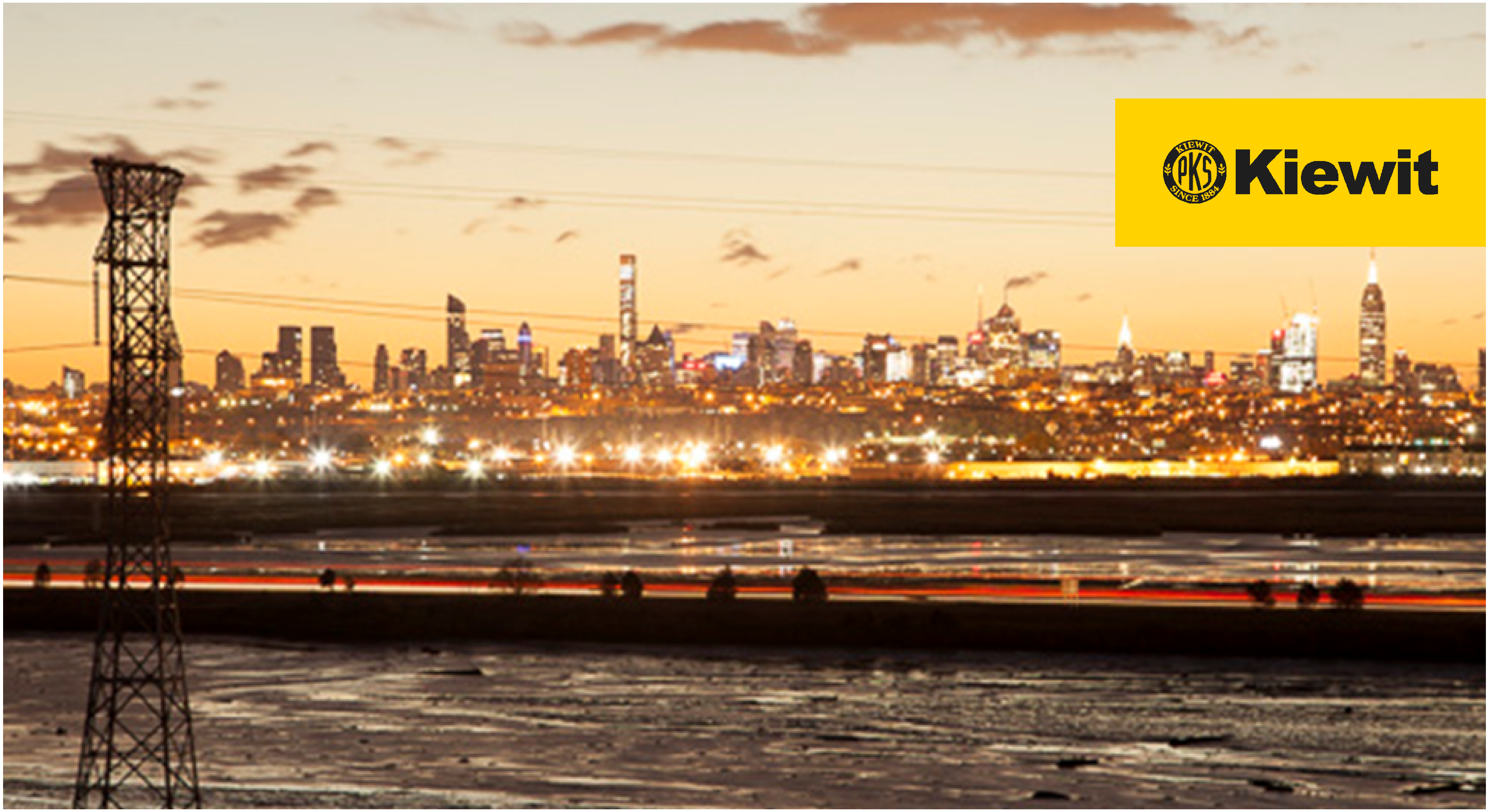


GRID REVOLUTION: A COMMUNICATIONS PERSPECTIVE

Matthew Klinker – Director, Grid Modernization, Kiewit Engineering Group Inc.

OUTLINE

POWER GRID

GRID CONTROL AND COMMUNICATION

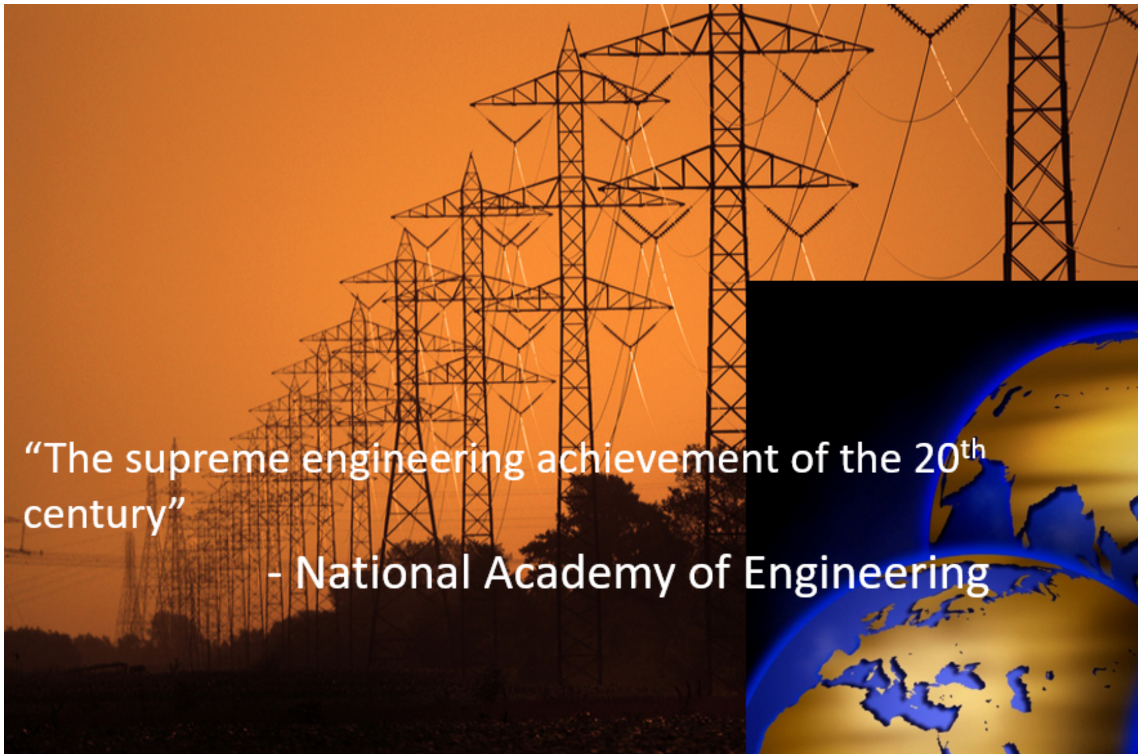
COMMUNICATION TOOLBOX

GOING FORWARD

QUESTIONS AND ANSWERS

THE POWER GRID

One of the most complex infrastructures ever built



"The supreme engineering achievement of the 20th century"

- National Academy of Engineering

ENERGY SOURCES IN THE U.S.

Source: U.S. Energy Information Administration

U.S. utility-scale electricity generation by source, amount, and share of total in 2019

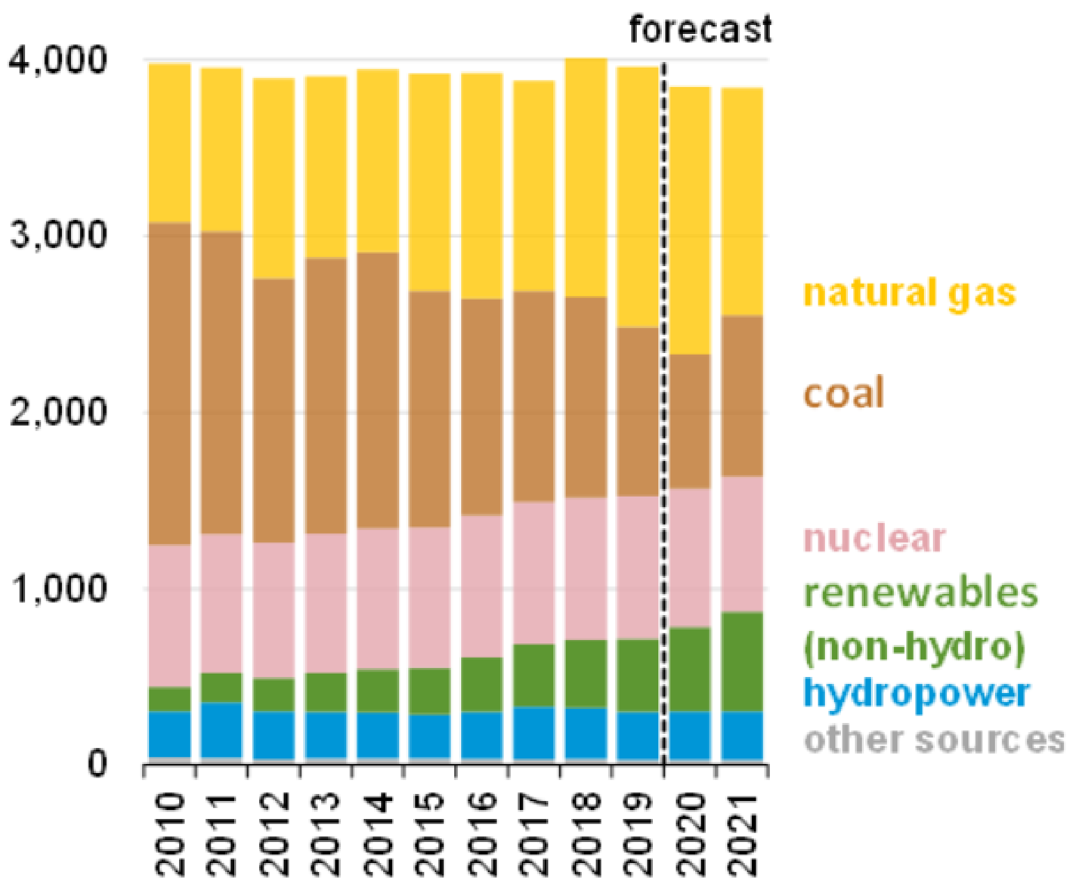
Energy source	Billion kWh	Share of total
Total - all sources	4,118	
Fossil fuels (total)	2,580	62.70%
Nuclear	809	19.70%
Renewables (total)	720	17.50%
Pumped storage hydropower[3]	-5	-0.10%
Other sources[3]	13	0.30%

