

Energy Services Interface (ESI)

From Theory to Practice

DOE Grid Modernization Laboratory Consortium

**GMLC 1.4.1: Standards & Test Procedures for
Interconnection & Interoperability**

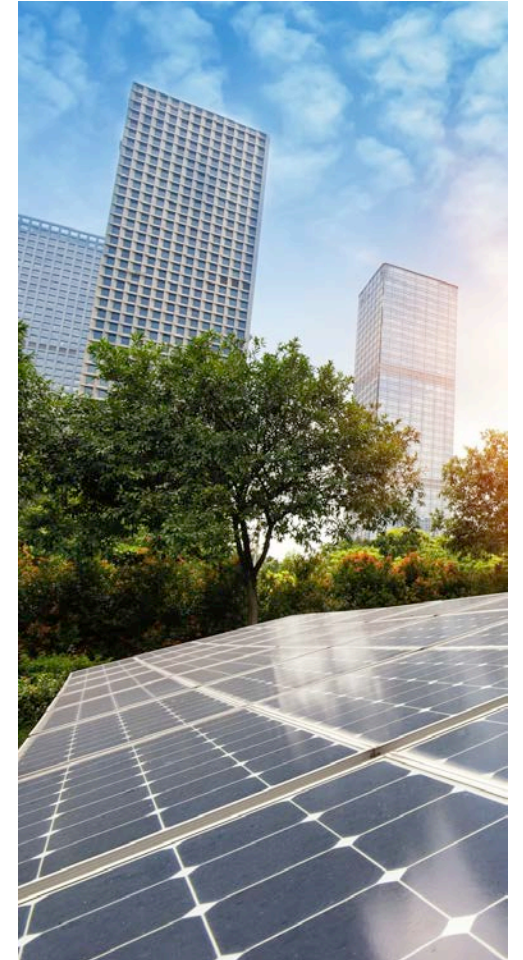
LBL: Mary Ann Piette (PI), Peter Schwartz (Co-PI), Rich Brown, Janie Page

PNNL: Paul Ehrlich

May 14, 2018

Presentation Topics

- ▶ Distributed Energy Resources (DERs) & Grid Modernization
- ▶ Energy Services Interface (ESI)
- ▶ State of ESI
- ▶ Standards Associated with ESI
- ▶ ESI Testing
- ▶ Stakeholder Feedback



GMLC 1.4.1 Standards & Test Procedures for Interconnection & Interoperability



Project Description

- Accelerate development & validation of interconnection & interoperability standards
- Ensure cross-technology compatibility & harmonization of requirements

Value Proposition

- Improve advanced generation & storage assets coordination
- Enable expansion of markets for key devices
- Eliminate barriers that may be addressed by improved standards

Project Objectives

- ✓ Interconnection & interoperability gap analysis & prioritization of high impact areas
- ✓ Standards coordination & harmonization for key grid services & devices
- ✓ Develop new testing procedures

GMLC 1.4.1 Standards & Test Procedures for Interconnection & Interoperability



Project Team

- David Narang NREL (Lab PI)
- Peter Schwartz LBNL (Lab +1)
- Theodore Bohn ANL
- Manish Mohanpurkar INL
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Project Team & Roles

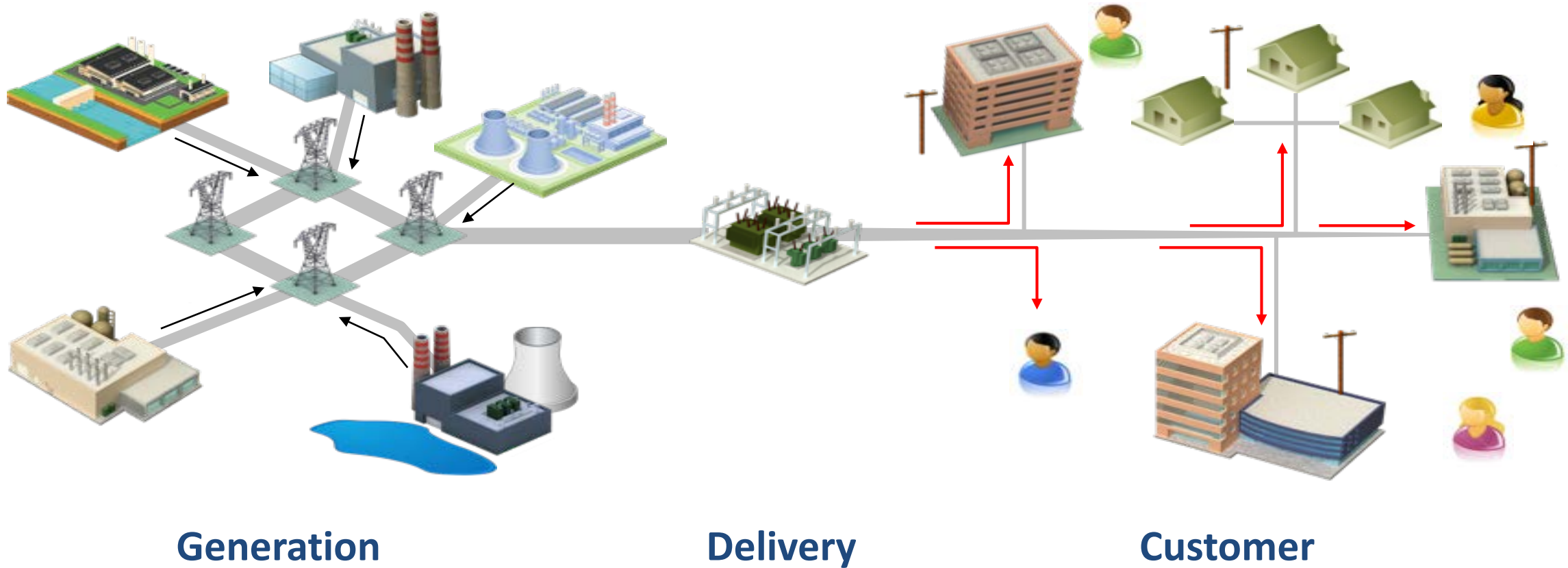
- **NREL** – Lead, Inverter-based generation
- **LBNL** – Co-Lead, Responsive loads
- **PNNL** – Controllable loads
- **ANL** – Automotive applications
- **SNL** – Inverter-based generation
- **ORNL** – Microgrids
- **INL** – Microgrids

