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Electric Utility Industry Standards Landscape

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ELECTRIC UTILITY INDUSTRY STANDARDS LANDSCAPE

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EXECUTIVE SUMMARY

The electric utility industry relies on robust communication protocols to manage complex electrical grid data. The inherent networked nature of electrical grids, coupled with the radial structure of the "last mile" portion delivering power to end-use customers, presents difficulties in describing electrical models using simple data constructs. The paper provides an overview of communication protocols that address electric utility data, including grid data, and classifies these protocols through identification key characteristics that make them suitable for different electric grid data domains. Because of their variety, grid edge devices and their associated dedicated protocols are assessed by groups: those primarily designed for energy production and storage, those related to flexible loads, and those related to electric vehicles.

The intent of this report is to provide guidance for stakeholders to navigate the challenges posed by the numerous overlapping protocols available to address electric grid data. Although further industry review, refinement, and validation of the categorization of these protocols is recommended, the authors propose this categorization as a start to improve electric grid awareness and understanding. In addition, this report includes three recommended industry actions regarding protocols to improve communications on the electric grid.

Recommended Actions:

1. **Select the Foundational Information Model:** Distribution and transmission system operators should agree on an information model for data exchange, choosing from among the UCA Common Information Model (CIM), IEC 61850, and MultiSpeak. Since the CIM comprehensively covers transmission and distribution and is meant to be extensible, International Electrotechnical Commission (IEC) 61850 and MultiSpeak could be federated.

2. **Select the Communication Model for Virtual Grid Resources:** Select a communication protocol for integrating edge devices into the grid infrastructure. IEC 62746-4 (CIM-based) is recommended for a seamless transition, although other protocols like OpenADR and IEEE 2030.5 also have merit.

3. **Select Appropriate Device-Focused Communication Models:** Standards need to be tailored to devices in these groups and agreement on the standards present the need for traditional electric industry players to work with manufacturers who might not have been historically involved in the electric grid.

1. INTRODUCTION

Electric utility data is challenging to manage on several levels. Detailed electrical models of the grid are needed to perform long-term studies of the system's stability and are necessary as the foundation upon which operational control systems are built. These electrical models are not easy to describe using simple data constructs, as electrical grids are inherently networked, although the "last mile" portion of the grid that delivers power to end-use customers is often radial in nature. Small errors in the data can lead to incorrect results, so data quality and timeliness are paramount.

These challenges are not easy to meet. They have been addressed through dedicated communication solutions sending and receiving data with both speed and security. Protocols have been deployed in a relatively uniform fashion: for example, for field communications it is common to use Supervisory Control and Data Acquisition (SCADA) implemented over IEEE 1815, also known to as DNP3. Peer-to-peer control center communications are supported by the Inter-Control Center Communications Protocol (ICCP), standardized under International Electrotechnical Commission (IEC) 60870-6 and also known as TASE.2. IEC 61850 has also been implemented for communicating and controlling equipment in electrical substations.

The common feature of all these solutions is that they connect different components, all of which are owned by the utility. These components include customer meters, telemetry points located at various points on the grid, and field communication devices deployed with construction and maintenance crews. Under deregulation, generation sources have been shifted to commercial entities outside the utility; however, the number of these facilities is relatively small, and utility-owned telemetry used to monitor the sources for reliability has remained in place, even if the "end" device is no longer owned by the utility.

As grid-edge devices become a significant source of both load and generation on the grid, traditional systems of data gathering are changing. Asynchronous communications between the utility and many external entities are now necessary, and these communications cross the utility's telecommunications boundary. The handful of industry-focused communication protocols cannot fully support the world of electricity storage, flexible heating, ventilation, and air-conditioning (HVAC) systems, and electric vehicles. Likewise, protocols used for home automation, building controls, the electronics industry, and the automotive industry are generally not easily adaptable to the utility's information requirements, and when utility connectivity and security requirements are considered, the challenges are exacerbated.

