NIST Conceptual Model Overview and Evolution

Copiously cribbed from presentation by

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Chairman and CTO

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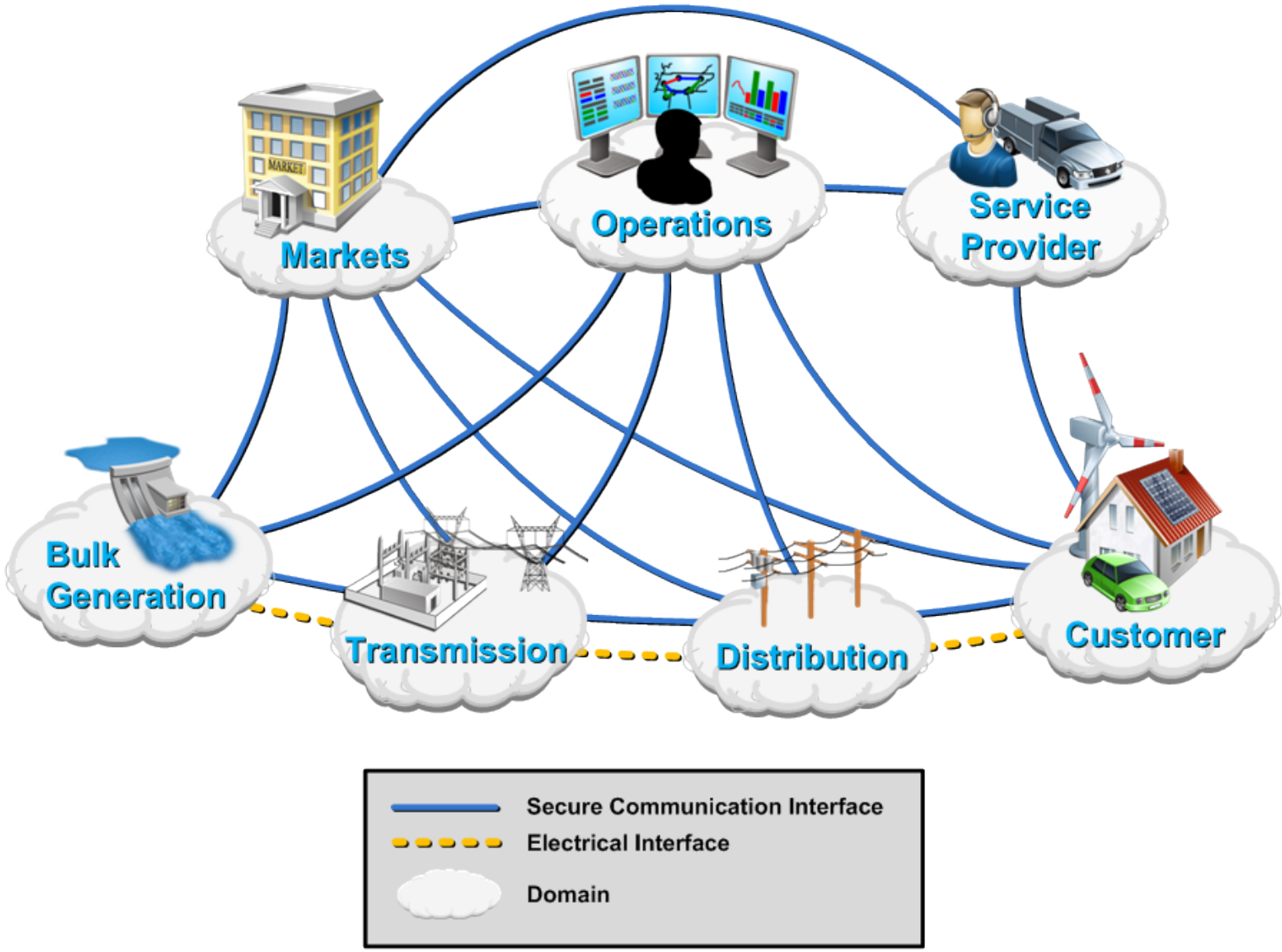
Why Use a Model and Tools?

- Systems are Becoming More Complex
- Scale and Scope of Next Generation Equipment
  - Thousands to Millions of Pieces of Field Equipment
  - Diverse Physical Media
  - Equipment Supplied by Multiple Providers
  - More Sophisticated Control and Management
- Need to Manage and Document Systems:
  - Initial Requirements and Designs
  - Life Cycle Management
- Open Standards Drives Need for Well Managed Equipment Interfaces and Integration