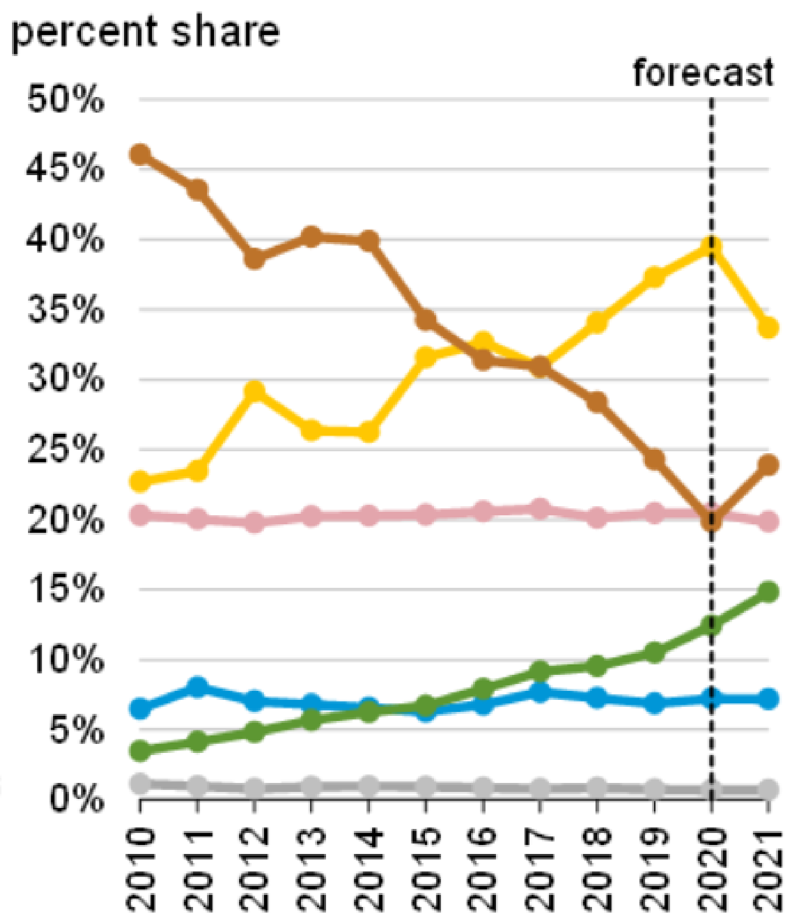
[3] Pumped storage hydroelectricity generation is negative because most pumped storage electricity generation facilities use more electricity than they produce on an annual basis. Most pumped storage systems use fossil fuels or nuclear energy for pumping water to the storage component of the system.

SHORT-TERM OUTLOOK

Source: U.S. Energy Information Administration

U.S. Electricity Generation by Fuel, All Sectors
Billion kilowatt-hours





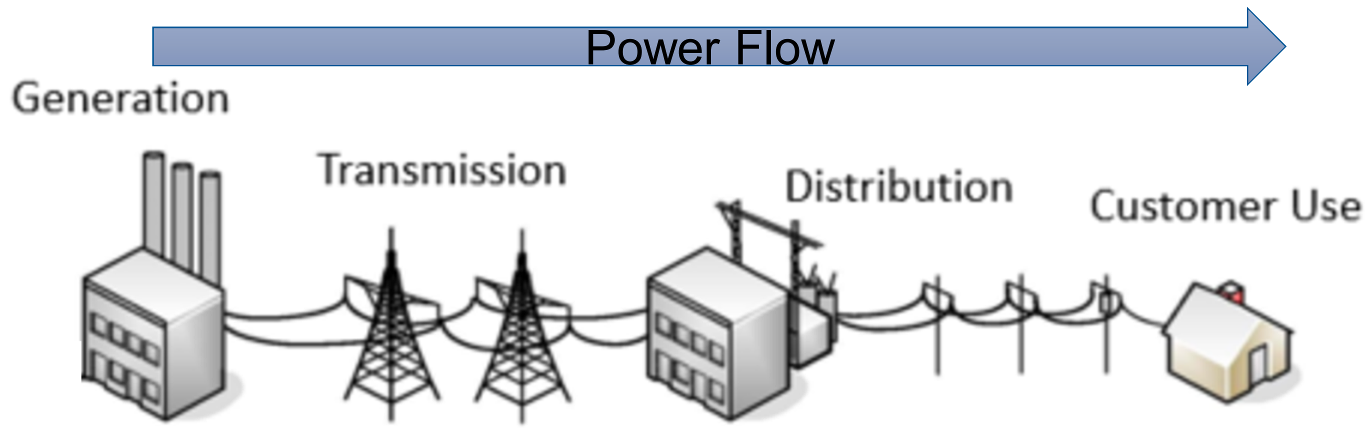
RENEWABLES THE FASTEST-GROWING

Source: Center for Climate and Energy Solutions

- Renewables made up more than **17%** of net U.S. electricity generation in 2018, with the bulk coming from hydropower (7.0 percent) and wind power (6.6 percent).
- Solar generation (including distributed) is projected to climb from 11 percent of total U.S. renewable generation in 2017 to **48% by 2050,** making it the fastest-growing electricity source.
  - Water (hydropower and hydrokinetic)
  - Wind
  - Solar (power and hot water)
  - Biomass (biofuel and biopower)
  - Geothermal (power and heating)
- With their current rate of growth, DERs can no longer be managed in a silo. Electric utilities need DER-awareness and orchestration across their full IT/OT network.

TRADITIONAL POWER GRID

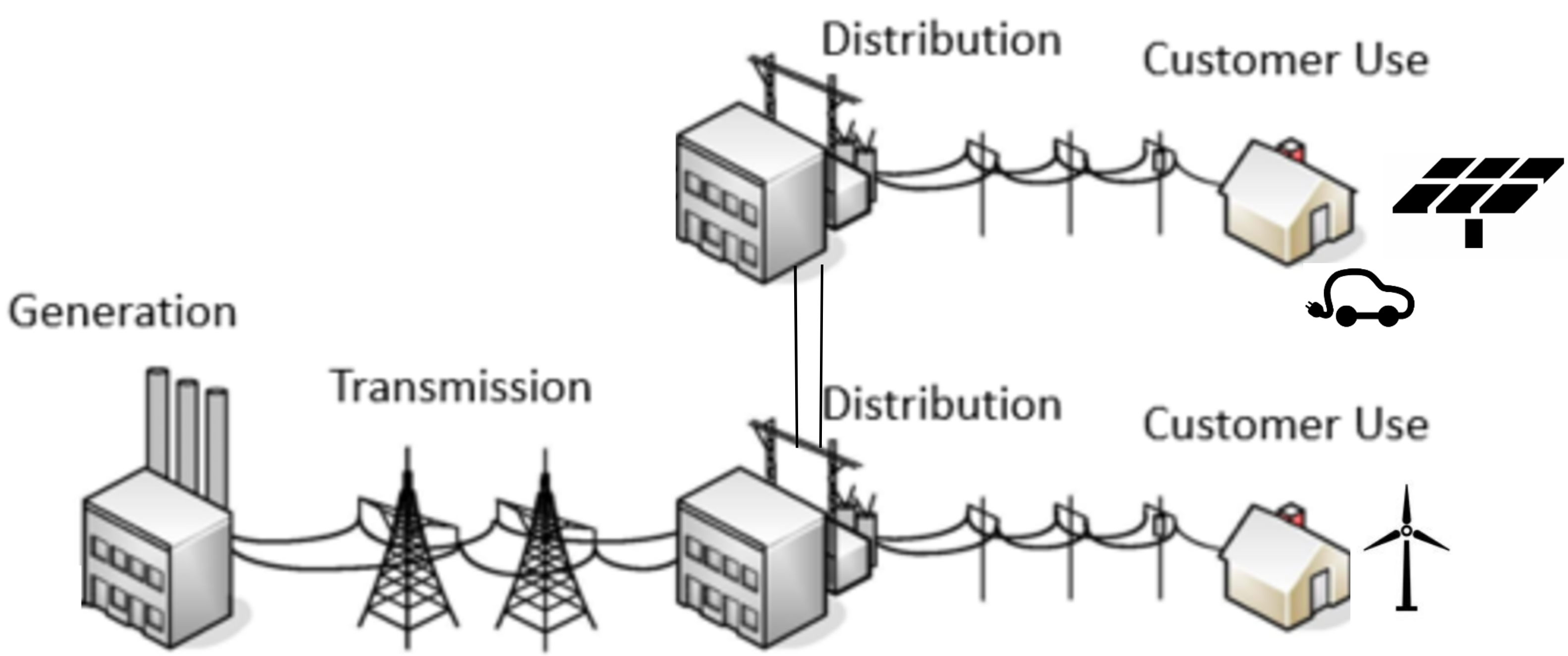
- Linear system from centralized Generation to the Customer through Transmission and Distribution systems. Power systems were not designed to accommodate active storage and generation at the distribution level.