This report is meant to help those in the electricity industry who are looking "out" and those outside the electricity industry who are looking "in" to better understand the wide array of communication approaches that are commonly discussed within utilities, at conferences, at research laboratories, and within vendor software and hardware development labs. By documenting key features of each standard in a uniform fashion, this analysis is intended to provide insight into which standards are most likely to be essential in the future, which standards compete in various domains, which are complementary, and which might be dependent on each other.

2. STANDARD LANDSCAPE SURVEY

To compare different communication protocols with the goal of understanding which ones are best suited for a particular application, it is useful to understand the different "levels" of protocols. There are different methodologies for categorizing these levels, from the generic Open Systems Interconnection (OSI), which has roots in the 1970s, to the more recent electricity utility-specific models from both the GridWise Architecture Council (GWAC) based in the United States and the more European-centric Smart

Grid Architecture Model (SGAM) from the IEC's System Committee for Smart Energy. More information about these models is provided in the Appendix.

These classification systems help us think about levels of abstractions; most importantly, it is critical to separate **information models** (shown in blue in Figure 1) from **communication protocols**. Information models identify data objects, and, importantly, a good information model identifies relationships among those data objects. Information models can be thought of as models of "data at rest" and allow software developers to build applications using these definitions as a foundation for common understanding. On the other hand, communication protocols focus on "data in flight." A communication protocol with a narrow scope is more likely to define its own data requirements, whereas communication protocols that exchange a variety of different data sets for different business purposes are more likely to leverage an underlying information model.