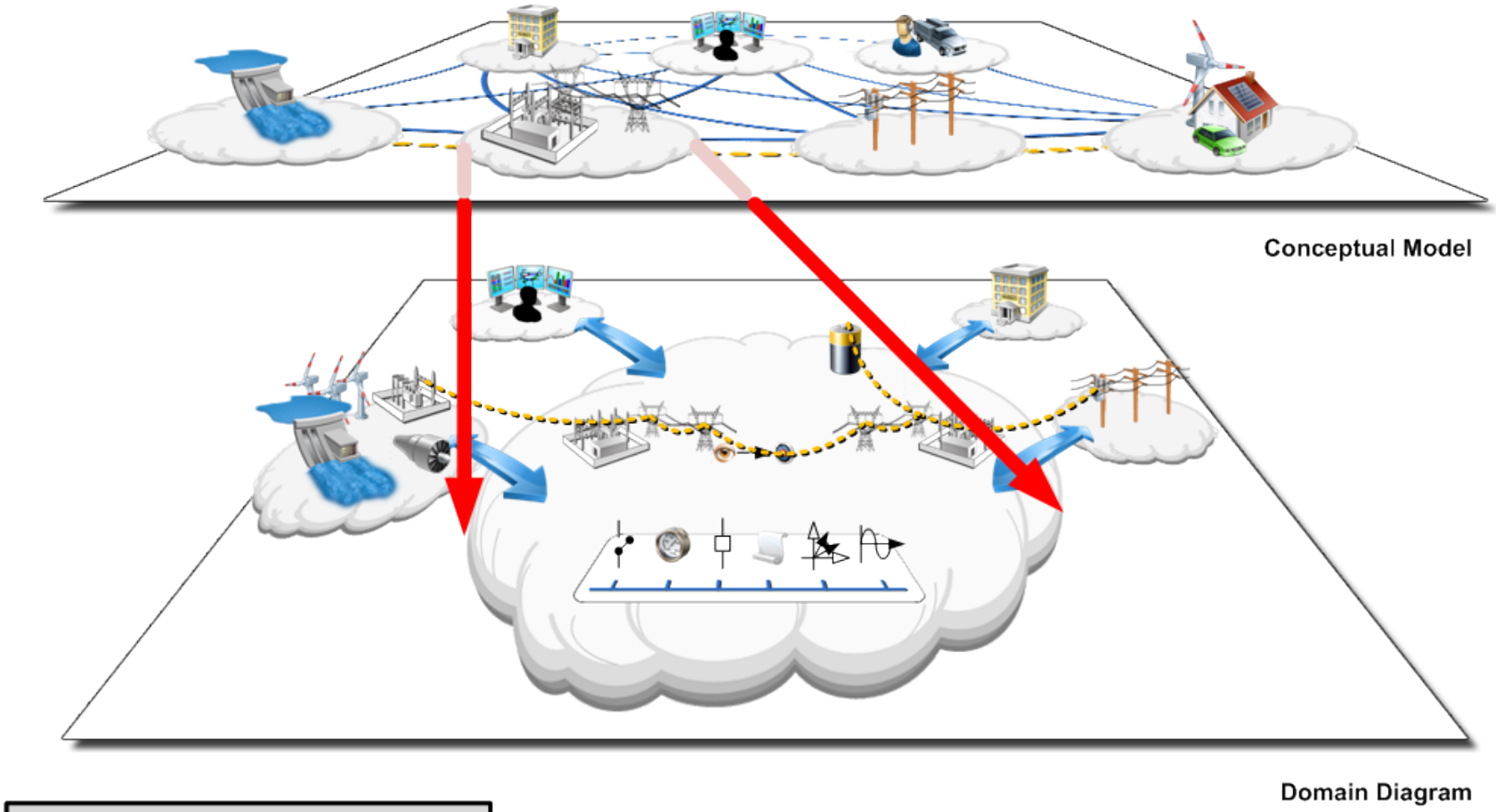
Conceptual Model: Core Principles

- The NIST Smart Grid Conceptual Model
  - A framework for discussing the characteristics, uses, behavior, interfaces, requirements and standards of the Smart Grid
  - System of Systems – multiple architectures
- General Concepts
  - **Loose Coupling** - bilateral and multilateral transactions can occur without elaborate pre-arrangement
  - **Layered Systems** – a collection of conceptually similar functions that provides services to the layer above and receives services from the layer below.
  - **Shallow Integration** - avoids deep knowledge of the managed or configured components
- Interface Related
  - **Symmetry** - **each action can run both ways**
  - **Transparency** - transparent and auditable chain of transactions
  - **Composition** - the building of complex interfaces from simpler interfaces
  - **Cyber Security** - managed over the life-cycle of the systems deployed; fundamentally about managing risk; commensurate with the vulnerabilities and exposures from any given application; considered at the time the application requirements are being developed since the domain experts are in the best position to understand what is at stake.

