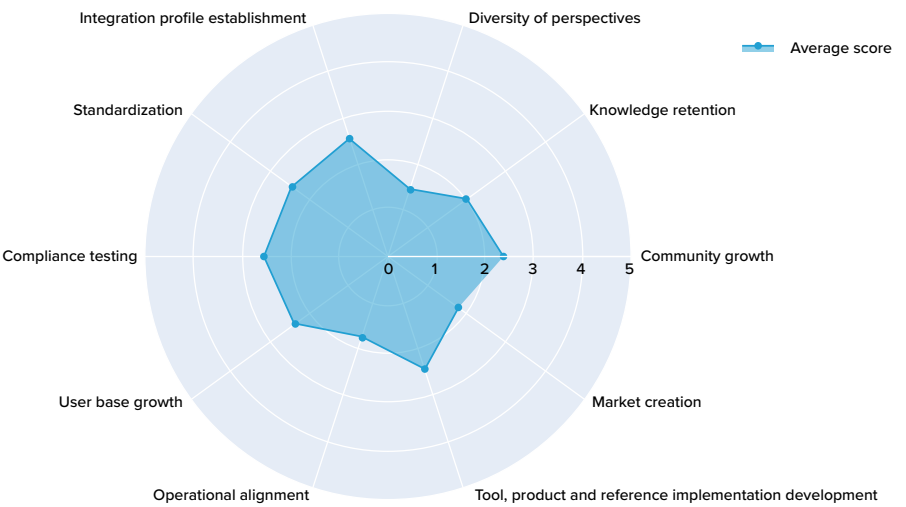

Figure 4. *Overview of the maturity cores for each of the 10 sub-capabilities.*

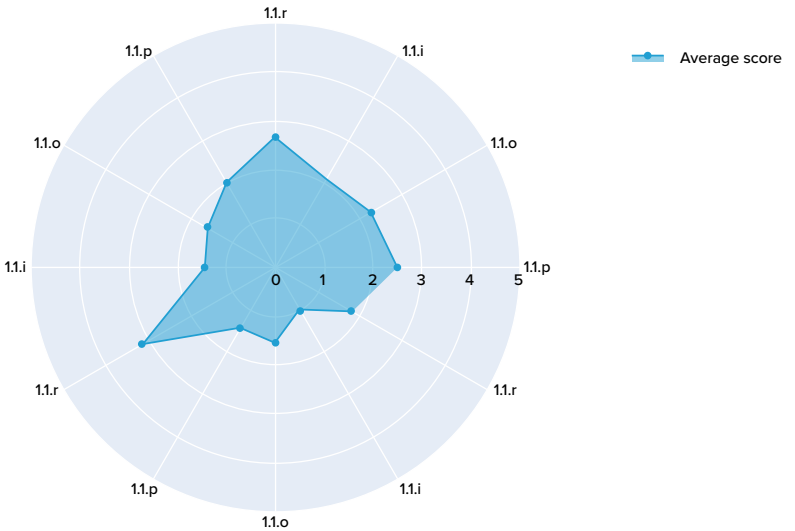

Figure 5. *Radar diagram showing the maturity scores for each dimension of the Community Facilitation capability.*

To get an insight of what a maturity assessment could provide to an interoperability community, the preceding two cases are good examples, including making it clear that not every low score demands immediate evaluation. The community understands its own needs best and the maturity assessment is a tool that is aimed at facilitating the discussion on how to improve.

Who Can Benefit from This Approach?

EMINENT, as an interoperability maturity model, can help interoperability communities become more robust. But what kind of communities should consider using it? Examples include the following:

- Standardization communities
- Industry/sector collaborations (these may or may not be organized in umbrella organizations)
- Open-source software and open-source hardware communities
- Communities of energy companies, TSOs, distribution system operators (DSOs), energy service providers, regulators, and the technology providers for all these organizations

This tool may also be relevant to certain collaborations inside organizations. There are plenty of scenarios in which departments within an organization collaborate on joint subjects of interest. These collaborations cut across the established decision-making structures and therefore struggle with many of the same challenges as interorganizational interoperability communities. Examples of these include the following:

- Expert groups, communities of interest, or guilds [11,12]
- Interdepartmental programs or change initiatives (coordination between different responsibilities within a utility, such as planning, design, operations, regulatory, purchasing)

Ultimately, users of the grid, be they consumers or businesses, will benefit from a more open, interoperable grid in the following ways:

- A more open grid that supports a higher variety of users' needs, as those perspectives were part of the design process.
- Reduced costs:
  - Grid operators/owners are less likely to fall into vendor lock-in, as interoperable solutions are easier to replace by other vendors' options that comply with the same standards.
  - A more competitive industry for grid components and services.