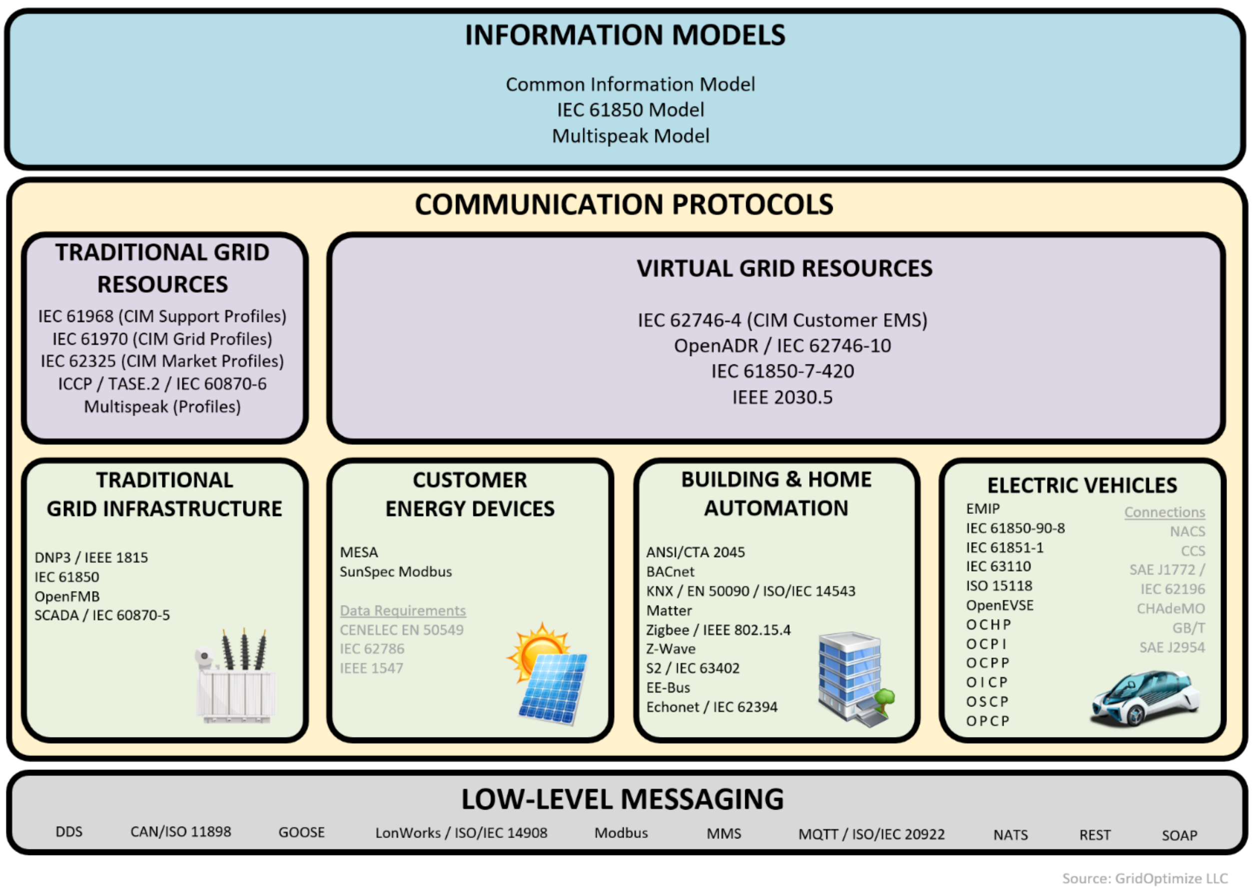


Figure 1. Standards landscape business domain.

The purpose of the standards landscape is to guide the industry towards communication protocols that can facilitate the energy transition. The next layer in the standards landscape business domain diagram (shown in purple in Figure 1) are resource-focused protocols, broadly grouped into **traditional grid resource** communications—which have been developed to address data related to utility-owned assets like bulk-power generators, substation equipment, and transmission and distribution assets—and **virtual grid resource** communications—which are newer and focused on communicating with either grid-edge devices or aggregations of those devices.

These protocols are, in general, not intended to communicate with the grid devices directly; rather, a device-focused protocol is used to translate these messages into something a class of device can process. These protocols (shown in green in Figure 1) are broadly grouped into **traditional grid infrastructure**, **customer energy devices**, **building & home automation**, and **electric vehicles**. The latter three groups support customer-owned grid-edge devices like photovoltaic generation systems, backup battery systems, flexible loads like controllable HVAC systems, and even the eventuality of electric vehicles that can provide gid support services.

Low-level messaging protocols are generally not industry specific, and a given implementation of a communication protocol often has options to implement the protocol in one or perhaps multiples of these technologies. These protocols rely on OSI layers three and below, also corresponding to GWAC network connectivity and basic connectivity. For more details on how these communication classification schemes are related, see the Appendix.

It is illustrative to think of these layers in an analogy, that of human language. Information models map the set of all words in the human language; words can be distinguished by languages. Information models are separate from one another, but there can be mapping between them so that elements (words) from one information model (language) can be translated. The purple and green layers shown in Figure 1 can be thought of collections of words composed into sentences, each in a particular language. The lowest level can be thought of as the media available to communicate, for example print, e-books, and audiobooks. Each of these conveys the same information simply using a different mechanism.

3. DATA DOMAINS

With the broad groupings by business domain established, the standards landscape documents the scope of information covered in each protocol by data domains. Since each data domain focuses on data that helps the utility understand the state of the power system at any given time, or to describe it as it might be in the future or how it was in the past, a variety of different types of data is required. These data domains, defined subsequently, fall into three major categories: **device** data, **grid** data, and **optimization** data.

3.1 DEVICE DATA

A device is a piece of technology connected to the power system and, depending on the context, could also be referred to as a piece of equipment or an asset. Devices cover both utility-owned technologies and customer-owned technologies and range from large-scale generation all the way to unmetered, small devices that can alter load patterns within a customer's premises. Data subdomains include the following:

1. Device **capabilities**. The device capabilities data subdomain includes information such as total capacity (generally kilowatt-hours) and production rate (generally kilowatts), as well as ratings, such as voltage interconnection range. For built-to-specification devices, data is often referred to as "nameplate" data. For devices that are commoditized, shared information might be found on "datasheets." Device capabilities are generally a one-way information flow, from the device (or the device's owner) to the utility at the time of interconnection request and/or periodically over time to track changes to the inherent properties of a given device.

2. Device **configuration**. The device configuration data subdomain represents how the device responds to stimuli, including models of the steady-state and/or dynamic response, as well as configurable settings like the operational mode and parameters for protection schemes. Device configuration is often a two-way dialogue between device and utility, with queries to the device for current and/or available options and controls from the utility to alter the configuration.