- Traditional: Manual controls, supervisory control and data acquisition (SCADA), and distribution management systems (DMS)

MODERN POWER GRID

- De-centralized assets with unpredictable and intermittent generation profiles
- Renewables: Solar, Wind, Biomass, others

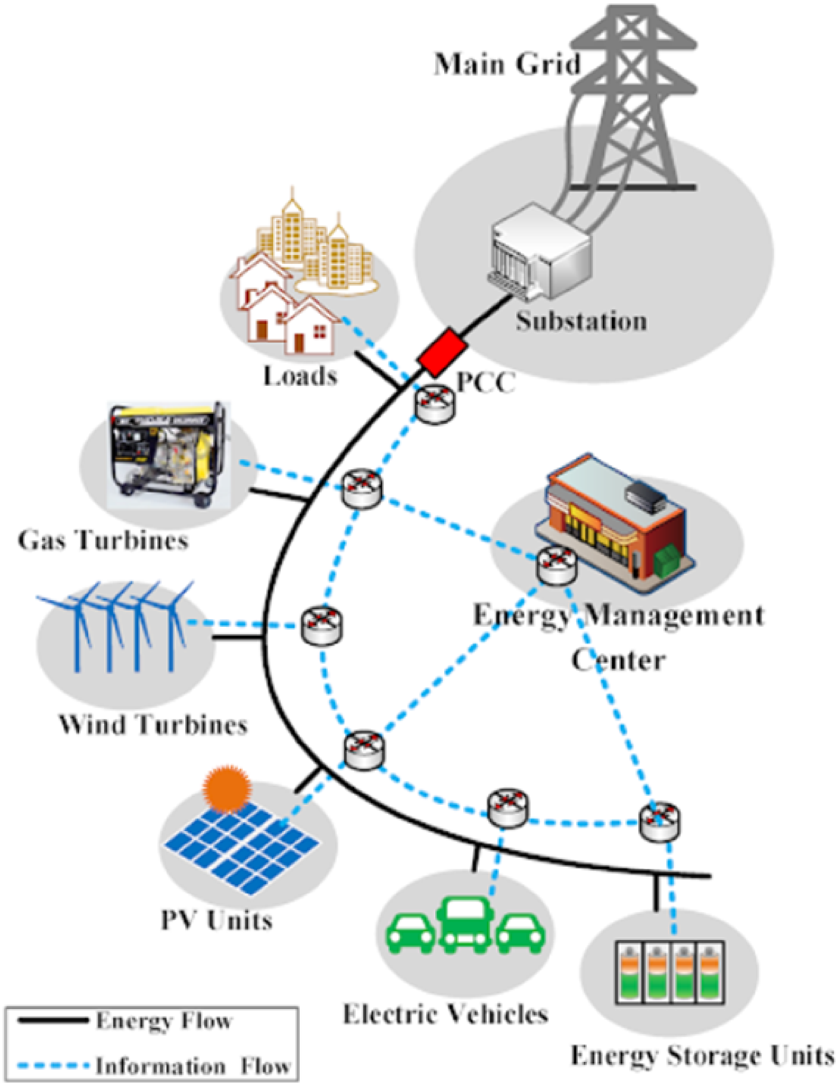


MICROGRID

Source: ACE Solar

- A microgrid is a localized group of interconnected loads and distributed energy resources

- The microgrid controller:
  - Controls solar, wind, storage
  - Coordinates with traditional grid
  - Ensures power quality
  - Automatic islanding



BATTERY ELECTRIC STORAGE SYSTEM

Source: Research and Markets

- Lithium-ion (Li-ion) is the most widely used storage solution, followed by flow batteries and sodium-sulfur (NaS) batteries
- The overall global energy storage was at 4.2GW in 2019 and estimated to reach 6GW in 2020. **Growth is expected to be nearly 22% annually**.
- Both residential-scale storage and utility-scale storage are seeing growth aided by a steady price decline of Li-ion batteries and the logical companion to solar installations.
- Allows for time-shifting of energy based on demand.

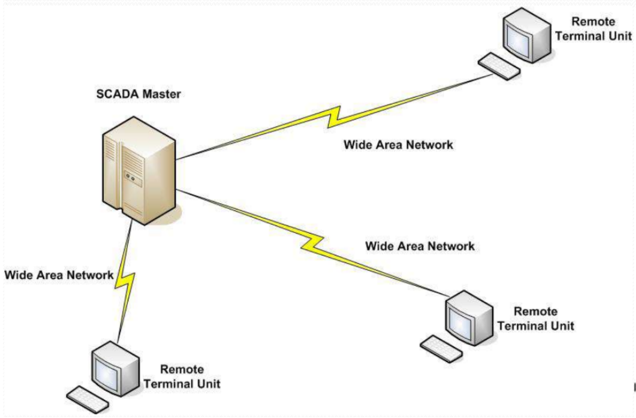
GRID CONTROL

- New power flow model = rethinking the infrastructure and control mechanisms
- Control –
  - Inconsistent Generation causes **gaps and variable power quality**
  - Real-time monitoring and control needed
  - **Distributed energy resource management system (DERMS)**
- Integration –
  - DER / traditional integration = more consistent supply but can be tricky
  - Need rapid **ramp up and ramp down**
- Reliability –
  - New grid control establishes better **reliability through automation** that can react quickly
- Storage –
  - major benefit = leveling out fluctuations and excess power