CONCLUSION AND NEXT STEPS

Interoperability is a quality of technical systems that requires multiple parties to collaborate and agree. Models like the SGAM describe the technical/operational aspect one needs to consider when targeting interoperability; EMINENT, with its capability and maturity models, gives interoperability communities a reference for how to further develop as a community that can support the development of interoperable solutions. The maturity assessment can help these communities identify areas for development.

Having strong communities that can address the full scope of interoperability, from specification and design to implementation and adoption, will greatly improve the industries' ability to develop the solutions for the challenges that it faces. Investing in these communities should therefore be a priority for any leader in this industry.

Next steps in the application of the maturity model involves surveying organizations that are part of the overall energy community in Europe: TSOs with the cooperation of the European Network of Transmission System Operators (ENTSO-e), DSOs with the cooperation of European Distribution System Operators (EDSO), energy service providers, policymakers, and standards organizations and working groups. Results of these surveys will be compiled and will form a baseline for existing interoperability maturity within the European energy systems. Recommendations for addressing important gaps will be developed, including development of further standardization and interoperability testing needs for the energy transition. Most importantly, the int:net project establishes an open and cross-domain community: the Interoperability Network for the Energy Transition (int:net). Within this interoperability network, the project brings together all stakeholders relevant to the European energy sector to jointly work on developing, testing, and deploying interoperable energy services.

11 In the context of (scaled) agile organizations.

12 These usually do not have products to develop, so not all capabilities may be equally relevant.

EPRI will extend this concept to the broader worldwide energy community. The opportunity to apply the maturity model assessment tools across the broader cross section of EPRI members and associated organizations (such as regulators and technology providers) will provide a more robust baseline for interoperability priorities to support the worldwide energy transition.

APPENDIX

This appendix gives some examples of characteristics that are described in the section on "Defining Organizational Maturity".

Process

This example illustrates how the "process" dimension is applied to the "knowledge retention" capability and how the characteristics describing different maturity levels are described (Figure 6).

Description: Capability 1.2, knowledge retention in the context of interoperability, refers to the intentional preservation and accessibility of critical information, expertise, and insights related to the seamless integration and connectivity of diverse systems and technologies. It involves capturing, storing, and making available the knowledge gained from experiences, best practices, challenges, and solutions associated with interoperability efforts.

Examples: Examples of processes for knowledge retention include the following:

- Onboarding and debriefing/exit processes
- Processes for education and training about the problems, technologies, and solutions the community aims to address

Level 0: There are no processes for knowledge retention.

Level 3: Key processes for knowledge retention are documented community-wide, ownership is defined, and handoff points established. Adoption, execution, and results are inconsistent.

Level 5: Processes for knowledge retention are continuously reviewed, benchmarked, and improved, resulting in industry-leading practices and results.

People and Organization

This example illustrates how the "people and organization" dimension is applied to the "standardization" capability and how the characteristics describing different maturity levels are described (Figure 7).

Description: Capability 2.2, the capability of standardization in the context of interoperability, refers to the process of establishing a set of agreed-upon norms, specifications, and protocols that solve the problem stated in the integration profile. Standardization plays a crucial role in fostering interoperability by providing a common framework that ensures compatibility, consistency, and predictability in the exchange of data and functionality.