3. Device **conditions**. The device conditions data subdomain captures rapidly changing information. Like configuration data, conditions data is often a two-way dialogue. The device provides information about the current state such as connected/disconnected, production/consumption levels, current flow, voltage, and temperature. The utility provides information such as operational limits and production/consumption targets.

3.2 GRID DATA

As opposed to the individual devices on the grid that are generally "unconcerned" with the system to which they are connected, grid data consists of the data that describes how devices interact with each other. As with device data, there is semi-static data related to how the equipment is connected, known as the grid topology, along with defined limits and operational states and rapidly changing data related to grid measurements and estimates. Unlike device data, grid data is determined by the utility and is published internally to support business domains like planning and operations. However, a subset of the grid data is often shared with other utilities and even with the public.

1. Grid **topology**. Grid topology is a "map" of how each of the devices is connected to one another. Depending on the device, for example, a generator, a load, a conductor, a switch, or a transformer, will have a specific number of terminals. Terminals are connected to conduct electrical current, and, broadly speaking, devices might be connected in a linear nature (known as a "radial" circuit) or in a meshed fashion (known as a "networked" circuit).

2. Grid **behavior**. Once the grid topology is defined, the utility studies the grid as a system to determine its inherent electrical behaviors. This data subdomain includes information like circuit ratings and circuit impedances. This calculated data guides operation of the power system during all phases of grid development from planning through operations.

3. Grid **constraints**. Many factors both external and internal to the utility limit how the grid can be operated. Examples of data in the grid constraints subdomain include firm load levels, thermal line limits, and reserve requirements. Constraints are often variable, dependent on inputs like weather forecasts and identified contingencies.

4. Grid **state**. The grid state data subdomain contains data with the highest rate of change and includes rapidly changing data like currents, voltages, and phase angles. This data is so voluminous it often has its own dedicated storage solution within the utility that can track high volumes of data in a compressed format.

3.3 OPTIMIZATION DATA

Optimization data focuses on how the grid is operated, optimized for variables that include maximized reliability and minimized cost, and potentially variables tangential to the grid like minimized carbon footprint. Optimization data includes definitions of the types of grid services needed to keep the grid stable and which services are available from the various devices connected to the grid. Most of this data has economic indicators, such as clearing prices, ask/offers prices, and settlement prices.

1. Optimization **services**. Optimization services are defined by the utility. In addition to energy, wholesale electricity markets have established long-standing wholesale services, such as the required level of reserve generation capacity. New services are emerging for the bulk power system, as well as for the first time at the distribution level. In addition to what services are needed by the grid operators, the optimization services data subdomain also communicates which services any given

resource—physical or virtual—can provide, often based on (or at least limited by) data that can be found in the device capabilities subdomain. Optimization services are generally semi-static.

2. Optimization **negotiation**. The optimization negotiation data subdomain contains more frequently changing data related to how much of a given service is available from a device/resource and potentially at what price or under what conditions. Ultimately, all generation sources and load sinks might be price sensitive and communicate preferences from many months in advance to near real time.

3. Optimization **fulfillment**. The optimization fulfillment data subdomain can be thought of as "the other side" of optimization negotiation. Based on a wide variety of grid constraints, the grid operator can publish some combination of resource set points and localized pricing signals. Other signals, like stress level of the grid and the level of "green" power that is available, might supplement these economics signals.

4. Optimization **compensation**. After operations, based on information gathered from the field either through traditional metering or via emerging, more flexible measurement techniques, the settlements for energy and support services are calculated. Traditional monthly billing will likely evolve into more immediate transactional systems as dynamic resources, especially electric vehicles, become flexible grid resources. All performance-related information from measurement through settlement is included in the compensation subdomain.