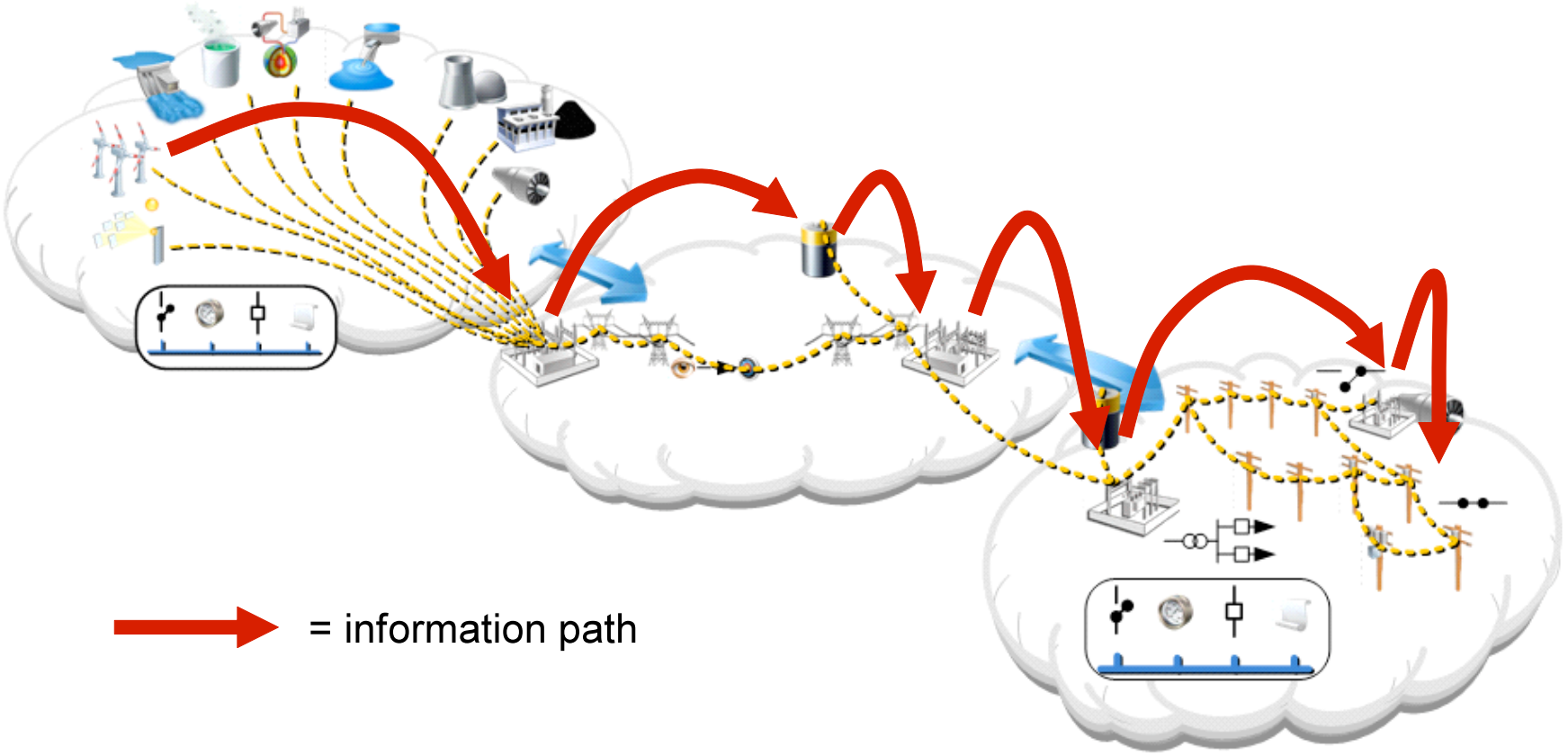
Conceptual Model – Views as a Tool



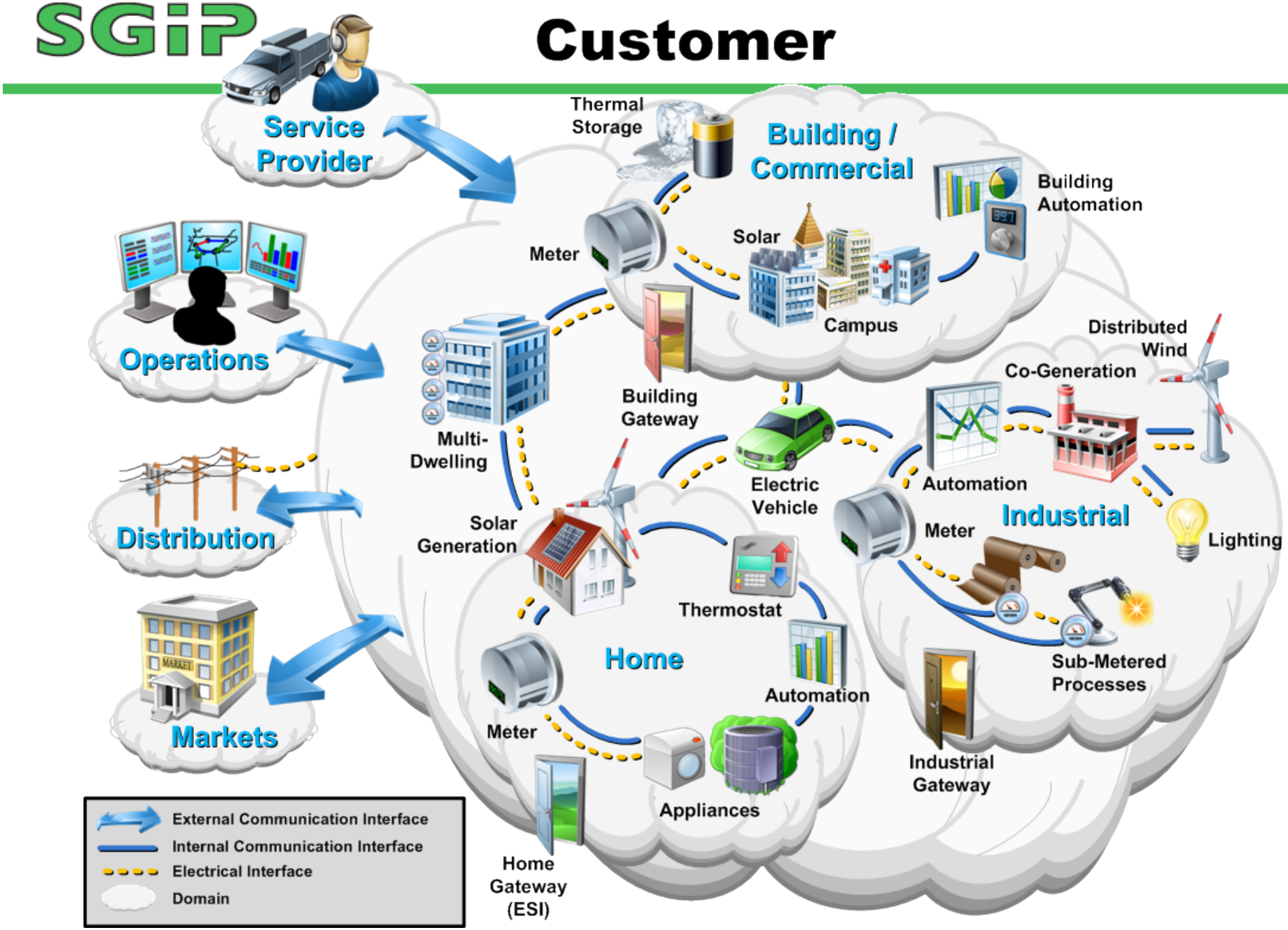
Levels of the Conceptual Model



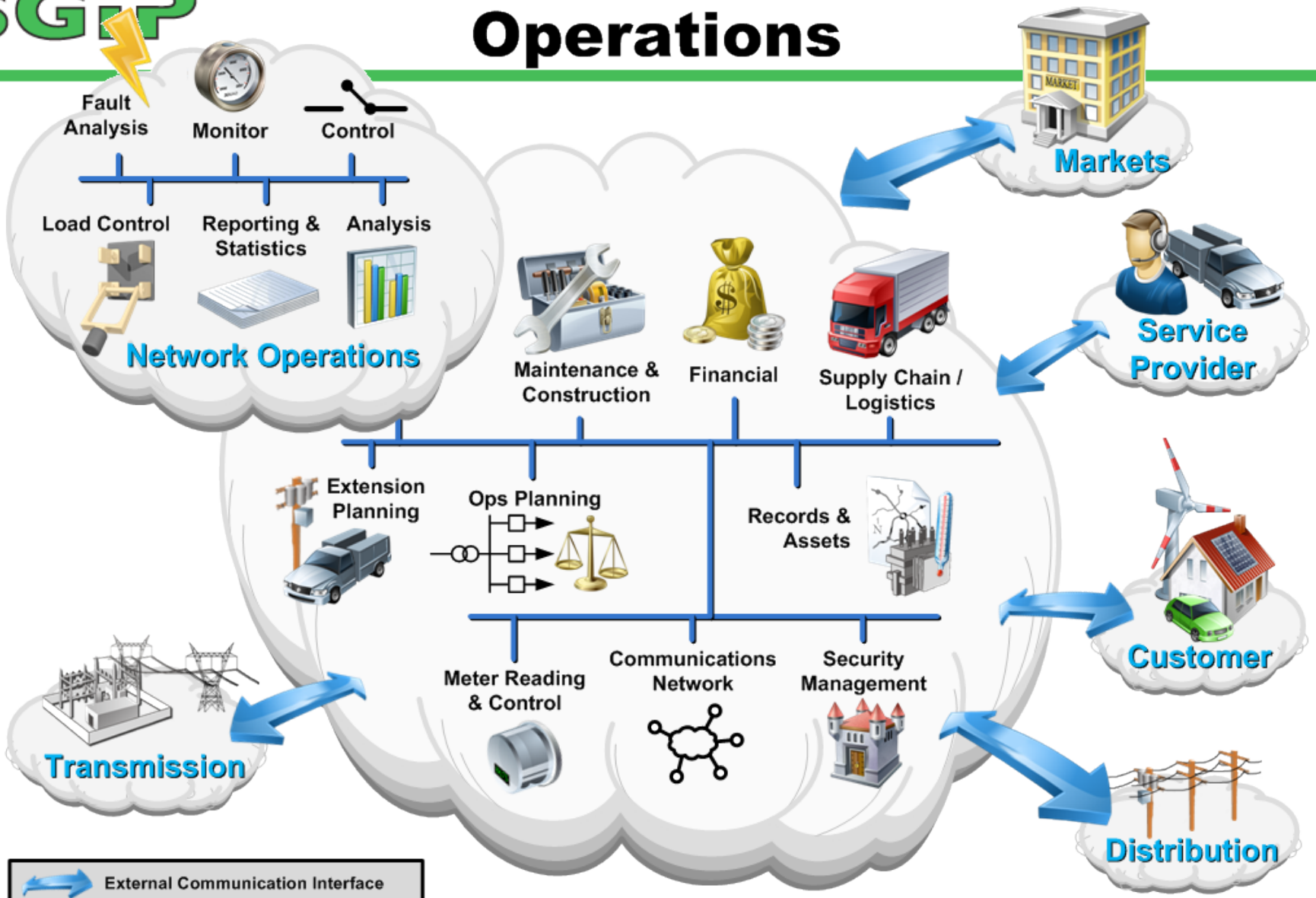
Use Cases: Paths Through the Model



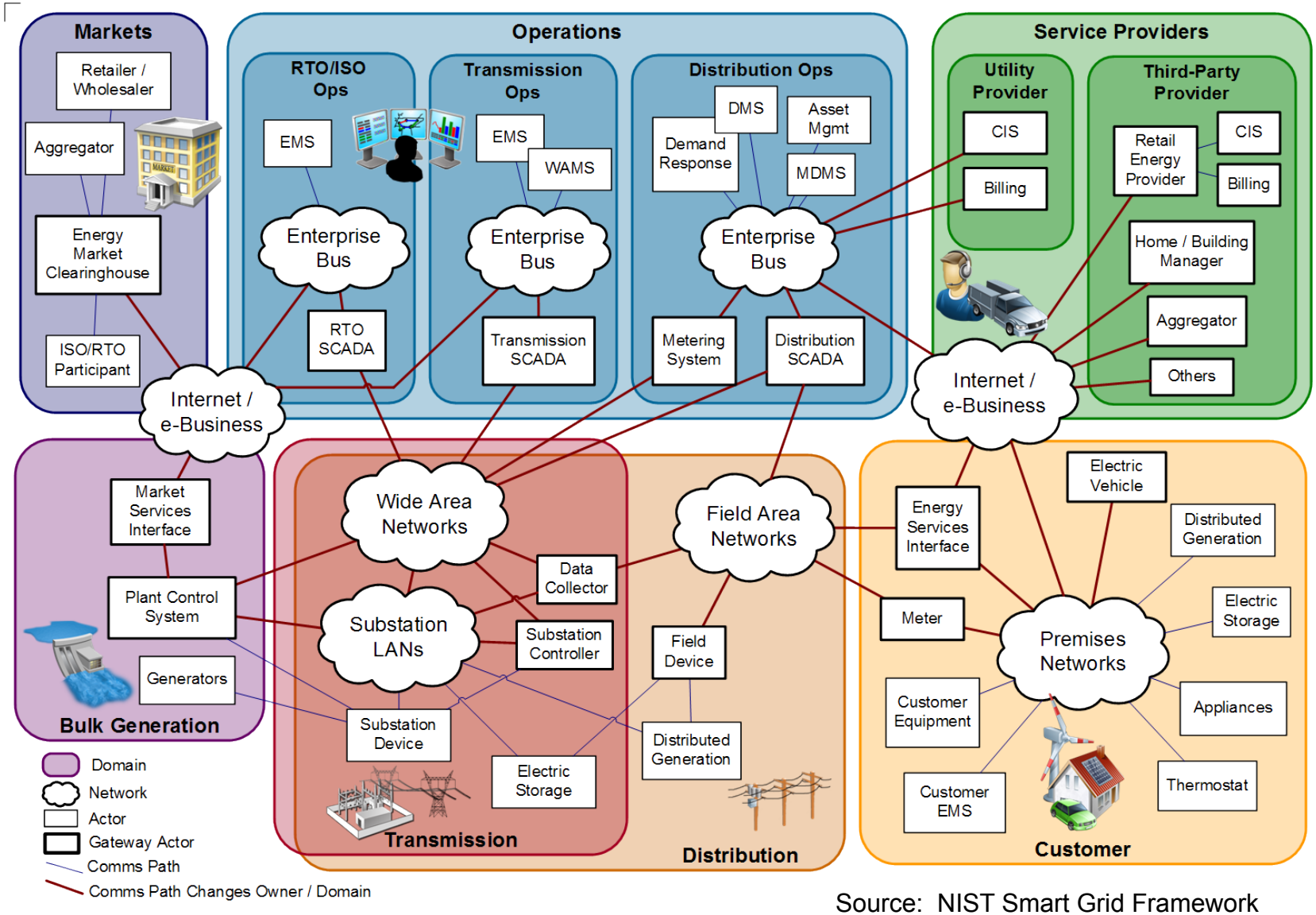
Customer


Service Provider
Operations
Distribution
Markets
Thermal Storage
Building / Commercial
Building Automation
Meter
Solar
Campus
Multi-Dwelling
Building Gateway
Distributed Wind
Co-Generation
Electric Vehicle
Automation
Industrial
Meter
Lighting
Solar Generation
Thermostat
Home
Automation
Meter
Sub-Metered Processes
Industrial Gateway
Appliances
Home Gateway (ESI)
External Communication Interface
Internal Communication Interface
Electrical Interface
Domain