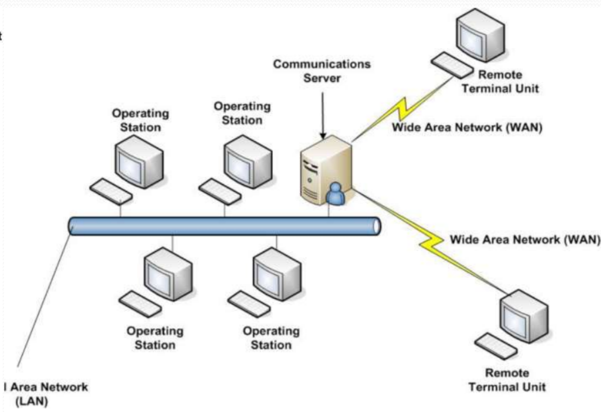
SCADA EVOLUTION

Source: Itron

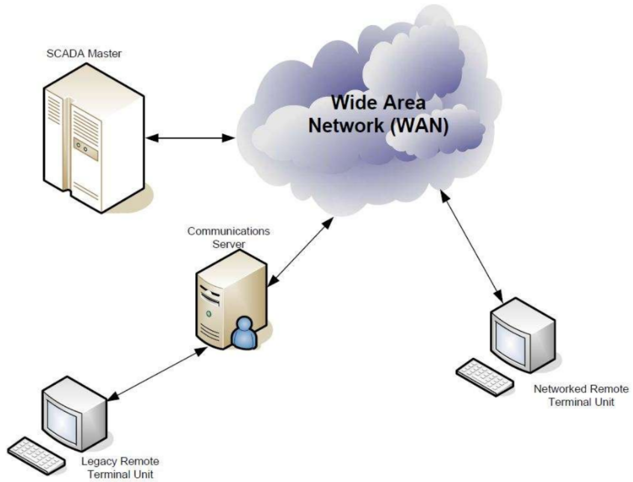
First Generation SCADA System



Second Generation SCADA System



Third Generation SCADA System



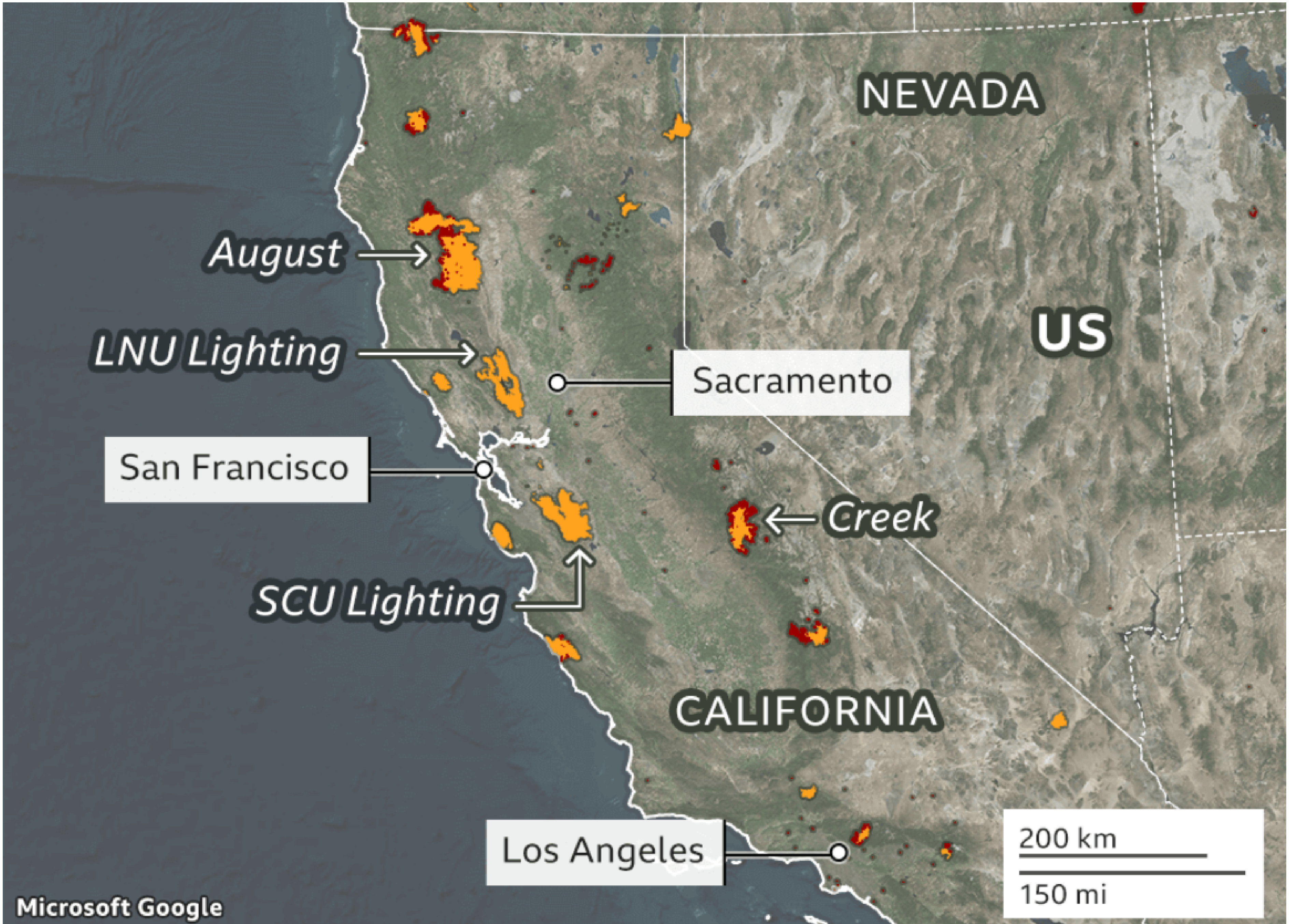
First Generation: Localized

Second Generation: Utility providers' version of distributed (decentralized in a way)

Third Generation: Cloud centric (Modern)

RESILIENT GRID

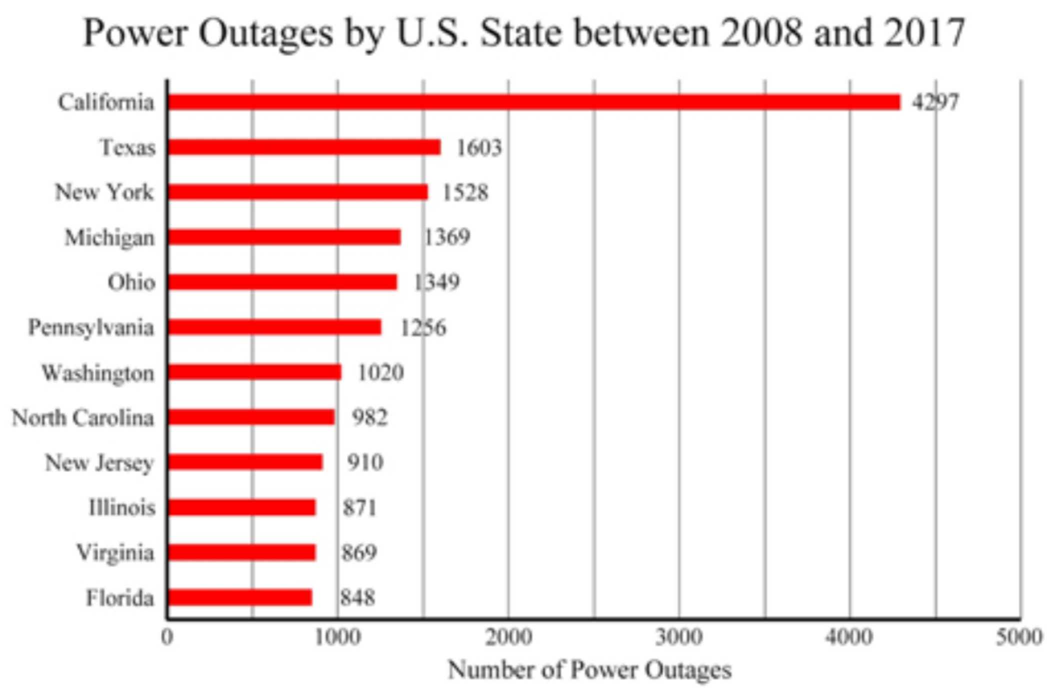
- Multiple sources of energy: large generation, medium (Commercial Solar/Wind/Other), and small (EV, consumer Solar/Wind)
- Multiple points of use: EV chargers, commercial, private
- More flexibility to avoid outages – example California fires



Source: National Interagency Fire Center, NASA FIRMS

CALIFORNIA FIRES

Source: Eaton

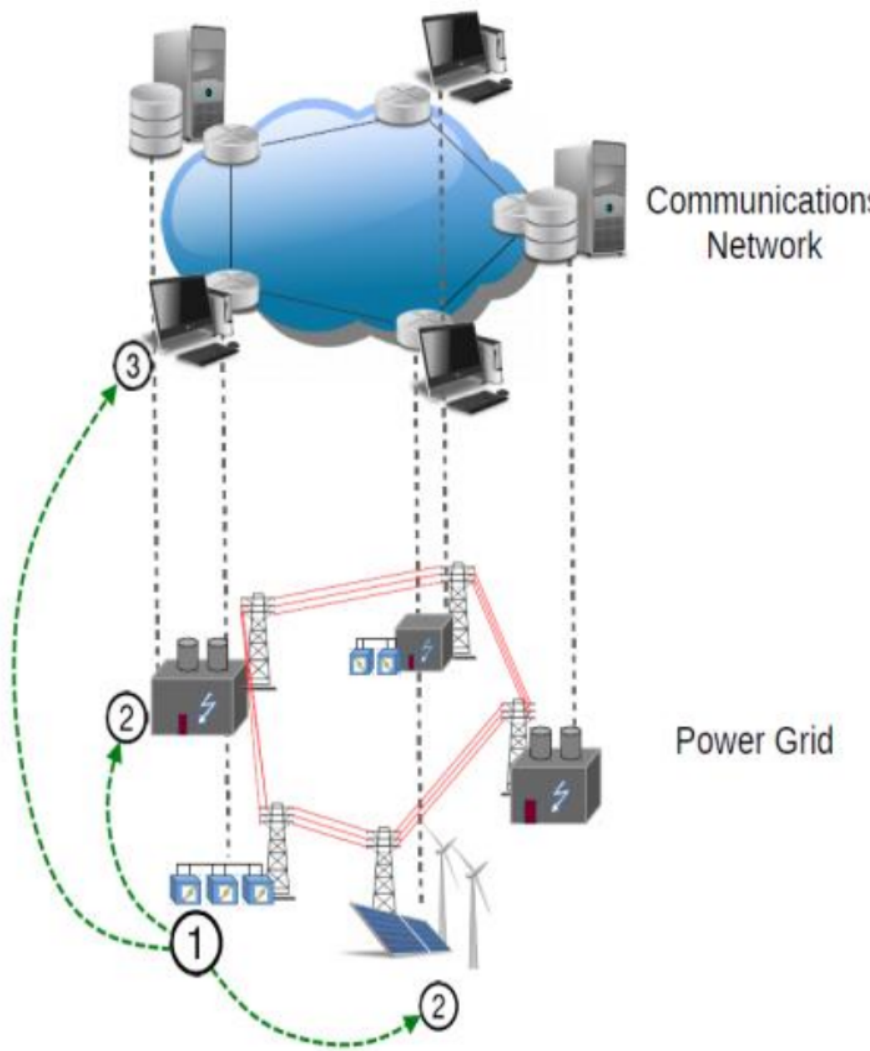


Increased power outages are forcing utility service providers to think outside the box.

EFFECT ON COMMUNICATIONS

Source: Siemens

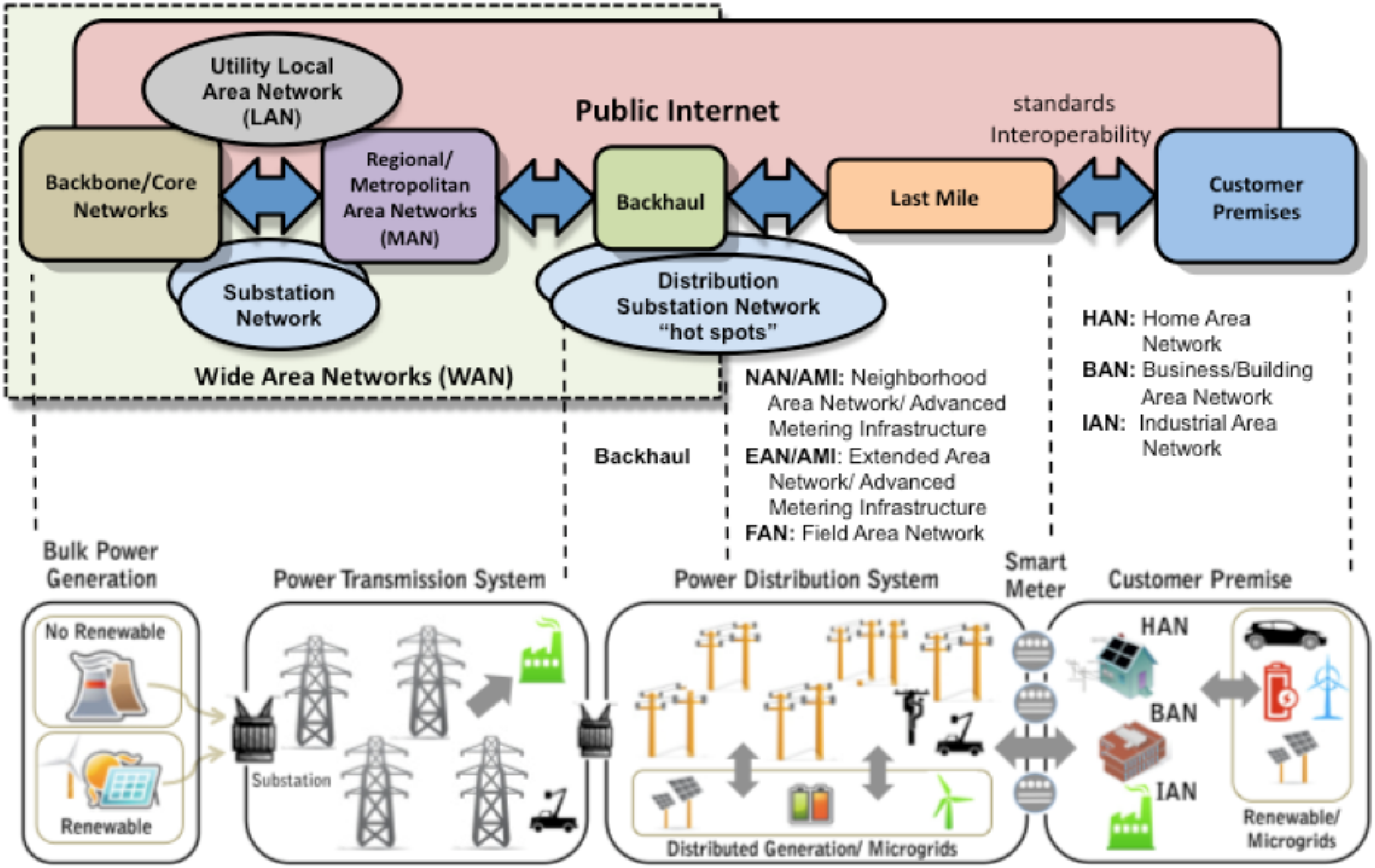
- A disturbance in
  - (1) DER causes edge failures in
  - (2) the power grid, as well as node and edge failures in
  - (3) the communications network
- Disturbance creates a domino effect in a linear system
- Latency increases by a factor of 10 at each node