Examples: Examples of people and organization to support standardization include the following:

- Domain experts
- Project management support
- Education/training programs to educate participants in how to properly produce standards

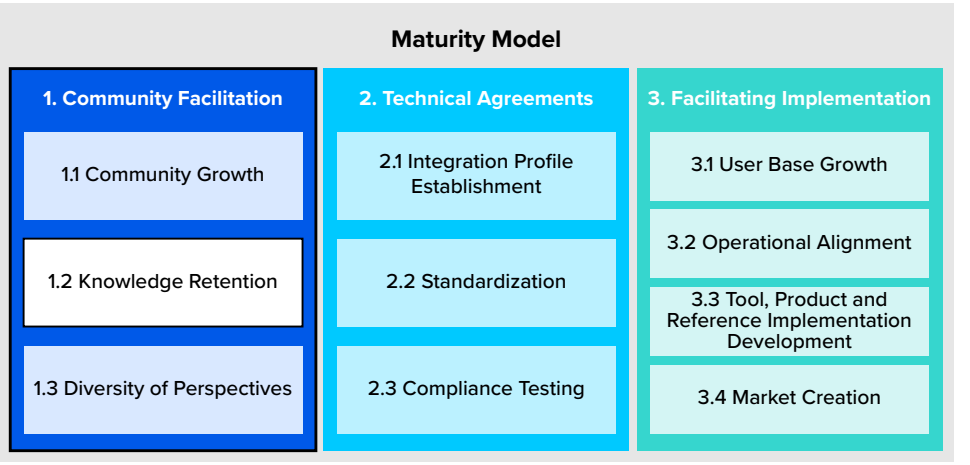

Figure 6. *Illustrating the knowledge retention capability in the context of the capability model.*

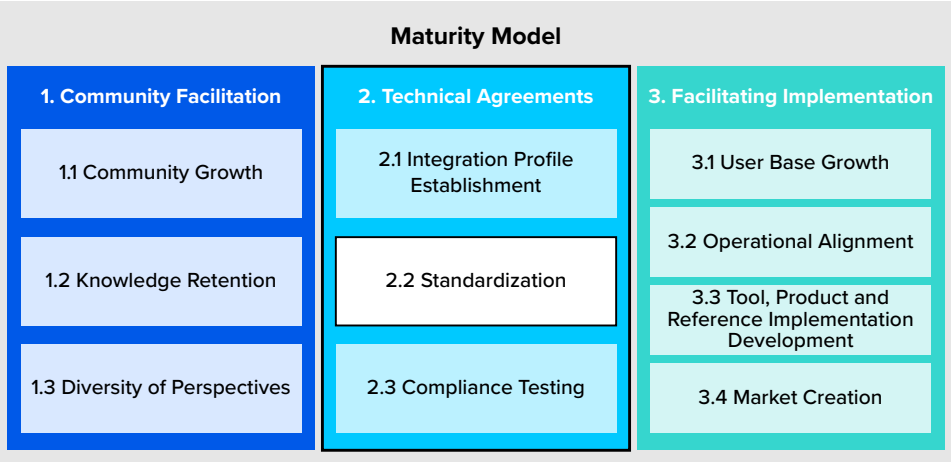

Figure 7. *Illustrating the standardization capability in the context of the capability model.*

Level 0: There is no organization for standardization.

Level 3: Community members have good skills and experience, and available training is in place to help standardization. Roles and responsibilities are defined and assigned to members/working groups.

Level 5: Community members have an expert and deeply contextualized understanding of standardization and are working in a culture that supports and actively embraces continuous improvement, benchmarking, and innovation.

Information

This example illustrates how the "information" dimension is applied to the "compliance testing" capability and how the characteristics describing different maturity levels are described (Figure 8).

Description: Capability 2.3, the capability of compliance testing in the context of interoperability, refers to the systematic evaluation and verification processes designed to ensure that interconnected systems, components, or solutions adhere to established standards, specifications, and protocols. Compliance testing is instrumental in validating that interoperable systems meet the required criteria, fostering consistency, reliability, and adherence to industry or organizational norms.

Examples: Examples of information to support compliance testing include the following:

- Documented testing procedures
- Historical testing data and results
- Registry of certified testing facilities

Level 0: Data/information to support compliance testing do not exist.

Level 3: Information governance defines how information for compliance testing is collected, stored, understood, accessed, owned, and deleted.