DERs & Grid Modernization



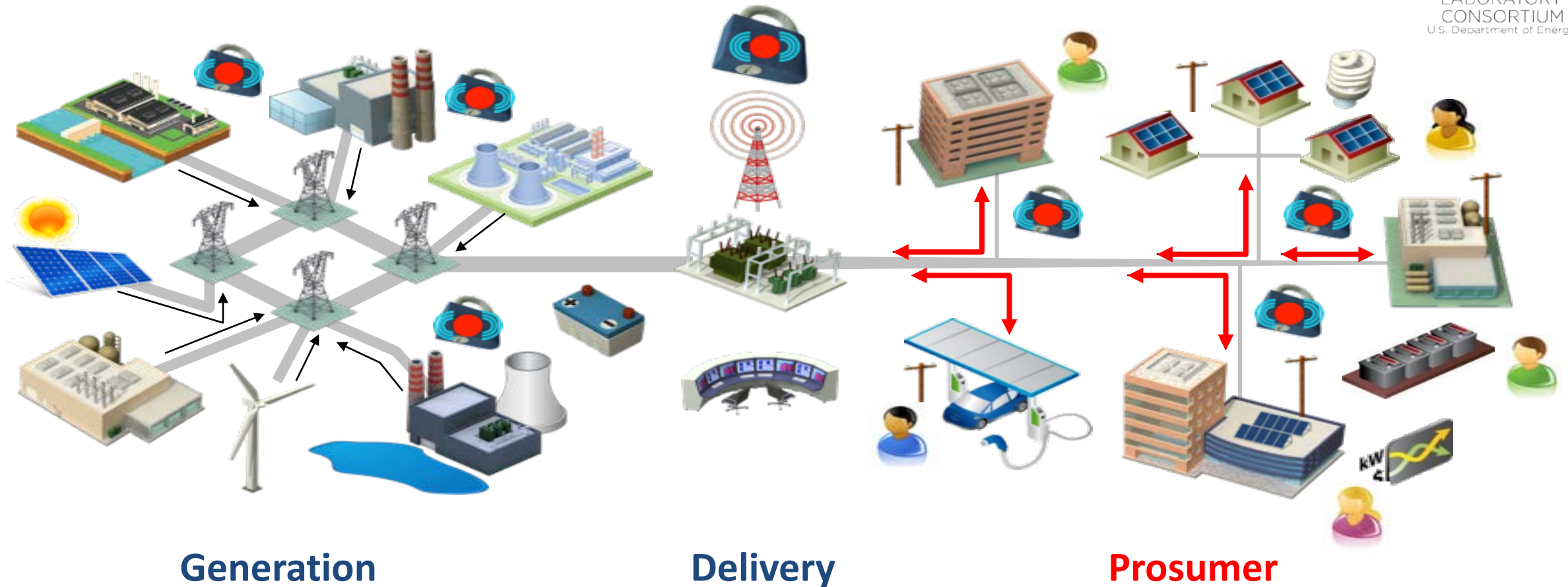
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The Grid of the Past



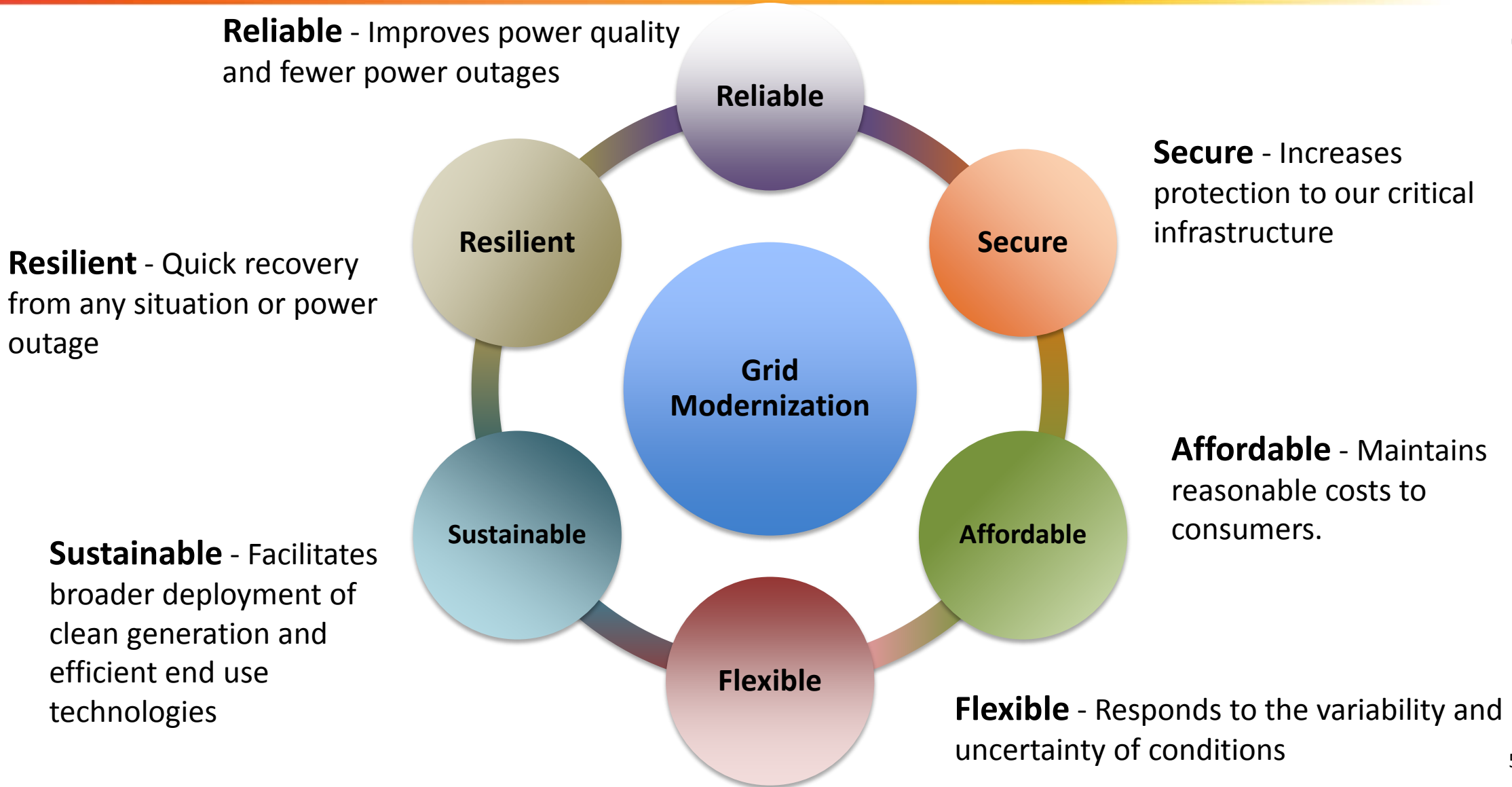
Source: EPRI, 2009

The Grid of the Future



Source: EPRI, 2009

Key Future Grid Attributes



Modern Grid Vision

- ▶ New technologies for generating, storing & using power require new grid operating paradigm
 - Distributed, dynamic, coordinated, automated grid operation
 - Improve reliability & reduce cost & environmental impact of providing electric power
- ▶ Distributed Energy Resources (DERs): assets at grid edge (usually customer-owned) providing energy services to customers & the grid
- ▶ Energy Services: energy production, available capacity, consumption & storage as well as ancillary services (AS) needed to maintain normal grid operations
- ▶ To realize the modern grid, U.S. DOE launched an aggressive five-year, Grid Modernization Initiative that:
 - Formed Grid Modernization Lab Consortium (GMLC) with core scientific abilities & regional outreach to develop requisite technologies
 - Aligns its technology Offices' existing base activities into an integrated Multi-Year Program Plan (MYPP)
 - Developed new activities to fill major gaps in existing base