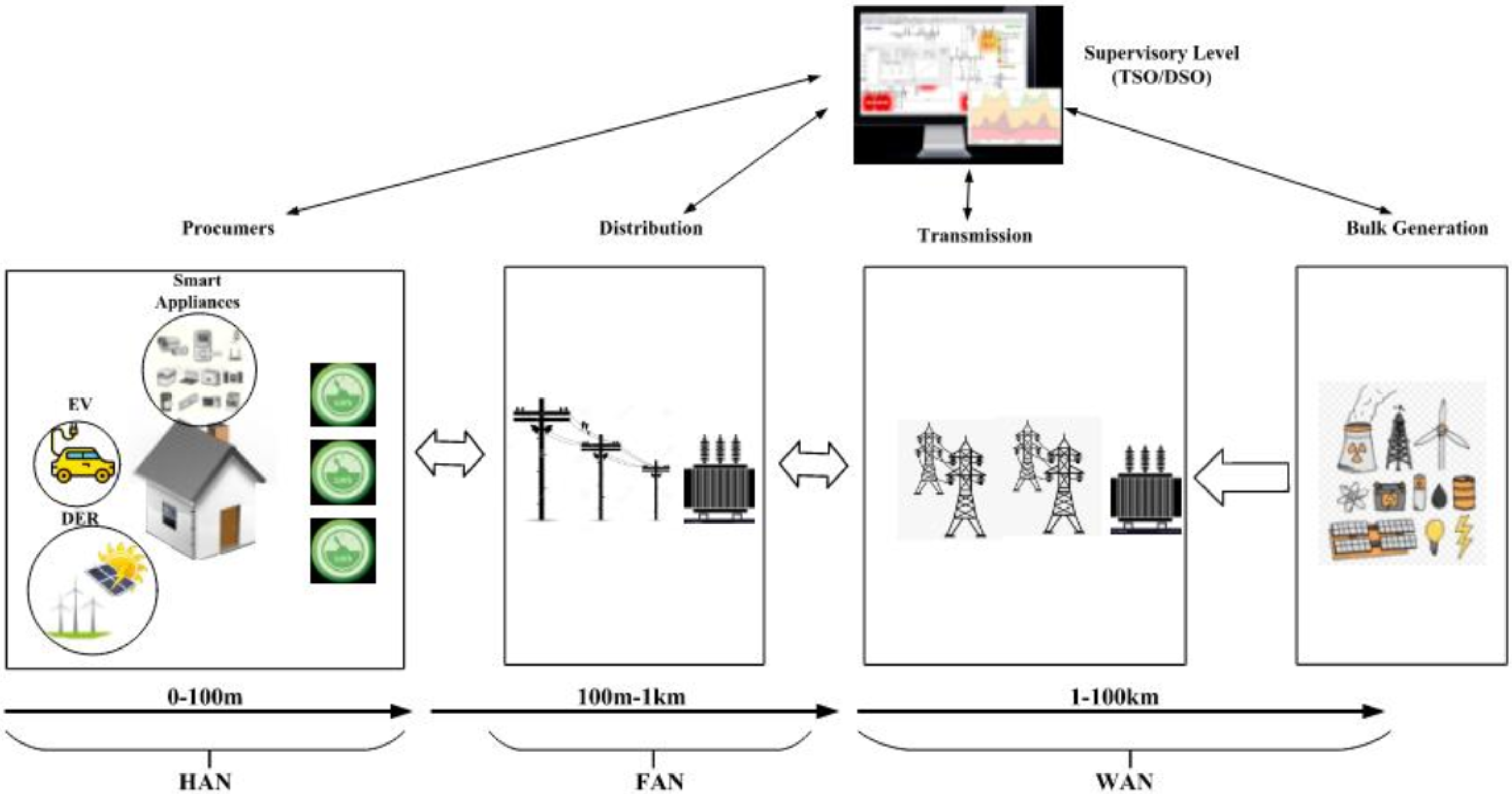
GRID COMMUNICATION

LINEAR UTILITY COMMUNICATION

Source: Siemens

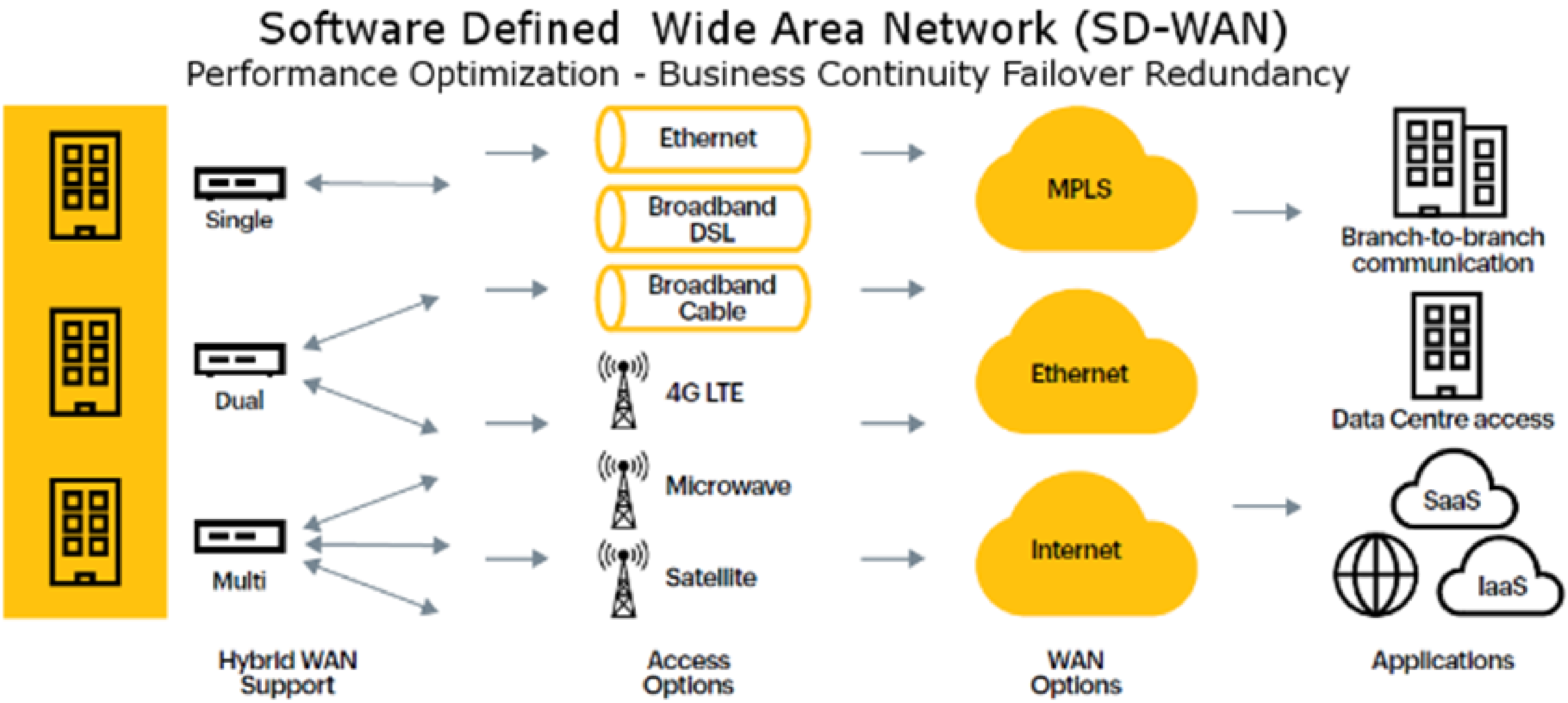


LEVELS OF COMMUNICATION



MODERN UTILITY COMMUNICATION

Source: Dell VMWare



Utility providers are learning from Telecom providers how to reduce latency and establish true real time communication.