4. PROTOCOL ASSESSMENTS

This initial version of the standards landscape provides a guide to which data domains are supported by each information model and each communication protocol. The initial review is based on the experience of the authors and readily available documentation and gives an indication of support:

● Candidate targets this data domain
○ Candidate is generally not focused on the data domain

If the standards landscape is further refined, more detailed assessments should be performed that would include review of additional documentation, some of which might not be readily available to the public, and discussions with the developers and implementors of each standard. That could lead to a more granular assessment of support using the following scale:

● Extensive support for data domain
◕ Rich support for data domain
◑ Moderate support for data domain
◔ Light support for data domain
○ Little-to-no support for data domain

4.1 INFORMATION MODELS

Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavior	State	Constraints	Services	Negotiation	Fulfillment	Compensation
Common Information Model	●	●	●	●	●	●	●	●	●	●	●
IEC 61850	●	●	●	○	○	○	○	●	●	●	○
Multispeak	●	●	●	●	●	●	●	●	●	●	●

The electric utility industry has several options for information models. The Common Information Model (CIM), managed at the UCA, is a very rich data model that supports all of the data domains, most notably in the area of grid data, which is challenging in that it is inherently networked (not each handled through parent-child data models) and requires not only the current state and historical snapshots but also views of potential future versions of the grid as changes are anticipated. The IEC 61850 information model is closely related to the CIM; however, the model in this case is managed at the IEC. The focus of IEC 61850 is narrower than the CIM with deeper modeling of the control functions of electrical equipment. Finally, MultiSpeak, managed by the National Rural Electric Cooperative Association, covers much of the same functional space as the CIM but with fewer options for implementation choices. This lack of flexibility is a strength as it eliminates variations in implementation and facilitates interoperability and lower cost tool sets.

4.2 TRADITIONAL GRID RESOURCES

Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavior	State	Constraints	Services	Negotiation	Fulfillment	Compensation
IEC 61968 (CIM Support)	●	○	○	○	●	○	○	○	○	○	○
IEC 61970 (CIM Grid)	○	●	●	●	●	●	●	○	○	○	○
IEC 62325 (CIM Market)	○	○	○	○	○	○	○	●	●	●	●
ICCP / TASE.2	●	●	●	●	●	●	●	○	○	○	○
Multispeak	●	●	●	●	●	●	●	●	●	●	●

Moving to the next level down in the standards landscape, there are several protocols that are focused on general "resource" communications, that is, communications that can be used with a wide range of technologies. Importantly, these protocols need to be paired with a device-level protocol to translate the commands into instructions a device can process. Traditional grid resources, which include both the infrastructure elements that are remotely controllable and generation, which can be dispatched, have been communicated for many years using long-standing models.

CIM profiles are available to cover the major domains, with the IEC 61968 series of standards focused primary on device-level activities, the IEC 61970 series focused primarily on grid-level activities, and the IEC 62325 series focused on optimizing the grid through market functions. The model is rich behind the standards, even when specific communication "profiles" have yet to reach the IEC, making the CIM a prime candidate for easy development of new message payloads. As noted previously, ICCP is used for control-room-to-control-room communications and support functions like interchange exchange checkout. MultiSpeak has a large overlap with CIM, focused on smaller utilities that want less costly solutions that are designed for "out-of-the-box" implementation at a municipal or cooperative utility.

4.3 TRADITIONAL GRID INFRASTRUCTURE

Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavoir	State	Constraints	Services	Negotiation	Fulfillment	Compensation
DNP3 / IEEE 1815	○	●	●	○	○	○	○	○	○	○	○
IEC 61850	●	●	●	○	○	○	○	●	●	●	○
OpenFMB	●	●	●	○	○	○	○	○	○	○	○
SCADA / IEC 60870-5	●	●	●	○	○	○	○	○	○	○	○

There is high overlap with the four standards in the category, with OpenFMB being a bit different from the rest in that it relies on other standards to build a library rather than being a unique, stand-alone protocol. Other than DNP3, which is not natively designed to exchange capabilities, all the protocols support the full suite of device services, which also include asking a device for its status (conditions) or pushing commands to the device (configuration). IEC 61850 is slightly broader, with the ability to provide some optimization services, primarily in hydroelectric power plant extensions covered in IEC 61850-7-410 and in the grid-edge device extensions covered in IEC 61850-7-520 (see the following).