Communication Essential to Modern Grid

- ▶ Coordinating diverse, distributed modern grid assets requires frequent communication:
 - Grid operators may tell DERs about grid state, power prices & request/command desired behavior
 - DERs may tell grid operators about DER state & capabilities
 - Free information flow is essential to achieving goals of dynamic, automated power system
- ▶ Modern communication networks reduce cost & complexity through standard *Interfaces*
 - Decompose system into loosely coupled components that expose only essential internal information through interface
 - Interface defines standard data & methods for interacting with a given system component
 - Same principles used in design of Internet
 - Allows integration & *Interoperability* of components of different types, vendors, etc.
- ▶ *Interoperability*: *Capability of two or more networks, systems, devices, applications, or components to externally exchange & readily use information securely & effectively. (IEEE 2030-2011)*

What Do the Grid & Buildings Want from Each Other?



What does grid want from buildings?

- ▶ Reduce peak demand
 - E.g., peak demand charge
- ▶ Help reduce operating costs
 - E.g., time varying price of electricity
- ▶ Rapid, short-term response to help managing renewables
 - I.e., Smooth renewable variability
- ▶ Stabilize the grid in an emergency
 - I.e., prioritize load to balance available generation
- ▶ 3rd-party investment

What do buildings want from grid?

- ▶ Incentive for responding
 - I.e, flexibility, planning is rewarded
- ▶ Low electric rates
 - I.e., average price of service goes down
- ▶ Choice of energy products to fit desires
 - E.g., support integration of renewables
- ▶ Reliability/resiliency value
 - I.e., few outages, quick recovery
- ▶ 3rd-party investment in energy efficiency & flexibility technology

**Alignment of objectives & capabilities
on both sides drives mutual benefit**

GMLC Interoperability Efforts



- ▶ To further grid interoperability, GMLC has 2 lab teams working on topic
- ▶ Strategic Interoperability (GMLC project 1.2.2)
 - Objectives: Interoperability – Overall strategy & vision
 - Approach: Establish a strategic vision for interoperability; Measure state of interoperability in technical domains; Identify gaps & develop roadmaps methodology; Ensure industry engagement
- ▶ Standards & Test Procedures for Interoperability & Interconnection (GMLC Project 1.4.1)
 - Objectives: overarching goal is to help develop & validate interconnection & interoperability standards for existing & new electrical generation, storage & loads that ensures cross technology compatibility, harmonization of jurisdictional requirements & ultimately enabling high deployment levels without compromising grid reliability, safety or security
 - Approach: National labs will develop an improved cycle of coordination that includes lab development & validation as well as working with industry through standards development organizations (SDOs) to accelerate establishment & revision of standards & test procedures for grid connected devices & systems.



Questions?

ESI Definition

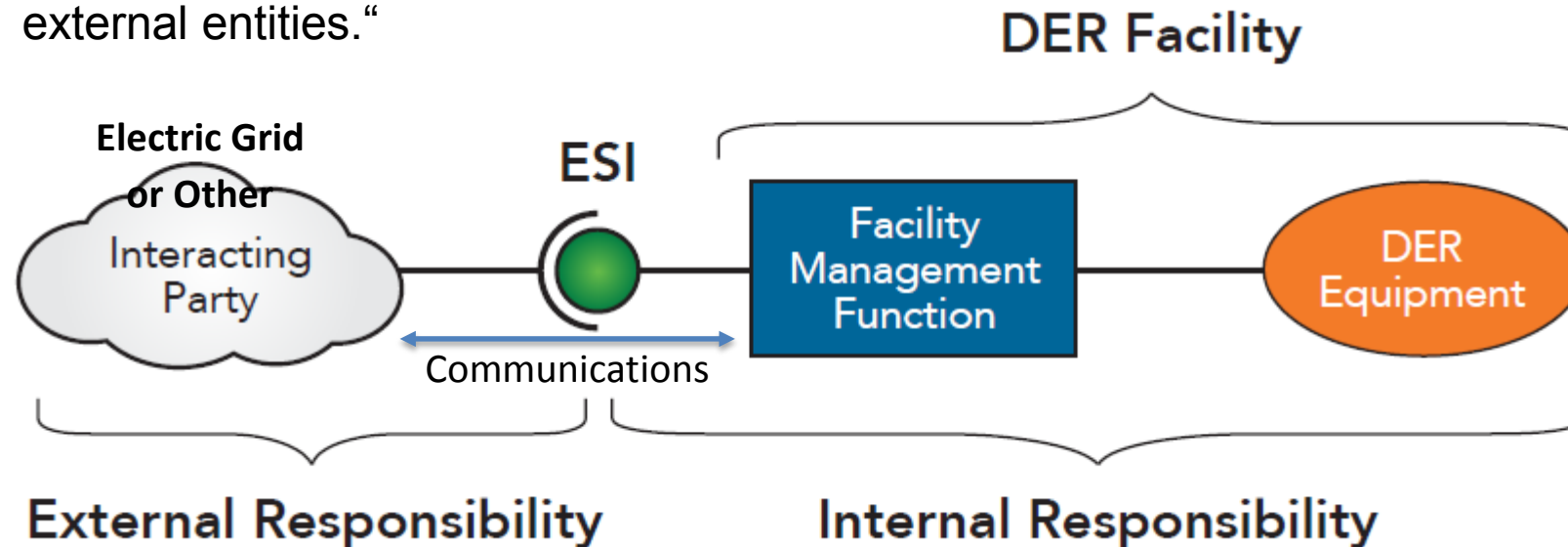


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Energy Services Interface (ESI) Vision for DER

Given the communication importance in the modern grid, the communication interface between the Grid & any DER has been generalized as an *Energy Services Interface (ESI)*

"An ESI is a bi-directional, [*service-oriented*], logical interface that supports the secure communication of information between entities inside & entities outside of a customer boundary to facilitate various energy interactions between electrical loads, storage, & generation within customer facilities & external entities."