Operations

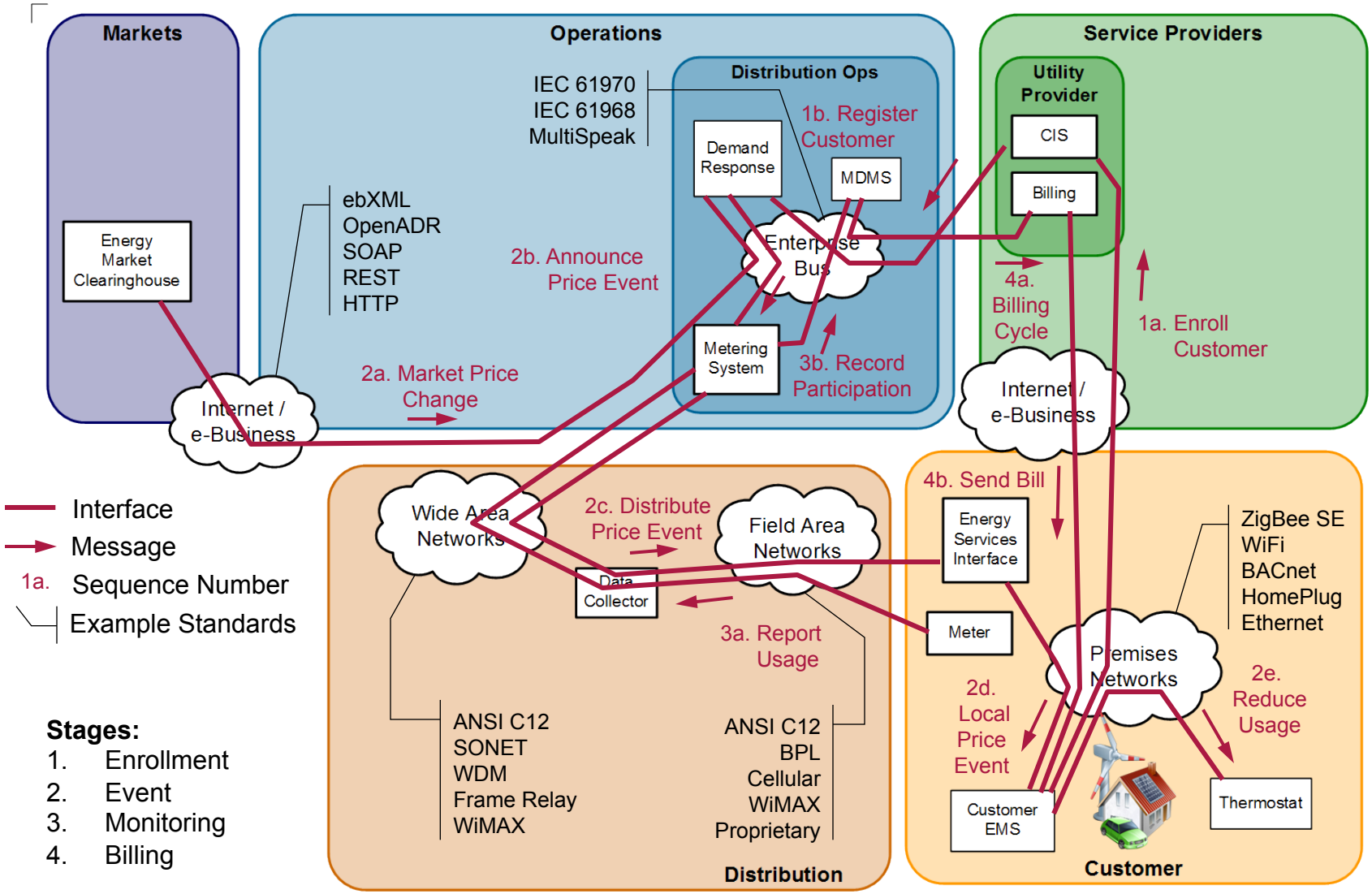

Fault Analysis
Monitor
Control
Load Control
Reporting & Statistics
Analysis
Network Operations
Markets
Service Provider
Maintenance & Construction
Financial
Supply Chain / Logistics
Extension Planning
Ops Planning
Records & Assets
Meter Reading & Control
Communications Network
Security Management
Customer
Transmission
Distribution
External Communication Interface
Internal Communication Interface
Electrical Interface
Domain

Conceptual Reference Model



Source: NIST Smart Grid Framework

Demand Response – Example Only!



Stages:

1. Enrollment
2. Event
3. Monitoring
4. Billing

Source: EnerNex

SGiP A brief overview of the Smart Grid

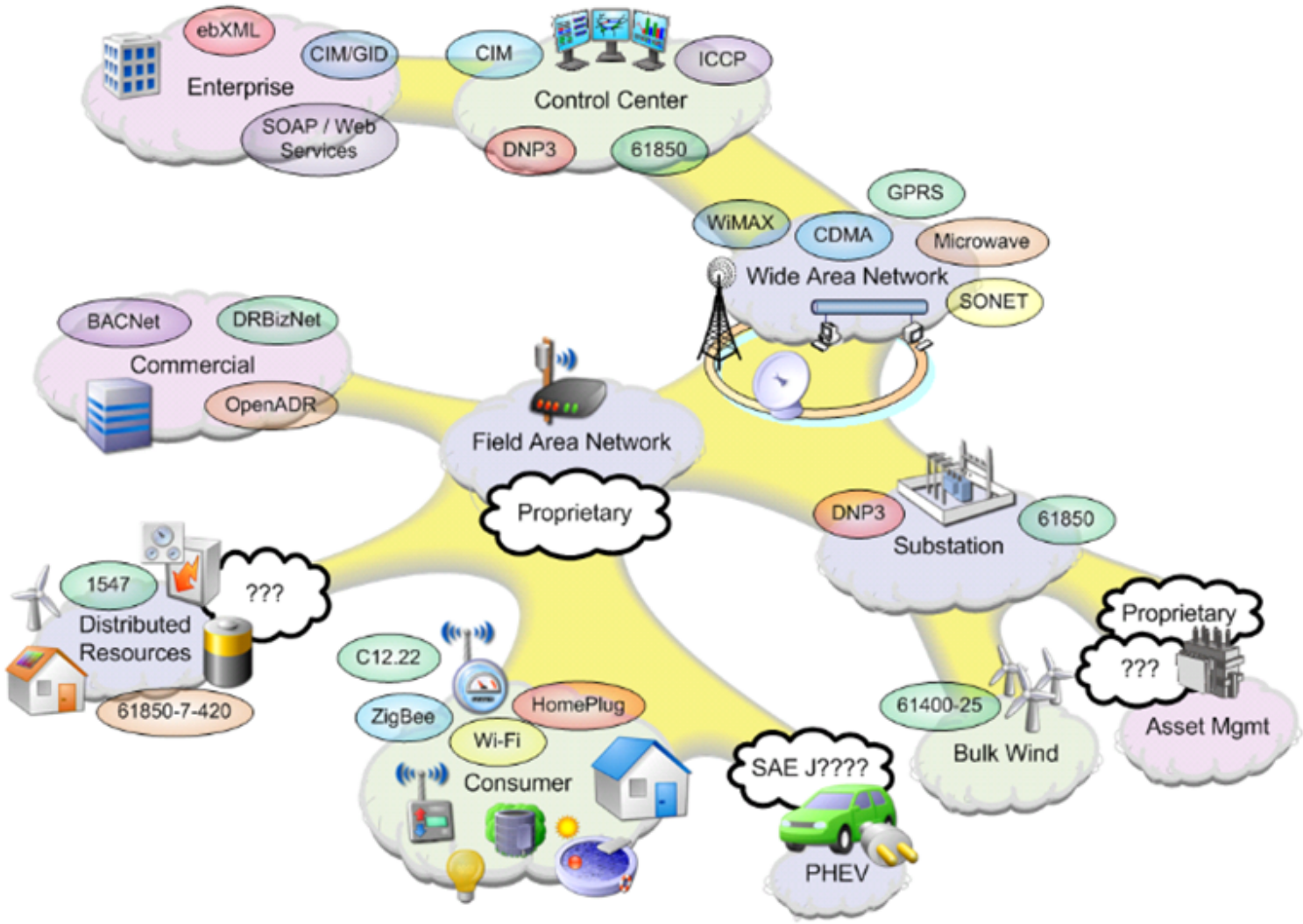
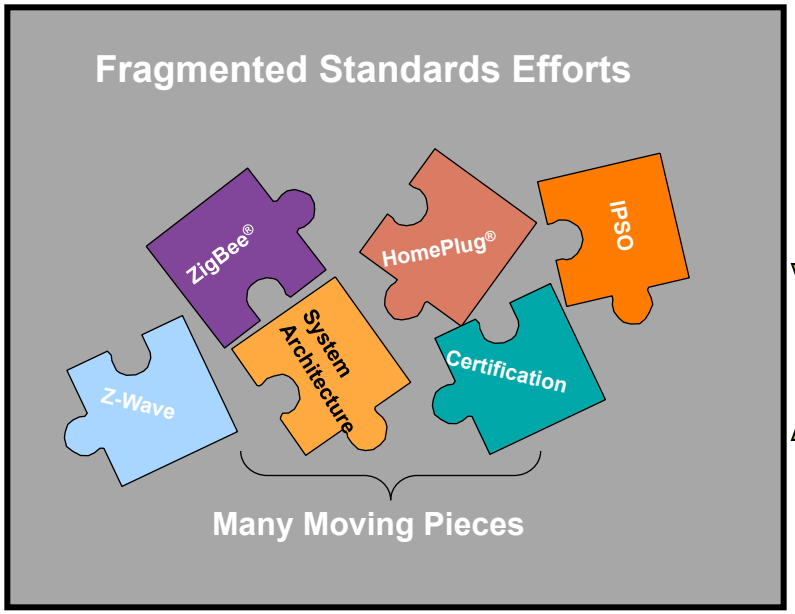