4.4 VIRTUAL GRID RESOURCES

Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavoir	State	Constraints	Services	Negotiation	Fulfillment	Compensation
IEC 62746 Series	●	○	○	○	○	○	○	●	●	●	●
OpenADR / IEC 62746-10	○	●	●	○	○	○	○	○	●	●	○
IEC 61850-7-420	●	●	●	○	○	○	○	○	○	○	○
IEEE 2030.5	●	●	●	○	○	○	○	○	●	●	○

Limitations in the protocols documented in Section 4.2, "Traditional Grid Resources," have led to extensions and in some cases entirely new protocols designed for a distributed set of grid resources. In the extensions, there is IEC 62746-4 leveraging the CIM and IEC 61850-70420 extending the IEC 61850 model. OpenADR (published as IEC 62746-10) is a stand-alone standard not leveraging any of the existing information models described previously. IEEE 2030.5, on the other hand, is new but does leverage a snapshot of certain components of both IEC 61850 and the CIM.

4.5 CUSTOMER ENERGY DEVICES

Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavoir	State	Constraints	Services	Negotiation	Fulfillment	Compensation
MESA	●	●	●	○	○	○	○	○	○	○	○
SunSpec Modbus	●	●	●	○	○	○	○	○	○	○	○
IEEE 1547	Requirements Standard (Not Communications Protocol)										
IEC 62786	Requirements Standard (Not Communications Protocol)										
CENELEC EN 50549	Requirements Standard (Not Communications Protocol)										

Customer energy devices today are primarily photovoltaic systems, battery energy storage systems, or combinations of the two. All three permutations are systems that require DC-to-AC inverters and hence the utility communications, primarily focused on protections settings at this stage, address the AC "side" of the inverter; the DC "side" and the generation and storage equipment are generally outside of the utility's visibility and—at least today—are monitored and controlled by vendor-specific protocols. These additional standards are listed here as they are often associated with inverter-based communications, namely IEEE 1547, IEC 62786, and CENELEC EN 5049. All three are not communication protocols; rather these are documents that standardize data definition, some or all of which might be transmitted via the named protocols (MESA and SunSpec Modbus).

4.6 BUILDING & HOME AUTOMATION

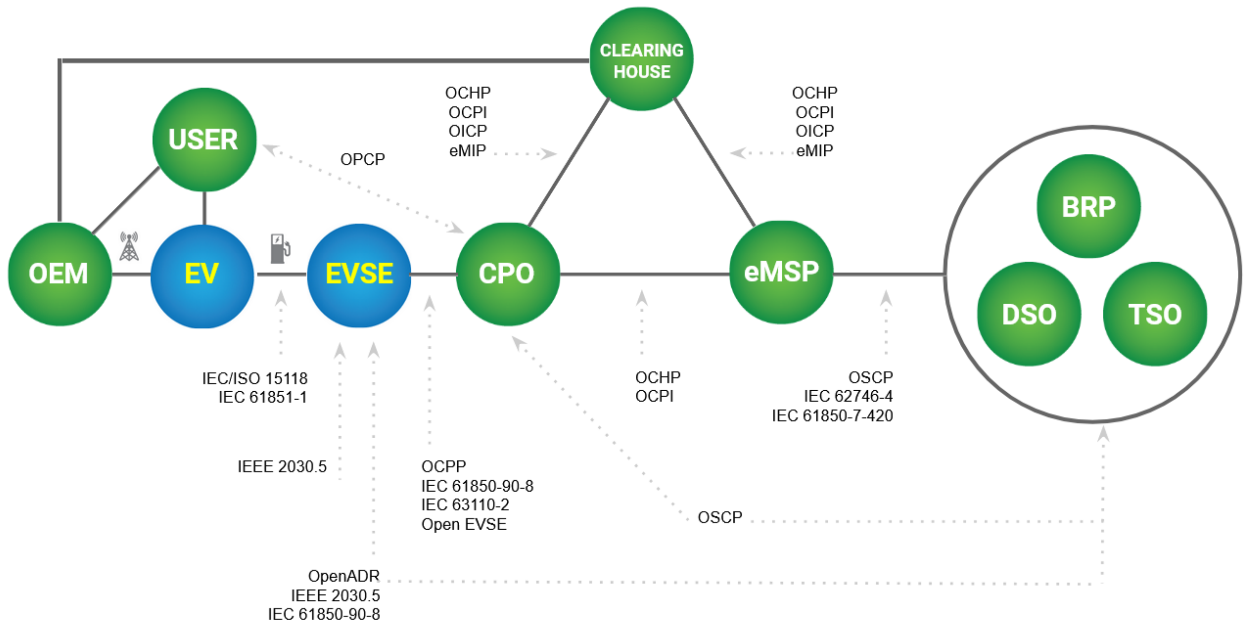
Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavoir	State	Constraints	Services	Negotiation	Fulfillment	Compensation
ANSI/CTA 2045	●	●	●	○	○	○	○	○	●	●	○
BACnet	●	●	●	○	○	○	○	○	○	○	○
KNX / EN50090 / ISO/IEC 14543	●	●	●	○	○	○	○	○	○	○	○
Matter	●	●	●	○	○	○	○	○	○	○	○
Zigbee / IEEE 802.15.4	●	●	●	○	○	○	○	○	○	○	○
Z-Wave	●	●	●	○	○	○	○	○	○	○	○