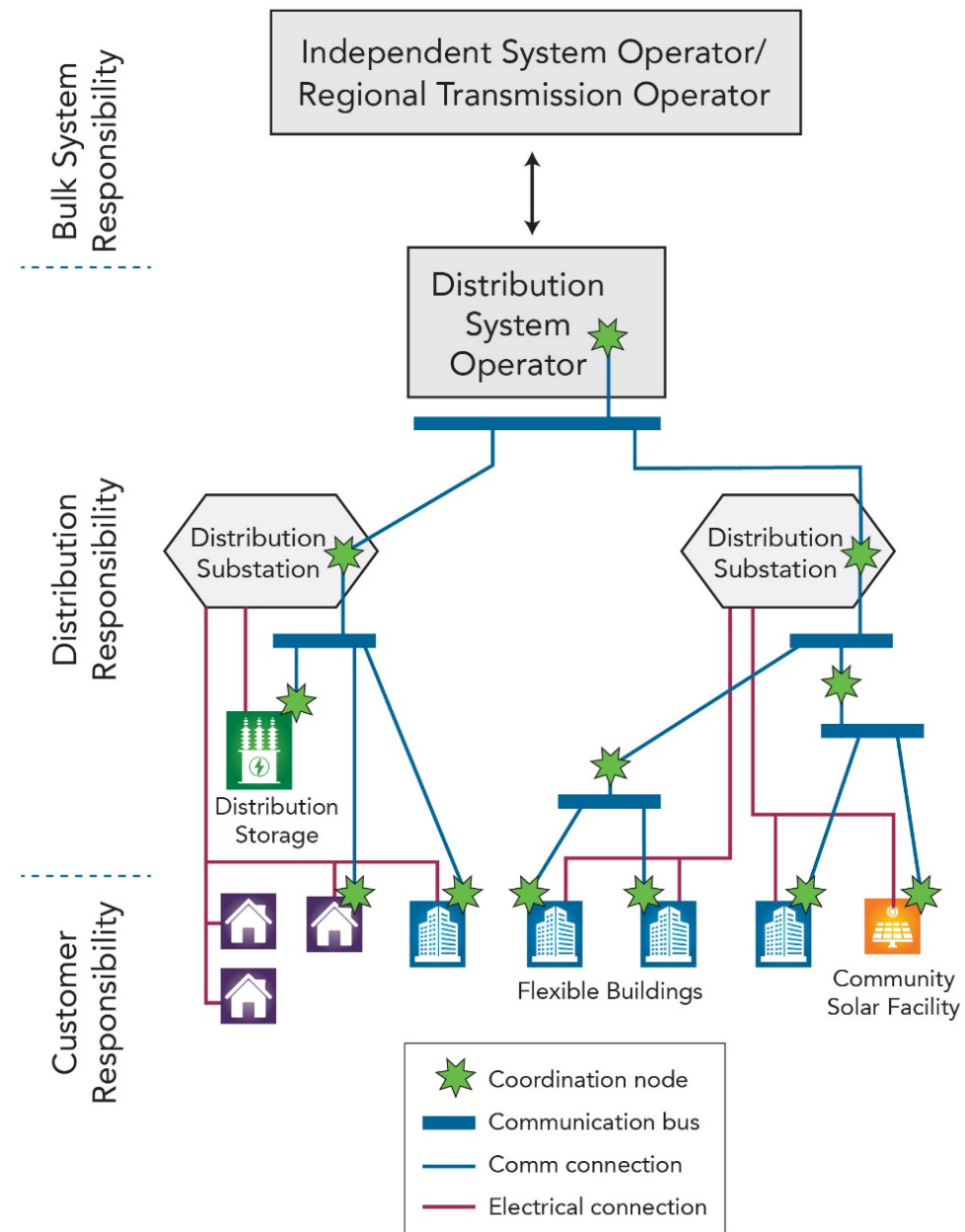
Hardin et al: http://www.gridwiseac.org/pdfs/forum_papers11/hardin_paper_gi11.pdf . Note, the words “service-oriented” are added to the definition here.

An Architectural Context for ESI

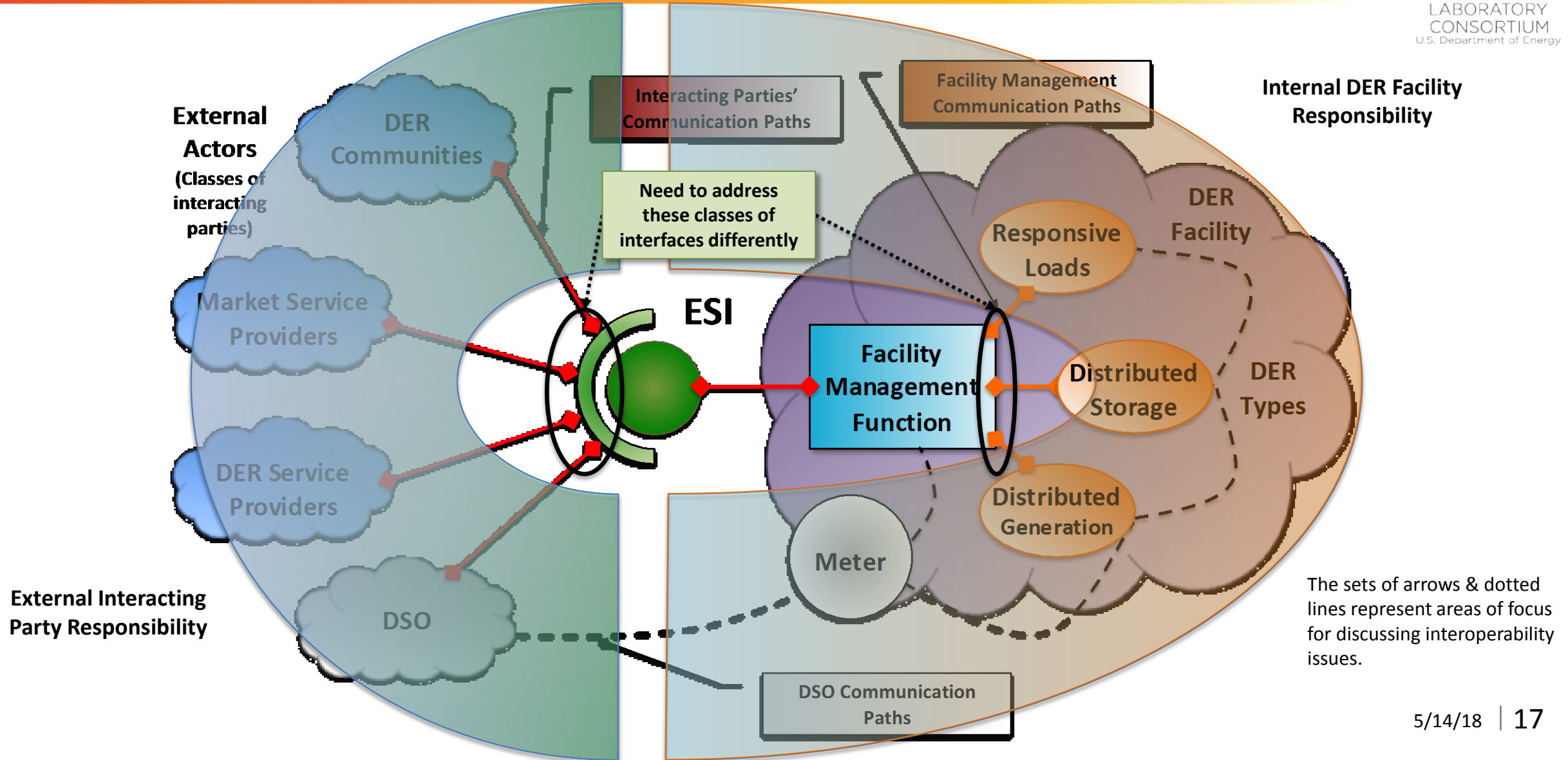
- ▶ **Architecture** describes system concepts, structure, and organizing principles
- ▶ **Interoperability** drives simplicity of system integration
- ▶ Example: Architecture prescribes layered decomposition coordination framework, which defines interface points for interoperability
- ▶ The ESI concept respects the boundaries of responsibilities at the grid & DER facility interface