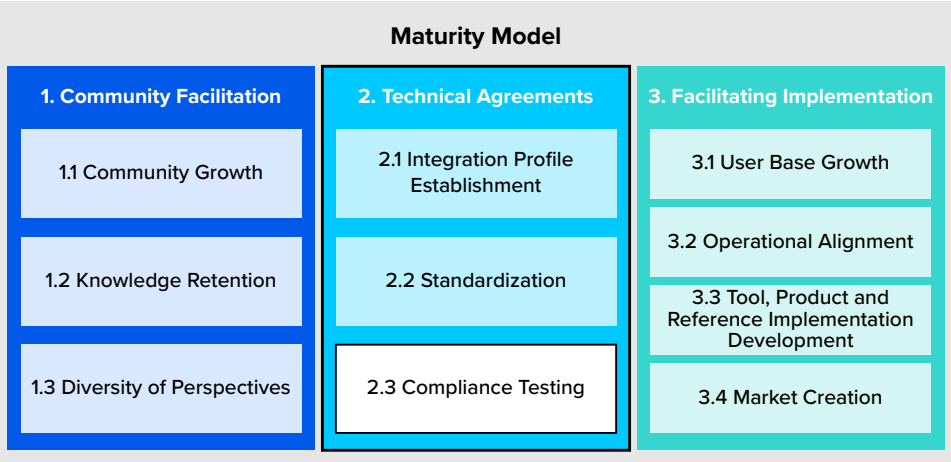

Figure 8. *Illustrating the compliance testing capability in the context of the capability model.*

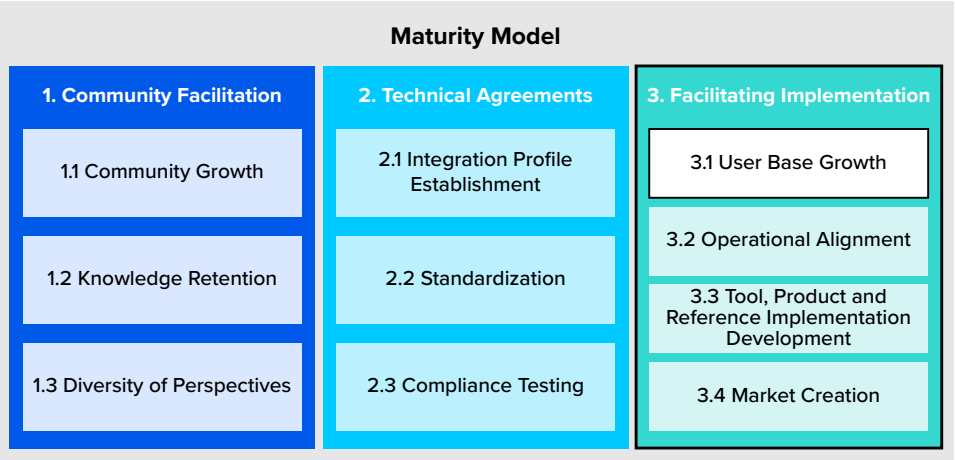

Figure 9. *Illustrating the user base growth capability in the context of the capability model.*

Level 5: New information for compliance testing is continuously identified and benchmarked.

Resources

This example illustrates how the "resources" dimension is applied to the "user base growth" capability and how the characteristics describing different maturity levels are described (Figure 9).

Description: Capability 3.1, the capability of user base growth in the context of interoperability, refers to the expansion and diversification of the community or user ecosystem that actively engages with and benefits from interoperable systems. This dimension recognizes the importance of not only increasing the number of users but also ensuring that a broad range of stakeholders, including individuals, organizations, and sectors, can effectively participate in and leverage interoperable solutions.

Examples: Examples of resources that support user base growth include the following:

- Marketing materials and branding
- Budget for community user base growth activities, such as outreach, conference participation, on-site demos, and the like
- Applications that allow for managing information related to community growth

Level 0: There are no resources available for user base growth. Individuals who do participate in user base growth do so voluntarily in their own time.

Level 3: The relationship of user base growth to resources is defined and requirements are part of the investment planning process. Most individuals performing work for user base growth are compensated for their effort by the organization they represent.

Level 5: New resources and other innovations that can improve user base growth are investigated, benchmarked, proven, and deployed. All work done toward user base growth is compensated.

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