Figure 4: Domain Decomposition

Current State of the Industry – according to Zigbee/Homeplug

Current State

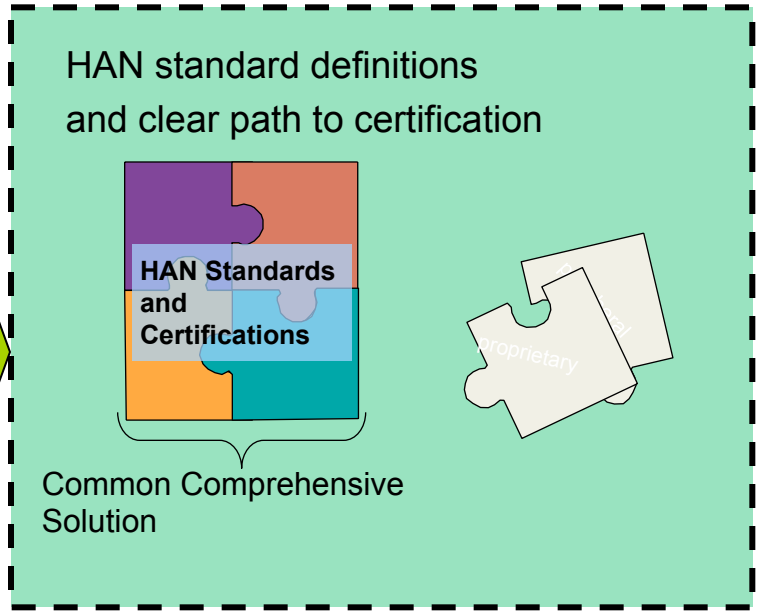


Minimal collaboration between industry resulting in proprietary processes to each utility

- Fragmented standards
- No common end-to-end system definition
- No comprehensive certification process

Joint Utility Leadership

Utility Requirements



There is an opportunity to align around a common comprehensive solution

- Timing is good
- Standards bodies are open to utility engagement
- Pick the best minimum solution

Factoid for the Internet Community

- Internet Protocol Suite seen as
  - "Complex"
    - Many optional protocols
    - Not engineered to AMI needs
  - "Threatening"
    - Business issues – "let's not Osborne the business"
    - Technical issues – not easily used in existing architecture and yet pressed by us and some utilities
- To make progress, we need to show flexibility
  - Make a building network a collection of 6lowpan and 6lowpan-like networks plus Ethernet/WiFi/WiMax sensors
    - MAC/PHY independence
  - Let vendor EMS manage our systems
    - The entire market is about management
  - Provide solutions that solve problems they are concerned about

Important observations on communications architecture

- All conversation are peer to peer
  - Actor reads sensor (request/response)
  - Sensor announces asynchronous events
  - Publish/Subscribe announcments
  - Command given to controller
- Sometimes these are “configuration”
  - Such as downloading certificates, rate tables, microcode, etc
- Often these are simply protocol exchanges
  - Command to reduce load temporarily
  - Current state

Important requirements placed on communications architecture

- Current base specification:
  - ANSI C12.19/22 OSI ACSE/ROSE on underlying architecture
  - Often “1, 2, 7”, which is to say application on link layer
  - IPv4 used in some places
- Basic stack use I’m recommending:
  - IPv4/IPv6, emphasis on IPv6
  - Transport such as UDP, TCP, NORM, etc.
    - Note that CoRe is recommending a UDP-based Restful HTTP/UDP
    - Zigbee is demonstrating utility of TCP for the purpose
  - TLS or IPsec
  - Simple encoding such as XML
- Security requirements include
  - Identification/Authentication of communicating peers
  - Authorization regarding instructions given
  - Signatures on *some* data
  - Encryption of *some* exchanges

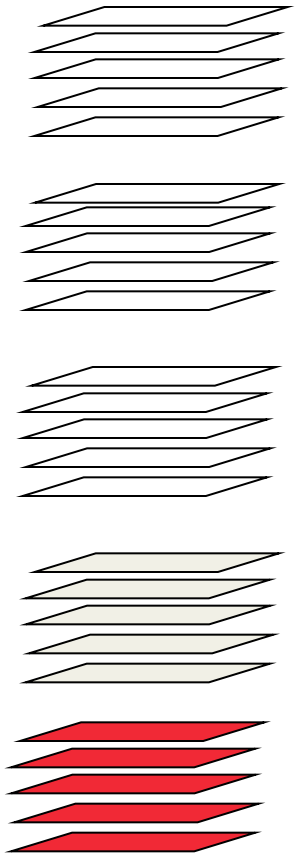
Possible directions

- Global perspective
  - Many places in the world deploying technology
- US perspective:
  - There is $billions on the table to be spent in the US over the next four years
- Current status
  - Vendors are excited, want to sell what they have
    - Generally proprietary, often Application-on-MAC/PHY
  - Utilities are worried, want to buy things they understand
  - ARIN to USG: “there aren’t IPv4 addresses to use…”