See Interop Strategic Vision GMLC whitepaper

<https://gridmod.labworks.org/resources/interoperability-strategic-vision>



DER Facility Conceptual Model



Key ESI Elements

- ▶ ESI facilitates automated (machine-to-machine) communications to support business practices; a service-oriented interface defining **what** is needed when, not **how** to deliver it
- ▶ ESI includes functionality to:
 - Define services (e.g., what service is the grid/DER requesting/offering and what is the performance requirement?)
 - Qualify & register for a service
 - Measure & validate performance
- ▶ ESI can be described by a functional specification focused on messaging
 - Communication conduit between grid & customer-sited equipment
 - Does not receive direct control signals nor contain control logic
 - Defined independently of implementation details such as data storage, etc.
- ▶ Key question: How someone would spec an ESI in the future & what features would it possess?
 - Foundational stepping stones building upon NIST efforts rather than ‘re-creating the wheel’
 - Autonomous control; autonomous grid services with different needs

ESI: Anticipated Benefits



ESI allows sites that choose to participate in grid services, a way to connect via consistent interface that:

- ▶ **Creates service-oriented architecture:** grid expresses service request; DERs decide how service is provided
- ▶ Improves **interoperability**; interoperable feature set
- ▶ Standard interface permits grid communication to **evolve independent** of control in buildings
- ▶ **Improves responsive loads' & grid performance** thru network optimization, unambiguous communication & transaction support that **improves resilience, capacity & intermittent resources' integration**
- ▶ **Protects** owners' assets & controls service levels
- ▶ Enables **open specifications** use in buildings codes & standards
- ▶ Supports more **open market competition among resources**
- ▶ Improves utility **DER procurement**
- ▶ **Reduces cost** for implementing services



Questions?

Status of ESI



Peter Schwartz, LBNL

Buildings & Grid Today

▶ Market is slowly evolving

- Utilities have been doing “DR” for capacity for decades (13.6 GW of capacity enrolled)
- Little in market today for services outside of capacity

▶ Most of market is fairly simplistic

- Residential is 40% of capacity (5.44 GW)
 - 53% of residential is an “AC Switch” that is radio controlled relay to shut off A/C (2.88 GW)
 - 4% is radio controlled relay for water heaters (0.22 GW)
 - 42% is through “smart thermostats” (2.28 GW)
- Commercial is 60% of capacity (8.16 GW)
 - 84% of capacity is done by calls, e-mail & fax (customer initiated) (6.85 GW)
 - Remaining 16% is fully automated using services such as OpenADR (1.31 GW)

Source: SEPA “2017 Demand Response Snapshot” report

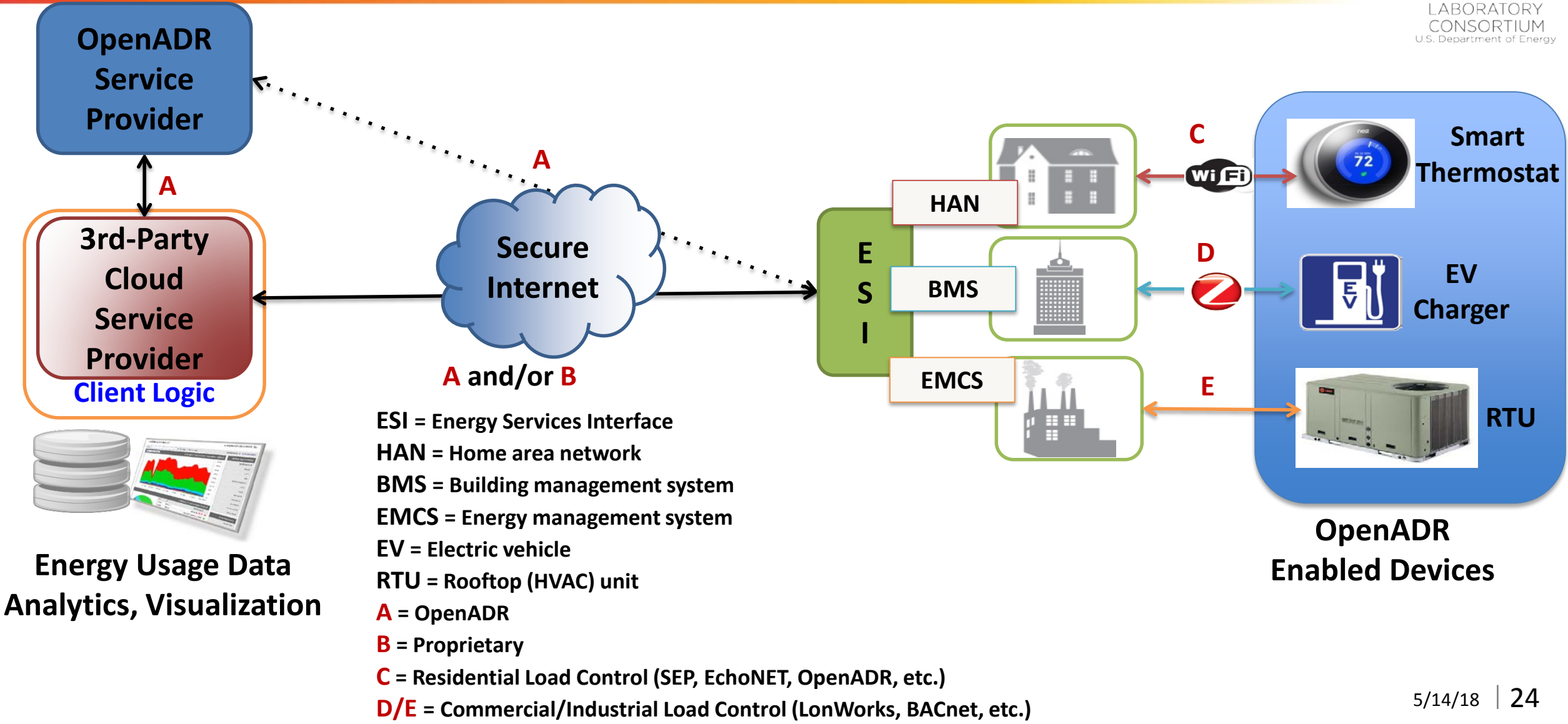
ESI Implementation Options

- ▶ **Proprietary ESI** – Many ESIs today do not use open standards
 - Example – direct air conditioner load control using vendor-specific broadcast protocol
- ▶ **Basic/Hybrid ESI** – mixed open & proprietary standards
 - Example – Niagara Tridium JACE Gateway – links grid signals via OpenADR to local BACnet controls
 - Example – WIFI thermostats with–OpenADR cloud VEN
- ▶ **Standard ESI** – extensive use of standards
 - Work is underway ASHRAE & elsewhere to create new standards for ESIs
 - Example – BACnet Smart Grid Working Group working to link Facility Smart Grid Information Model in BACnet Web Services.