Protocols in this domain are primarily existing standards for automating devices around the home and office, like audio, lighting, thermostats, and security equipment. Most of these devices have electricity usage crossovers, making them important for flexible demand programs. All are protocols that communicate with these devices, with ANSI/CTA 2045 adding another scope extending in the negotiations and dispatching domains.

4.7 ELECTRIC VEHICLES

Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavoir	State	Constraints	Services	Negotiation	Fulfillment	Compensation
eMIP (eMobility Interoperation Protocol)	○	○	○	○	○	○	○	●	●	●	●
IEC 61850-90-8	●	●	●	○	○	○	○	○	○	○	○
IEC 61851-1	●	●	○	○	○	○	○	○	○	○	○
IEC 63110	●	●	●	○	○	○	○	○	○	○	○
ISO 15118 (Plug & Charge)	●	●	●	○	○	○	○	○	○	○	○
OCHP (Open Clearing House Protocol)	○	○	○	○	○	○	○	●	●	●	●
OCPI (Open Charge Point Interface)	○	○	○	○	○	○	○	●	●	●	●
OCPP (Open Charge Point Protocol)	●	●	●	○	○	○	○	○	○	○	○
OICP (Open InterCharge Protocol)	○	○	○	○	○	○	○	●	●	●	○
OpenEVSE	○	○	●	○	○	○	○	○	○	○	○
OSCP (Open Smart Charging Protocol)	○	○	○	○	○	○	○	●	●	●	●
OPCP (Open Plug & Charge Protocol)	○	○	○	○	○	○	○	○	○	○	●
NACS (North American Charging Standard)	Defines EV Plug (No Communications Beyond EV/Charger)										
CCS (Combined Charging System)	Defines EV Plug (No Communications Beyond EV/Charger)										
SAE J1772 / IEC 62196	Defines EV Plug (No Communications Beyond EV/Charger)										
CHAdeMO (CHArge de MOve)	Defines EV Plug (No Communications Beyond EV/Charger)										
GB/T (Guóbiāo/Tiāozhěng)	Defines EV Plug (No Communications Beyond EV/Charger)										
SAE J2954	Defines Wireless Charging (No Communications Beyond EV/Charger)										

The fast growth of the electric vehicle market and regulations across countries and regions has resulted in numerous electric vehicle protocols, some of which overlap significantly. The following diagram illustrates the multiparty communication landscape where it is common to see multiple pathways to communicate the same set of data.



5. RECOMMENDATIONS

As noted previously, additional work should be undertaken to both validate and provide further details on the protocols discussed in this paper. Once that step is complete, information in this report can be used as a starting point to guide the industry towards standards that are most likely to enable the energy transition.