Backup Slides

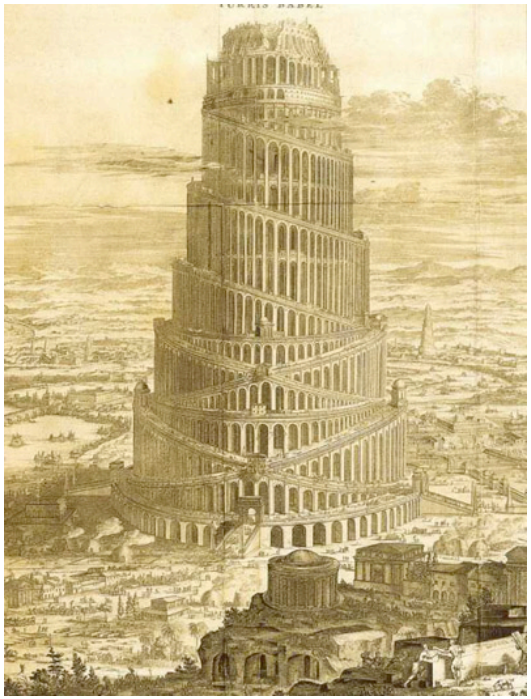
Use Case Management

Hundreds of relevant Use Cases to review



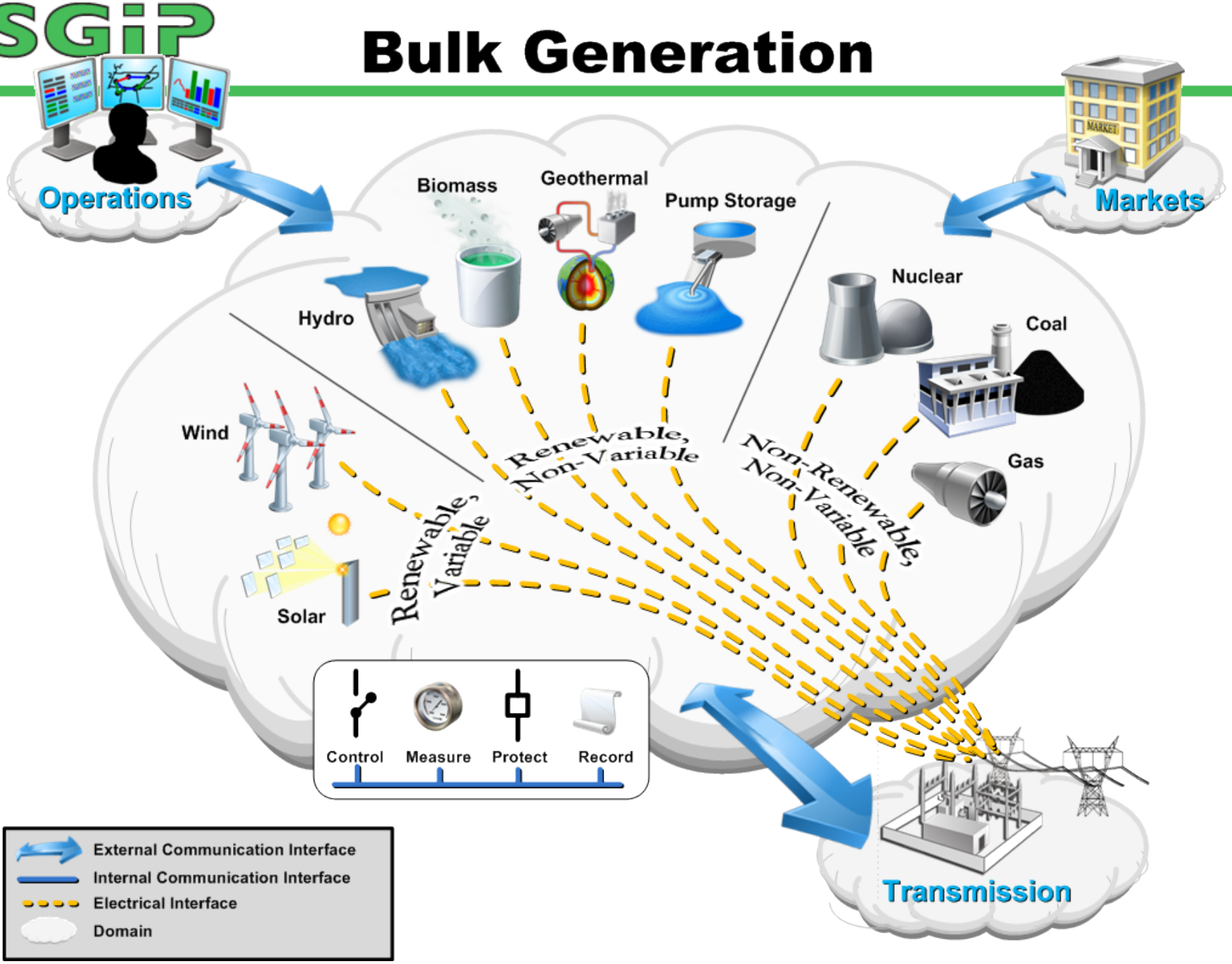
How to determine what to reuse?