While any of these is possible, Standard ESI is preferred because it offers more flexibility.

Note that some existing devices (JACE box, thermostats) have ESI functionality in addition to control logic, sensors, etc.

Energy System Interface (ESI) Types



ESI Exists Now

Needs	Grid Services	ESI	Commercial Building	Residential Building
Now	<ul style="list-style-type: none"> ▪ Used when there is inadequate peak capacity at transmission level ▪ Generally occurs for less than 100 hours/year 	<ul style="list-style-type: none"> ▪ Automated systems use proprietary gateway or OpenADR client ▪ Manual, AC switch or thermostat (currently lacking ESI – direct load control) 	<ul style="list-style-type: none"> ▪ 84% is manual in response to an e-mail, page or call ▪ 16% is automated systems are proprietary or Open ADR & have an ESI 	<ul style="list-style-type: none"> ▪ AC Switch or thermostat ▪ Limited OpenADR capability (offered via Cloud)

ESI Future; Expansion Needed



Needs	Grid Services	ESI	Commercial Building	Residential Building
Future	<ul style="list-style-type: none"> ▪ Extended to new services for reverse peak, voltage, frequency, ramping, etc. ▪ Events could occur continuously ▪ Should select most cost-effective solution & have a method to validate performance (i.e., transactive model) 	<ul style="list-style-type: none"> ▪ Open ESI model for reduced cost & complexity to deploy ▪ ESI should work for buildings, inverters, EVSE, etc. ▪ Needs to support transactive including bidding, dispatching, & validation 	<ul style="list-style-type: none"> ▪ Medium to large commercial bldgs. - Open ESI would be part of, or connected to, BAS or other controls systems (i.e., lighting) 	<ul style="list-style-type: none"> ▪ Small commercial likely to follow residential model ▪ 3 potential ESI models: <ul style="list-style-type: none"> • Cloud-based aggregator (i.e., NEST) • HEM system that is on site & has an ESI • Appliance-based connection using a plug standard such as CTA 20145



Questions?

Issues: Standards Associated with ESIs



Paul Ehrlich, PNNL

Existing Standards Related to ESI

- ▶ **SEP2.0/IEEE 2030.5:** This standard defines mechanisms for **exchanging application messages**, the exact messages exchanged including error messages, & security features used to protect application messages. With respect to OSI network model, this standard is built using four-layer Internet stack model.
- ▶ **OpenADR2.0A/B:** OpenADR is communications data model, along with transport & security mechanisms, which **facilitate information exchange between two end-points**, electricity service provider & customer.
 - Designed to facilitate automated DR actions at customer location, whether it involves electric load shedding or shifting.
 - Designed to provide continuous dynamic price signals such as hourly day-ahead or day-of real time pricing.
 - Interacts with facility control systems that are pre-programmed to take action based on DR signal, enabling a response to DR event or price to be fully automated with no manual intervention.
- ▶ **CTA 2045-A:** Modular Communications Interface (MCI) for Energy Management standard released by Consumer Technology Association Jan. 3, 2018.
 - Specifies MCI to facilitate communications with **residential devices** for applications such as energy management.
 - MCI provides standard hardware & communications interface for energy mgt. signals & messages to reach devices.
 - Such devices may include an energy mgt. hub, an energy mgt. controller, an energy mgt. agent, residential gateway, ESI, a sensor, a thermostat, an appliance, or other consumer products.

SEP2.0/IEEE 2030.5 Focuses on Messages to Devices



- ▶ Consumer device integration into smart grid
- ▶ Serves two general purposes:
 - Inform consumer (e.g., energy usage, pricing)
 - Request actions to assist grid (e.g., thermostat changes)
- ▶ Focus on communications related to: efficiency, usage, price, DR, load control & service provider messages
- ▶ An IoT “profile” originally part of the ZigBee standard
- ▶ Application messages have been abstracted; no longer tied to a single networking stack
- ▶ Optimized for embedded & battery-powered devices
- ▶ Encourages vast ecosystem that can incorporate devices already in field

High-Level SEP2.0/IEEE 2030.5 Design

- ▶ Divided into “Function Sets” – independent sets of functionality
 - Price communication
 - DR & load control
 - Energy usage information (e.g., meter data)
 - DERs
 - Service provider messaging
 - Prepayment metering
 - Billing communication
 - File download/update
- ▶ Any device can be a server and/or client for a function set
 - Servers provide data, clients use data
 - Can have multiple servers for function set – allows for multiple service providers
 - If desired, clients can be assigned to servers