Select the Foundational Information Model. The entities with the largest role in maintaining the electricity grid, that is distribution system operators and transmission system operators, should agree on a common model for exchanging information in all of the eleven data domains documented in this report from the candidates available: the CIM, the IEC 61850 Model, and the MultiSpeak Model. This decision should be made with other stakeholders providing perspectives, most critically the market operators who currently play large roles and will likely play larger roles in enrolling customer energy services for grid services. The selection of the model is relatively easy: the CIM covers all of the data domains and is scalable to meet the needs of any grid or market operator. The challenge is moving the industry in this direction through education and knowledge sharing and eventually through policy mandates, much as Europe has done over the last 20 years.

Select the Communication Model for Virtual Grid Resources. Like the information model choice that will guide much of the internal utility application communications, the virtual resource communication protocol is the major interface to bring virtualized grid edge devices into the grid view and, in some cases, control. The candidates are the implementations of the information models, namely the IEC 62746-4 for the CIM and IEC 61850-7-420 for IEC 61850, plus OpenADR and IEEE 2030.5. The decision-making process is more challenging here than in the case of the information model; although there is a clear benefit to selecting the CIM-based protocol (IEC 62746-4) to provide a more seamless transition between the utilities and the new players in the distributed marketplace for energy. That said, other protocols have strengths and should not be overlooked such as industry support, implementation successes, and historical regulatory support.

Select Appropriate Device-Focused Communication Models. This paper divides grid-edge devices into three groups: those primarily designed for energy production and storage, those related for flexible loads, and those related to electric vehicles. Conceivably, smaller categories might be necessary. In any case, standards need to be tailored to devices in these groups and agreement on the standards present the need for traditional electric industry players to work with manufacturers that might not be historically involved in the space, such as the suppliers of HVAC equipment, lighting, and automation systems, consumer, fleet, and commercial transportation.

APPENDIX: INFORMATION LAYERS

One of the concepts that makes an "apples-to-apples" comparison of communication standards difficult is that not every standard is, in fact, an "apple." The ISO/IEC 7498 standard is the "Open Systems Interconnection–Basic Reference Model"[1], or OSI Model, and describes communications by placing them into abstract layers. The OSI Model is especially useful in low-level communication classification but does not provide a way to describe how data that is exchanged is defined or how elements interrelate.

In 2008, the GridWise Architecture Council published the "Interoperability Context-Setting Framework"[2], essentially pushing the subtleties of the OSI models into a few lower levels and introducing multiple layers above to describe semantics, process, and policy information. Although helpful, this model is not the best for the comparison that is necessary for this work, as the communication standards examined here are primarily in the "middle" of the GWAC classification system. Therefore, this comparison uses the SGAM, published through the IEC's System Committee for Smart Energy,[3] as it provides a simpler breakdown of the classification layers that are more aligned with the "fuzzy" nature of protocols today.

SGAM Layer	GWAC Layer	OSI Stack
Business	Economic/Regulatory Policy	
	Business Objectives	
Function	Business Procedure	
Information	Business Context	
	Semantic Understanding	
Communication	Syntactic Interoperability	Application
		Presentation
	Network Interoperability	Session
		Transport
		Network
Component	Basic Connectivity	Data Link
		Physical

All communication standards described in this analysis cover the "**communication**" layer. Most allow for an IP-based "component" implementation; however, other protocols are noted when available or required. Importantly, the most robust communication models also have an associated "**information**" layer that describes the semantic understanding of the data being exchanged. Going beyond a simple glossary of definitions and often employing a modeling language such as Unified Modeling Language (UML), the semantic understanding of a standard defines the meaning behind the data exchange inherent in the modeling itself, even if not explicitly defined a single message exchange.

[1] https://www.iso.org/standard/20269.html.
[2] http://www.gridwiseac.org/pdfs/interopframework_v1_1.pdf.
[3] https://www.iec.ch/dyn/www/f?p=103:252:0::::FSP_ORG_ID,FSP_LANG_ID:11825,25.