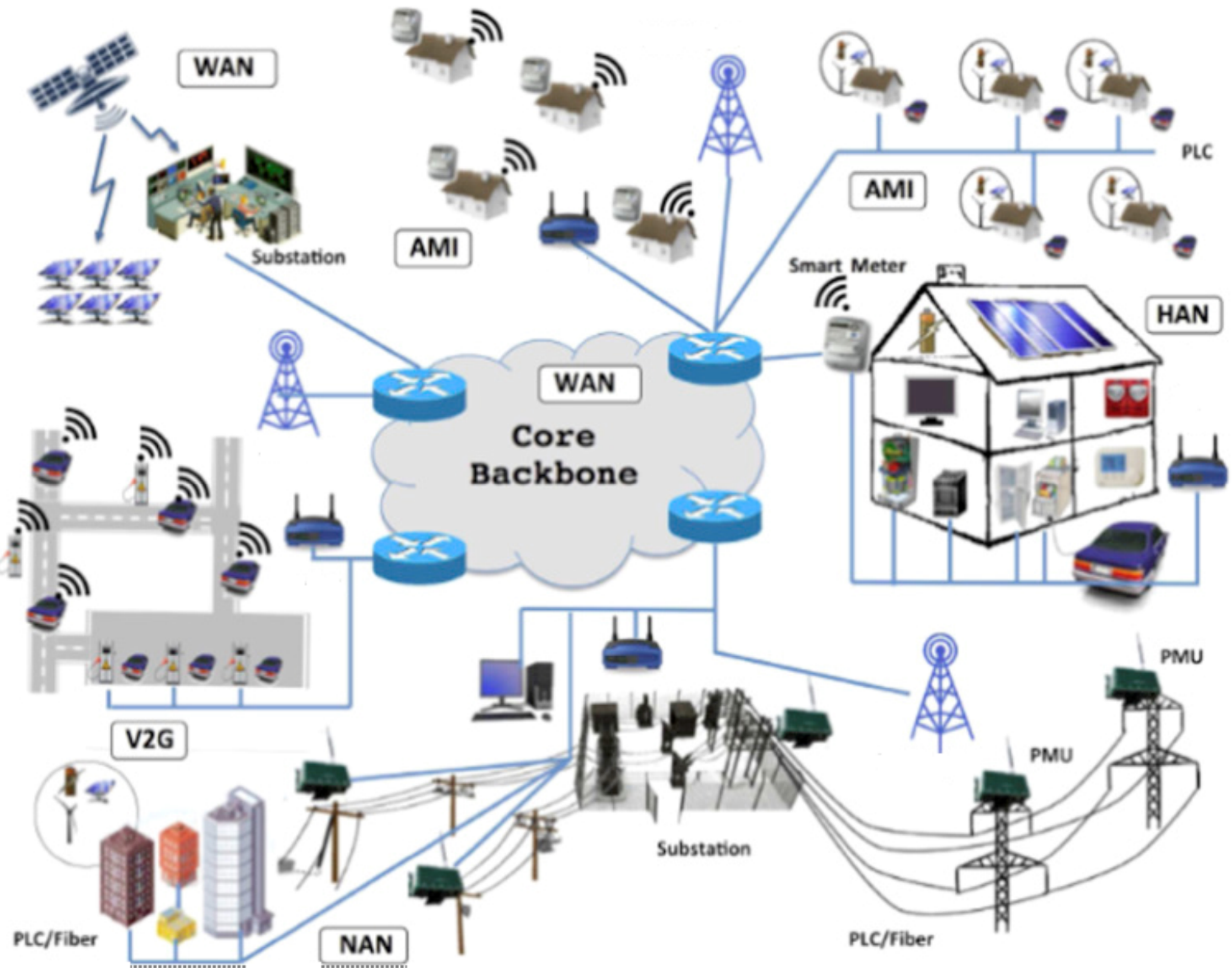
NEXT GEN SMART GRID

Source: Cisco

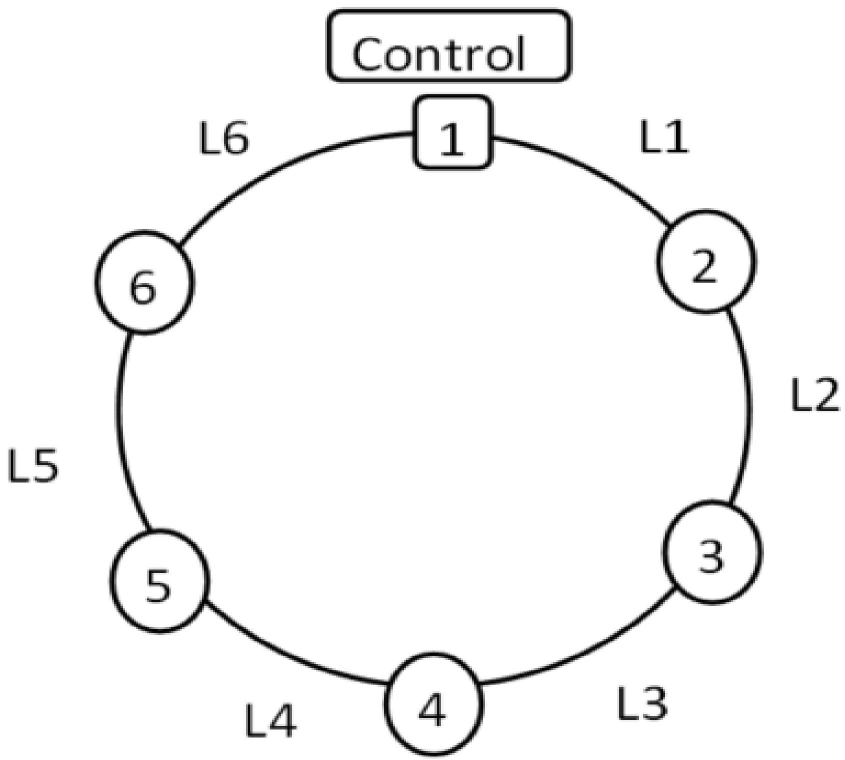
Multiple energy resources

and

Multiple communication methods



BANDWIDTH



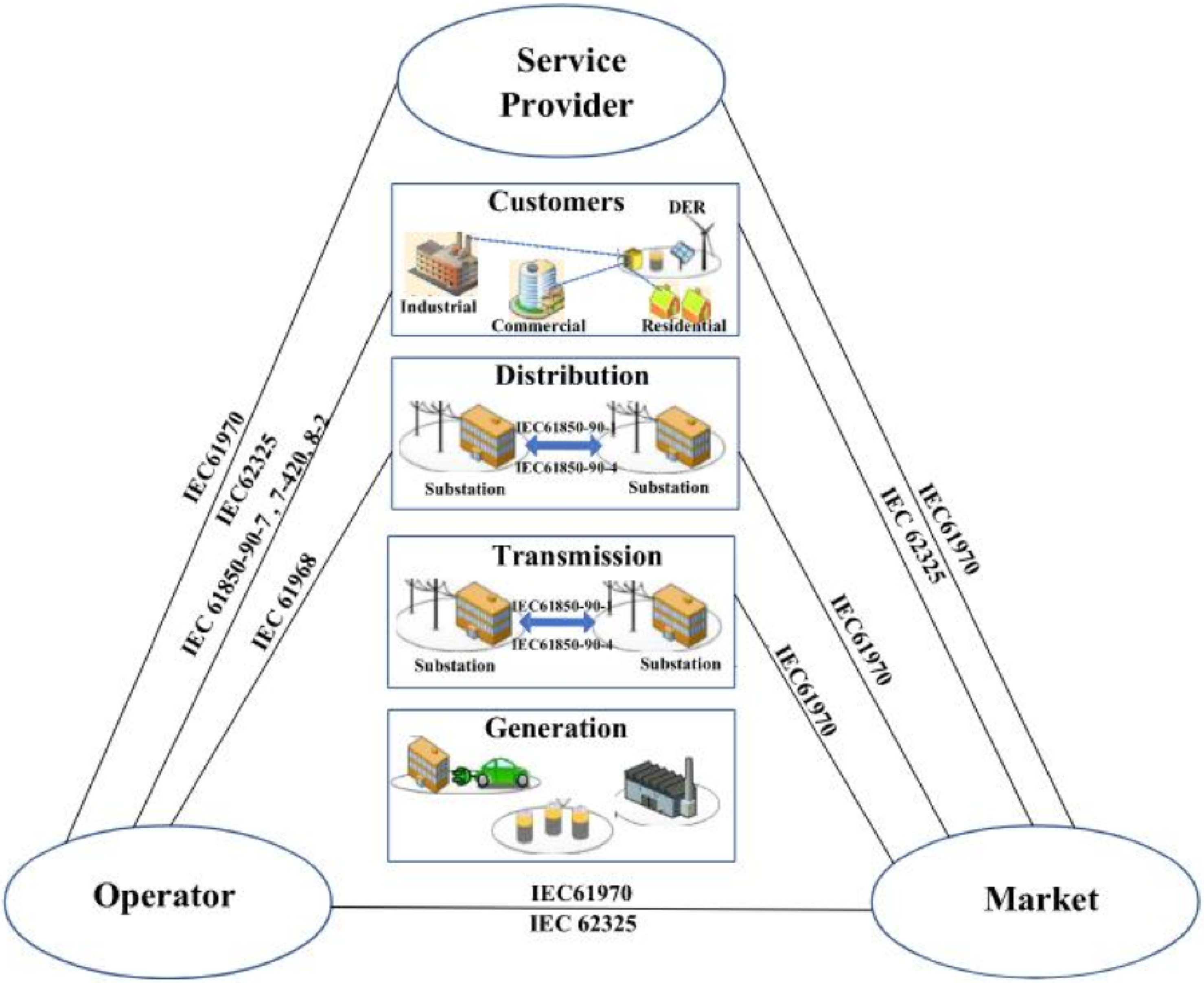
	Capacity Requirements
Teleprotection	300kb/s
SCADA	300kb/s
Voice	1Mb/s
Operational Services	10Mb/s
Corporate Networking	10Mb/s
Security	25Mb/s
PMU	3Mb/s

Different applications in the power grid have different requirements.