OpenADR Provides ESI Communications from Grid to Loads



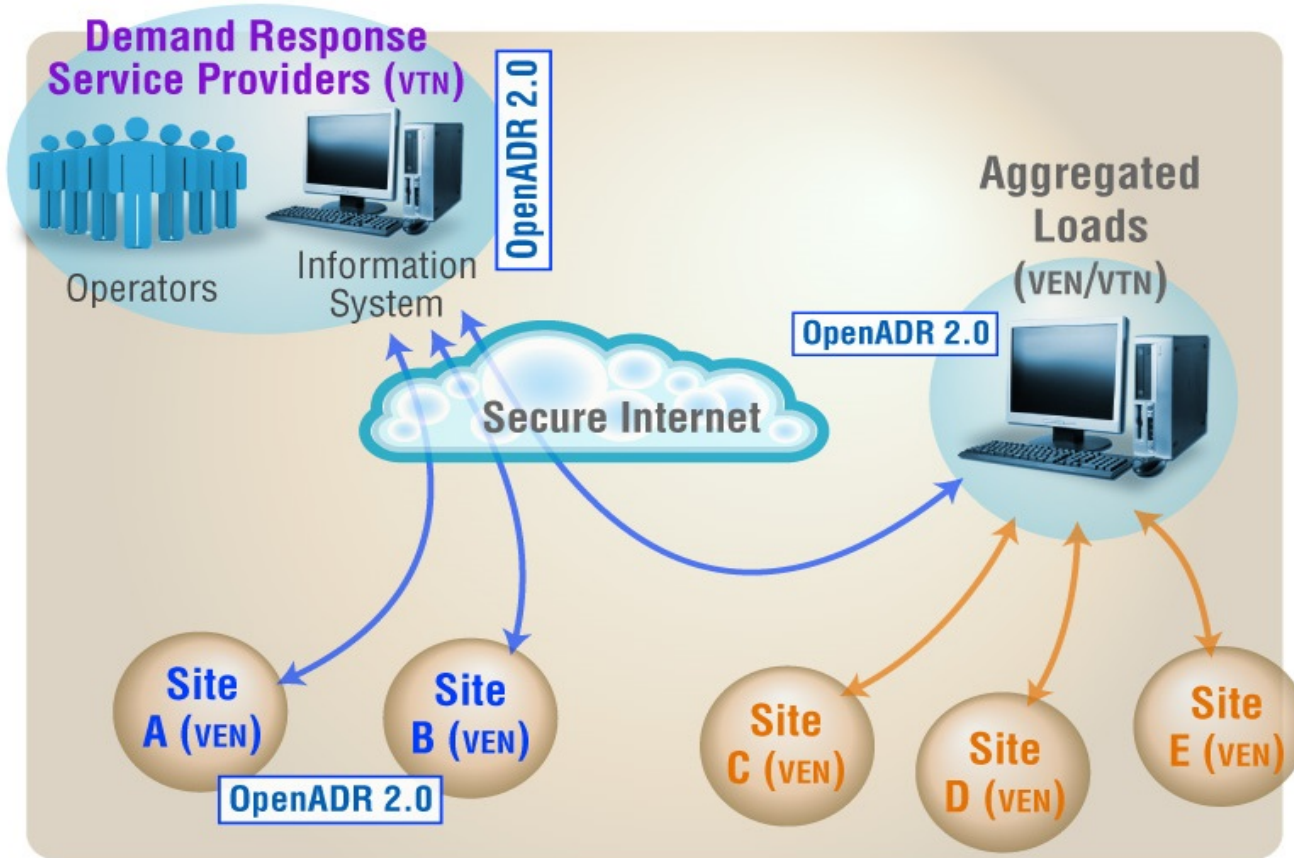
- ▶ Open standards
- ▶ Flexible VTN & VEN client-server architecture
 - VEN can act as VTN for aggregators
- ▶ Supports communications for many larger utilities' wide variety of existing DR programs
- ▶ Easily extended to support new DR & DER structures

NOTE:

VTN = Virtual top node

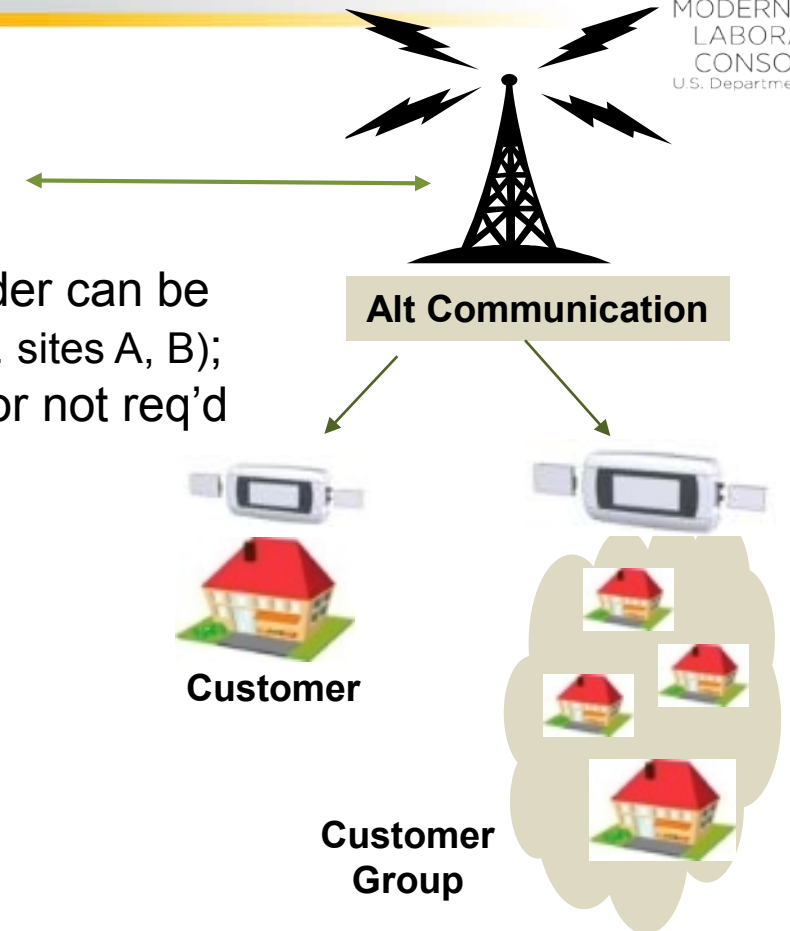
VEN = Virtual end node

OpenADR Offers Flexible Architectures



Commercial & Industrial

DR provider can be utility (e.g. sites A, B); aggregator not req'd

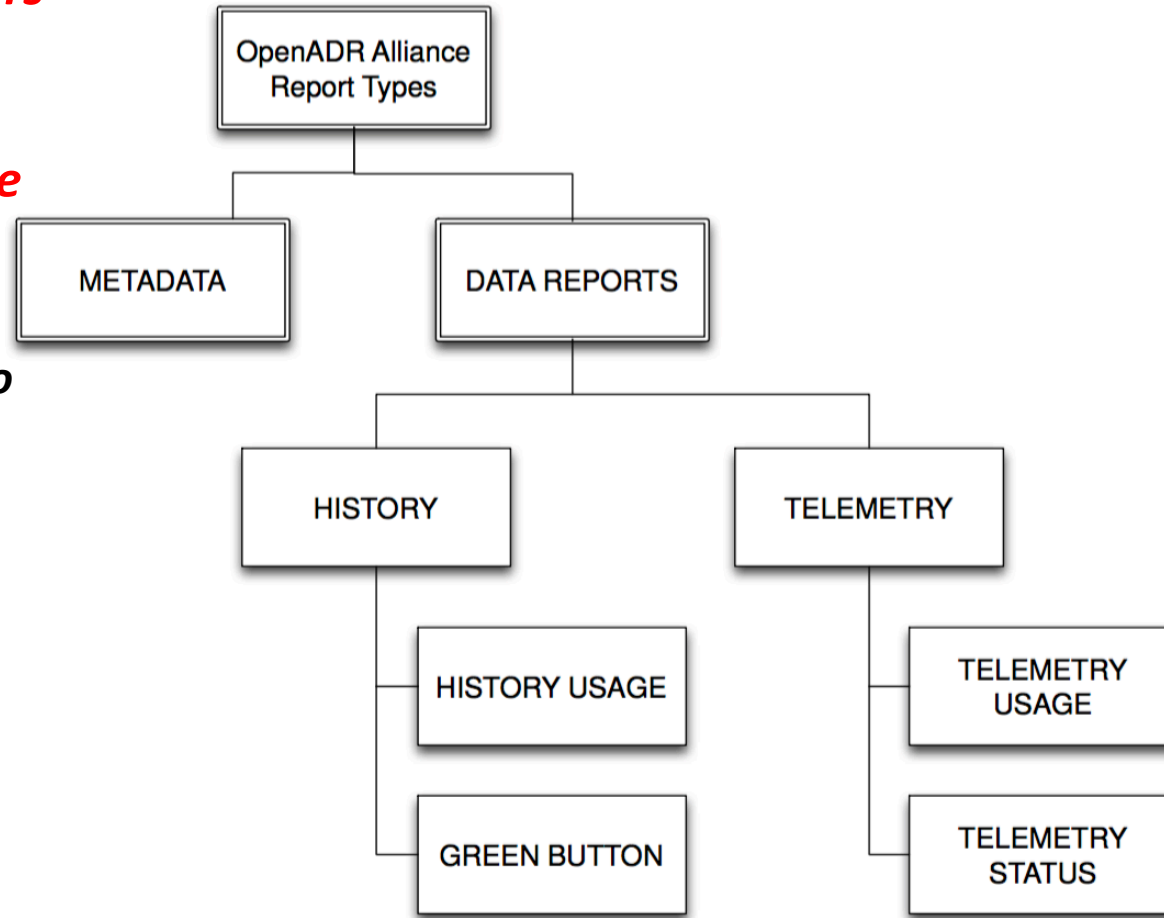


Residential, Small Commercial

What Information Does OpenADR 2.0 Convey?

Currently, OpenADR offers ESI elements. Research needs to confirm these elements & answer these questions:

- *To what extent can OpenADR be extended to cover anticipated future ESI needs?*
- *Are there any inherent limitations?*



OpenADR Targets Pre-Defined DER Types

- Thermostat
- Strip_Heater
- Baseboard_Heater
- Water_Heater
- Pool_Pump
- Sauna
- Hot_tub
- Smart_Appliance
- Irrigation_Pump
- Managed_Commercial_and_Industrial_Loads
- Simple_Residential_On_Off_Loads
- Exterior_Lighting
- Interior_Lighting
- Electric_Vehicle
- Generation_Systems
- Load_Control_Switch
- Smart_Inverter
- EVSE
- RESU
- Energy_Management_System
- Smart_Energy_Module
- Storage
- x-{user Defined}



Questions?

ESI Testing



Rich Brown, LBNL



ESI Testing Standards – Responsive Loads

Are existing SEP2.0/IEEE 2030.5 or OpenADR sufficient for current ESI needs?

Can they be extended to cover new needs of ESI with smart grid?

Functions: bid, deliver, validate, audit/confirm

- ▶ **CONNECTION:** confirmation of connection; confirmation of ability to send/receive signals from other side
- ▶ **SECURITY:** immune from hacking; provides a consistent, reliable interface over extended time; messages received as sent (not corrupted)
- ▶ **PARAMETERS:** protocol contains necessary and sufficient set of commands to adequately convey anticipated grid needs; protocol provides basis for determining if load responded and in what way
- ▶ **TIMELY:** verify latency and consistency of signal across interface from grid to load and separately from load to grid
- ▶ **OPT OUT:** if load explicitly opts out of an event, is grid appropriately notified?

Testing Needed

- ▶ Test objectives: determine if OpenADR2.0b or IEEE 2030.5 contains sufficient communications options to convey all likely grid needs to responsive loads as well as load responses back to grid, when needed. Responsive load can be modeled with these options:
 - BACnet & ModBus described communications within in larger responsive loads
 - SEP2.0 is prescriptive on-premise communications
 - ANSI/CTA 2045 describes a standardized form factor for providing communications
 - oBIX aims to find a standard set of descriptions for use in data acquisition & control systems in responsive loads

Domain/ Function	End-Use	Applicable Standards
Grid/ Grid Signaling	All	OpenADR (2.0a & 2.0b), IEEE 2030.5 (SEP 2.0)
Customer/ End-use Control	HVAC	ASHRAE 135 (BACnet), oBIX, IEC 14908-1 (LonTalk)
	Lighting	BACnet
	Water Heaters and other appliances	BACnet, CTA-2045

ESI Testing Types Needed; **Who Decides?**

- ▶ Evaluate advanced grid services' performance metrics in ESI architectures
 - Inertia
 - Voltage regulation
 - Load-following
 - Reverse DR
- ▶ Push vs. Pull system
- ▶ Latency
- ▶ Data reporting
- ▶ Response load capabilities
 - Sustained response (e.g., thermal)
 - Fast response (e.g., lighting)
 - Storage integration & capabilities
 - Give/take load expectations & limitations
 - Intermittencies
 - Synergies between responsive loads

Stakeholder Feedback



What is Needed to Support Future Use of ESI?

- ▶ What energy services need to be supported by the ESI?
- ▶ What is appropriate interaction between grid & DERs?
 - What information is needed by grid operators? By DERs?
 - Can a DER opt out as a responsive load as currently many do?
 - What are expectations of an opted-out entity?
- ▶ Key ESI elements: Bid, Deliver, Validate, Confirm – Are these adequate?
- ▶ What unambiguous use cases can cover needed ESI functions most effectively?
 - Prices/Bids
 - Contextual information
 - Time – actual or relative (e.g., “must respond by” time or needed duration of load change)
 - Magnitude (including +/-) of energy/capacity change
 - Location, if needed
 - Penalties, if any, for non-performance
- ▶ How do we best engage industry to work with us to fill the voids/gaps?
- ▶ What existing standards point to an ESI & what additional standards are required?
- ▶ What do we want to get out of the webinar or stakeholder engagement, data? For what use? Timing of solutions? Near-term 3-5 years, use case issues with today’s standards

ESI Research Gaps

- ▶ What is full set of grid services an ESI must support? (Both now & anticipated in future)
- ▶ Will enhanced interoperability reduce costs & improve responsive load capabilities? What is goal?
- ▶ Does ESI enforce single data model at interface – or does it create a mapping between different protocols on either side of the ESI?
- ▶ For what anticipated future grid services can an ESI provide support?
- ▶ What data models are needed on either side of the ESI? That is, what information needs to be conveyed openly & what operations on each side are considered proprietary? Where is the line to define necessary and sufficient interactions?
- ▶ What functional tests & performance specs are needed (to demonstrate and support functionality)?
- ▶ ESI role, if any, in market interactions & bidding

References

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- ▶ OpenADR2.0 profile specification 2.0b, version 1.0, 2013.
- ▶ Simpson, R., “IEEE 2030.5 Overview and Update for GMLC”, December 2017.



**Thanks for
Participating**