PROTOCOLS

- Understanding applicable protocols along with the support for cybersecurity is important
- Protocols: OpenADR, DNP3, IEEE 2030.5, IEC 61850, IEC 61970
- Smart inverters, gateways or other communication devices use:
  - IEEE 2030.5 protocol (Smart Energy Profile Protocol providing an interface between the smart grid and users) and IEEE 1815 protocol (DNP 3.0 application interoperability)
  - IEEE 1547-2018 (interconnection and interoperability between utility electric power systems (EPSs) and DERs)
- Network Protocols are TCP/IP, OPC, DNP3, Modbus, SEL, SNMP, IEC-104, IEC 61850, and others
- IEC 61970 provides for interfaces between Grid systems including the Energy Management System (EMS)

GRID PROTOCOLS



COMMUNICATIONS TOOLBOX

INTERACTION

Communication

Wired:
- Fiber Optics
- PLC
- Copper

Wireless:
- Wifi
- Cellular
- LPWAN
- Satellite

Work together

Grid

- AMI
- DR
- DER
- Control Center
- V2G
- MicroGrid
- Smart Home
- Storage

Results

- Resilient
- Safe
- Efficient
- Reliable
- Power Quality
- Asset Management
- Outage Management

GRID COMMUNICATION TRANSPORT

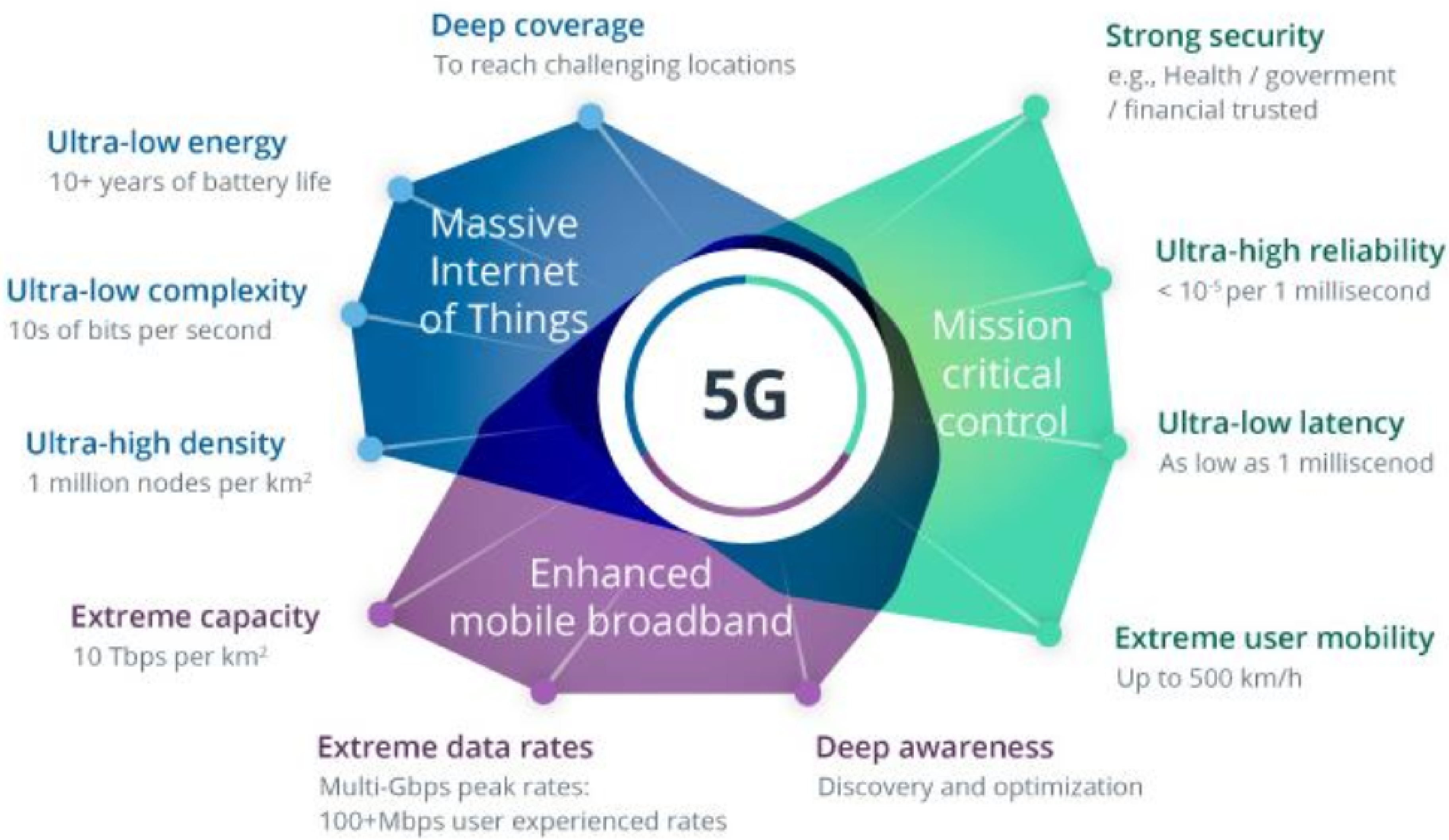
- Reliability and Performance:
  - Teleprotection and SCADA have stringent requirements
  - Additional services, physical security, require high bandwidth
- Time-division multiplexing (TDM):
  - Low latency, high availability, deterministic
  - DS0, T1, DS3
  - Synchronous optical networking/synchronous digital hierarchy (SONET/SDH)
  - Not flexible, inefficient bandwidth use
- Packet networks:
  - Internet protocol (IP)
  - Multi-protocol label switching (MPLS)
  - Provides scalability, reliability, security

COMMUNICATION TRANSPORT

- MPLS:
  - Supports both IP and TDM-oriented applications
  - Pseudo-deterministic, predictable latency
- Transport Media:
  - Microwave
  - Fiber Optics
  - Leased services
- Cellular:
  - Monthly billing
  - Easy installation

INDUSTRIES THAT WIN THE MOST FROM 5G

CATEGORIZATION OF 5G USE CASES



ROBUST & SECURE COMMUNICATION

RESILIENT GRID COMMUNICATION INFRASTRUCTURE

- A robust communication network is necessary for the critical communication needs of the Grid.
- Diverse communication paths are often touted but just as often fail to be truly diverse from one point to another along the path. Issues:
  - Routing of cable
  - Common equipment
  - Similar technologies
  - Natural interruptions
- Fast switching times are essential to maintain communication for latency sensitive applications. Rule of thumb is sub-50 milliseconds.

SECURE

- A smart grid architecture should ensure end-to-end protection of services using multiple layers of protection such as:
  - Comprehensive password protection at all levels
  - Centralized authentication and logging
  - Centrally managed and monitored firewalls
  - Security policies using access control lists, MAC-pinning, IP and bandwidth filters
- But security regulations, grid management, and the need for visibility and control make grid security a top priority in both design and implementation
- “In response to the growing security skills gap and attacker trends, extended detection and response (XDR) tools, machine learning (ML), and automation capability are emerging to improve security operations productivity and detection accuracy.” – Gartner
- Dr. Quint touched on security

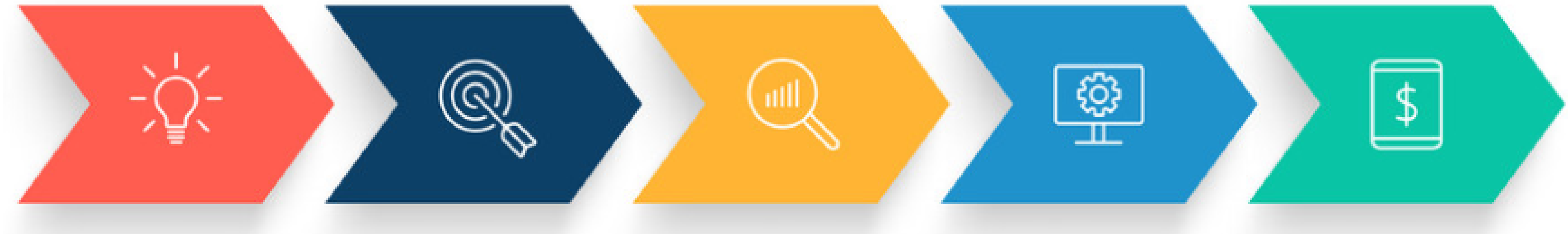
GOING FORWARD

PRIORITIES FOR A DIGITALIZED FUTURE

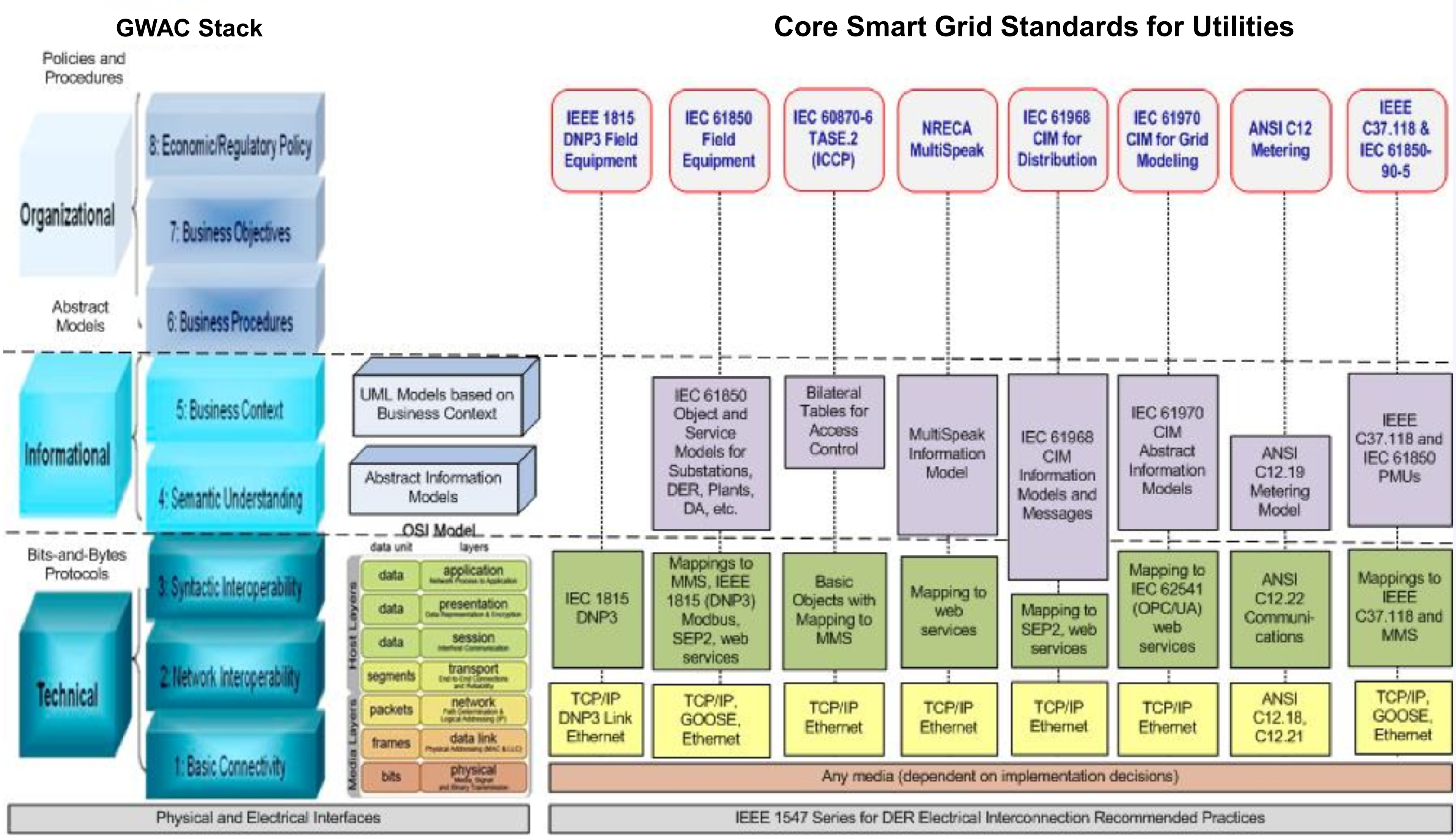
- Customer Satisfaction
- Asset Management
- Operations and Maintenance
- Productivity
- Business Decision Making

PLANNING

- The future of grid communication is a dynamic, robust, and secure network architecture known as “holistic networking”
- Planning is essential to ensure bandwidth, cyber security, and location requirements are met for all applications.
- It is important to identify and mitigate grid communication challenges and opportunities

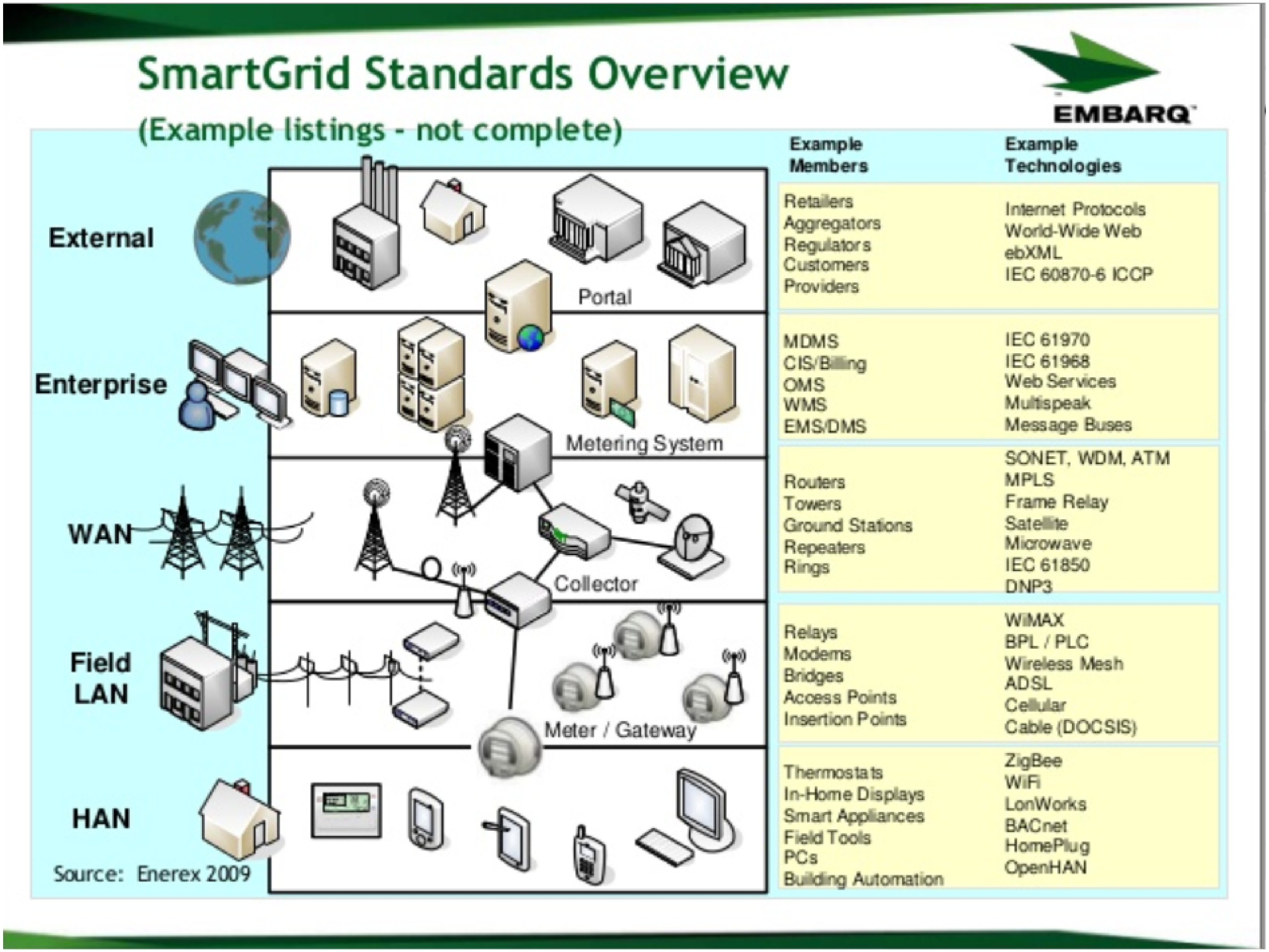


STANDARDS


GWAC Stack
Core Smart Grid Standards for Utilities
Policies and Procedures
Organizational
8: Economic/Regulatory Policy
7: Business Objectives
6: Business Procedures
Abstract Models
Informational
5: Business Context
4: Semantic Understanding
UML Models based on Business Context
Abstract Information Models
Bits-and-Bytes Protocols
Technical
3: Syntactic Interoperability
2: Network Interoperability
1: Basic Connectivity
OSI Model
data unit
layers
Host Layers
Media Layers
data
application
data
presentation
data
session
segments
transport
packets
network
frames
data link
bits
physical
IEEE 1815 DNP3 Field Equipment
IEC 61850 Field Equipment
IEC 60870-6 TASE.2 (ICCP)
NRECA MultiSpeak
IEC 61968 CIM for Distribution
IEC 61970 CIM for Grid Modeling
ANSI C12 Metering
IEEE C37.118 & IEC 61850-90-5
IEC 61850 Object and Service Models for Substations, DER, Plants, DA, etc.
Bilateral Tables for Access Control
MultiSpeak Information Model
IEC 61968 CIM Information Models and Messages
IEC 61970 CIM Abstract Information Models
ANSI C12.19 Metering Model
IEEE C37.118 and IEC 61850 PMUs
IEC 1815 DNP3
Mappings to MMS, IEEE 1815 (DNP3) Modbus, SEP2, web services
Basic Objects with Mapping to MMS
Mapping to web services
Mapping to SEP2, web services
Mapping to IEC 62541 (OPC/UA) web services
ANSI C12.22 Communi-cations
Mappings to IEEE C37.118 and MMS
TCP/IP DNP3 Link Ethernet
TCP/IP, GOOSE, Ethernet
TCP/IP Ethernet
TCP/IP Ethernet
TCP/IP Ethernet
TCP/IP Ethernet
ANSI C12.18, C12.21
TCP/IP, GOOSE, Ethernet
Any media (dependent on implementation decisions)
Physical and Electrical Interfaces
IEEE 1547 Series for DER Electrical Interconnection Recommended Practices

SMART GRID STANDARDS

EXAMPLES



Kiewit

QUESTIONS AND ANSWERS

THANK YOU!

Matt Klinker
Director – Grid Modernization

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GRID ACRONYMS

- DER: Distributed Energy Resources
- DERMS: DER Management System
- DNP3: Distributed Network Protocol (IEEE 1815)
- IEC: International Electrotechnical Commission
- SEP2: Smart Energy Profile 2.0 (IEEE 2030.5)
- Synchronous Optical Network (SONET)
- Multi-Protocol Label Switching (MPLS)
- Internet Protocol version 6 (IPV6)
- Common Interface Model (CIM) within (IEC 61970)

STANDARDS

HOW THEY INTERRACT