All using different nomenclature for same things

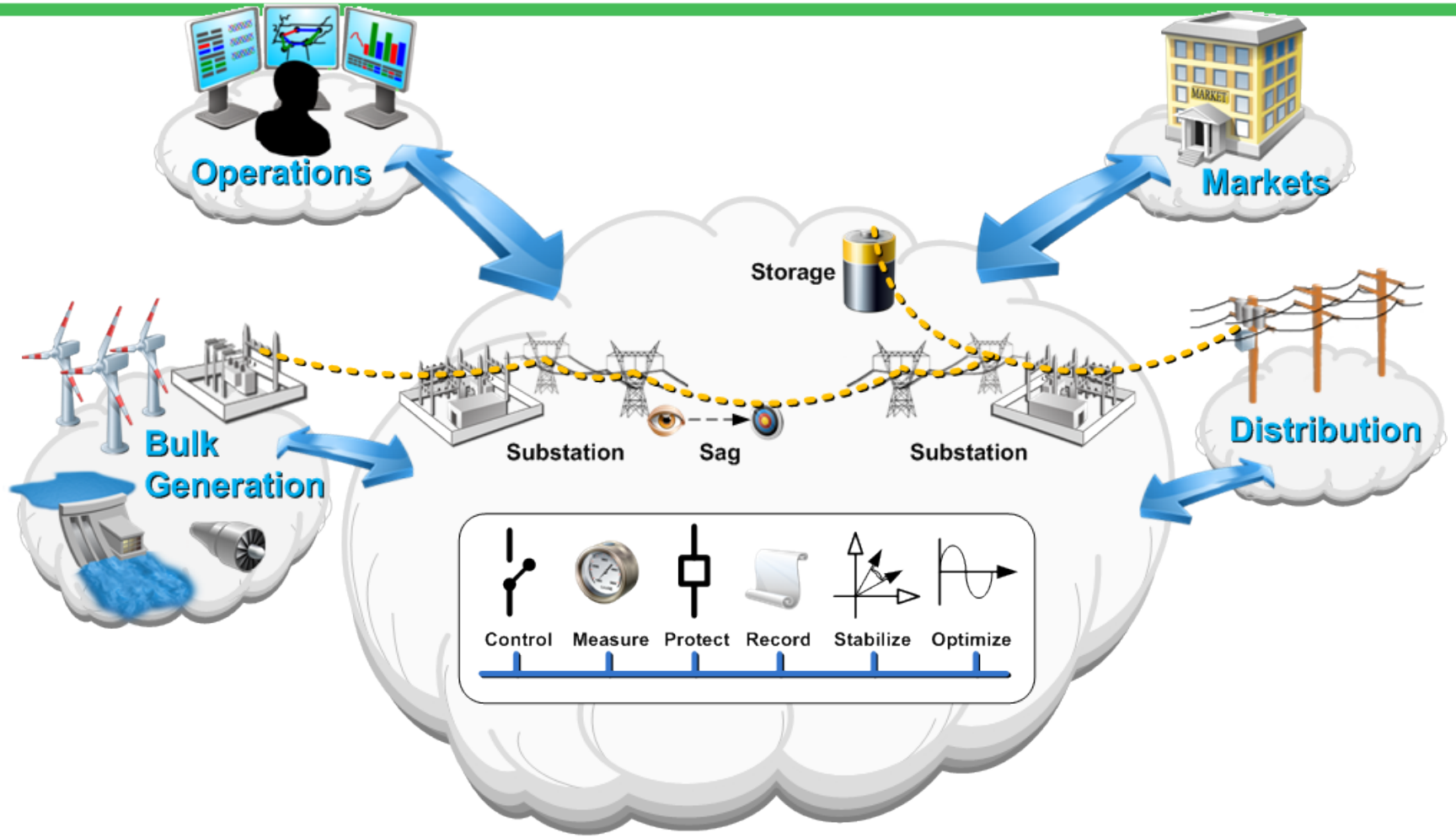


Turris Babel http://towerofbabel.391.org/athanasiuskircher.htm

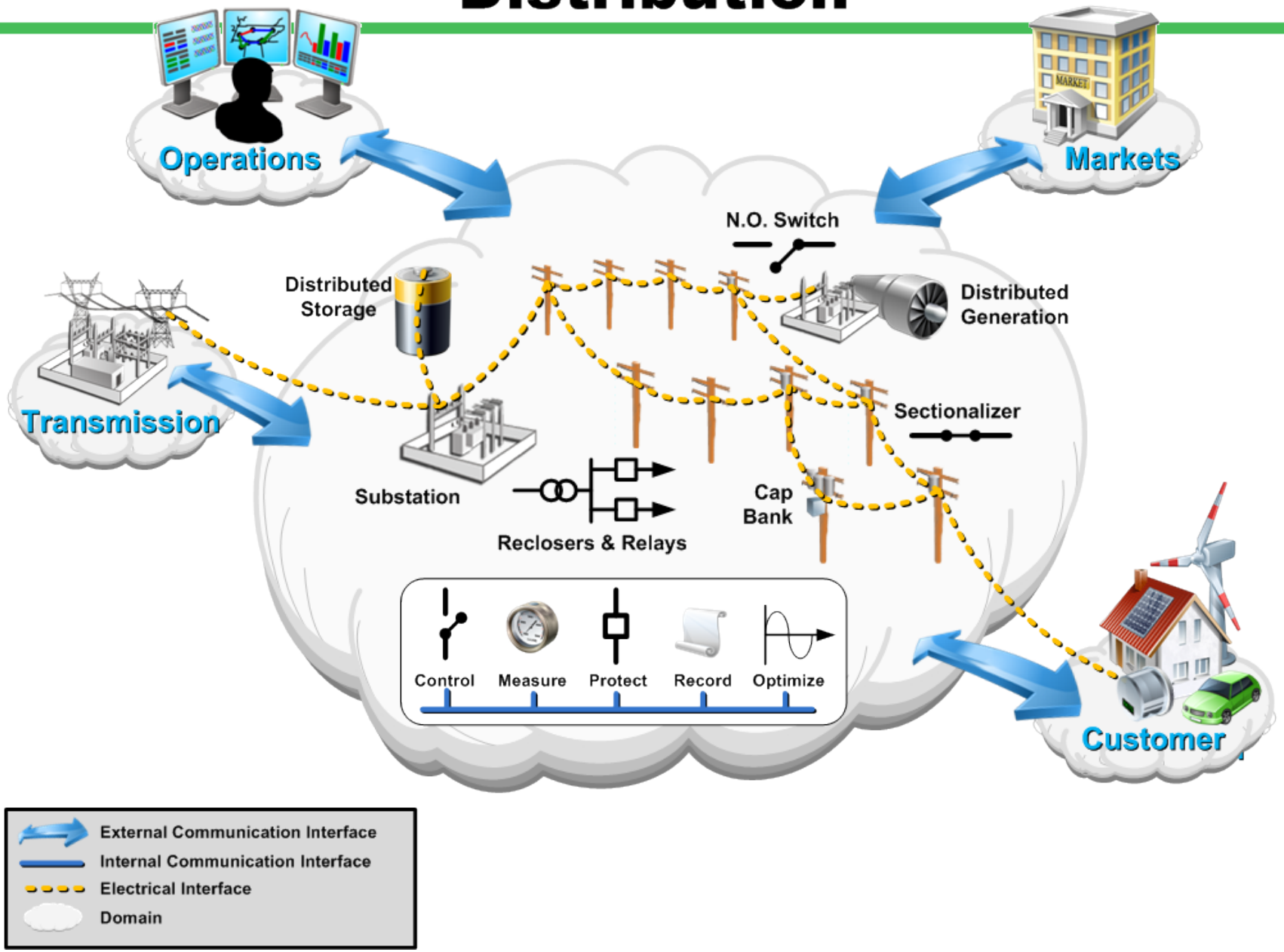
Bulk Generation



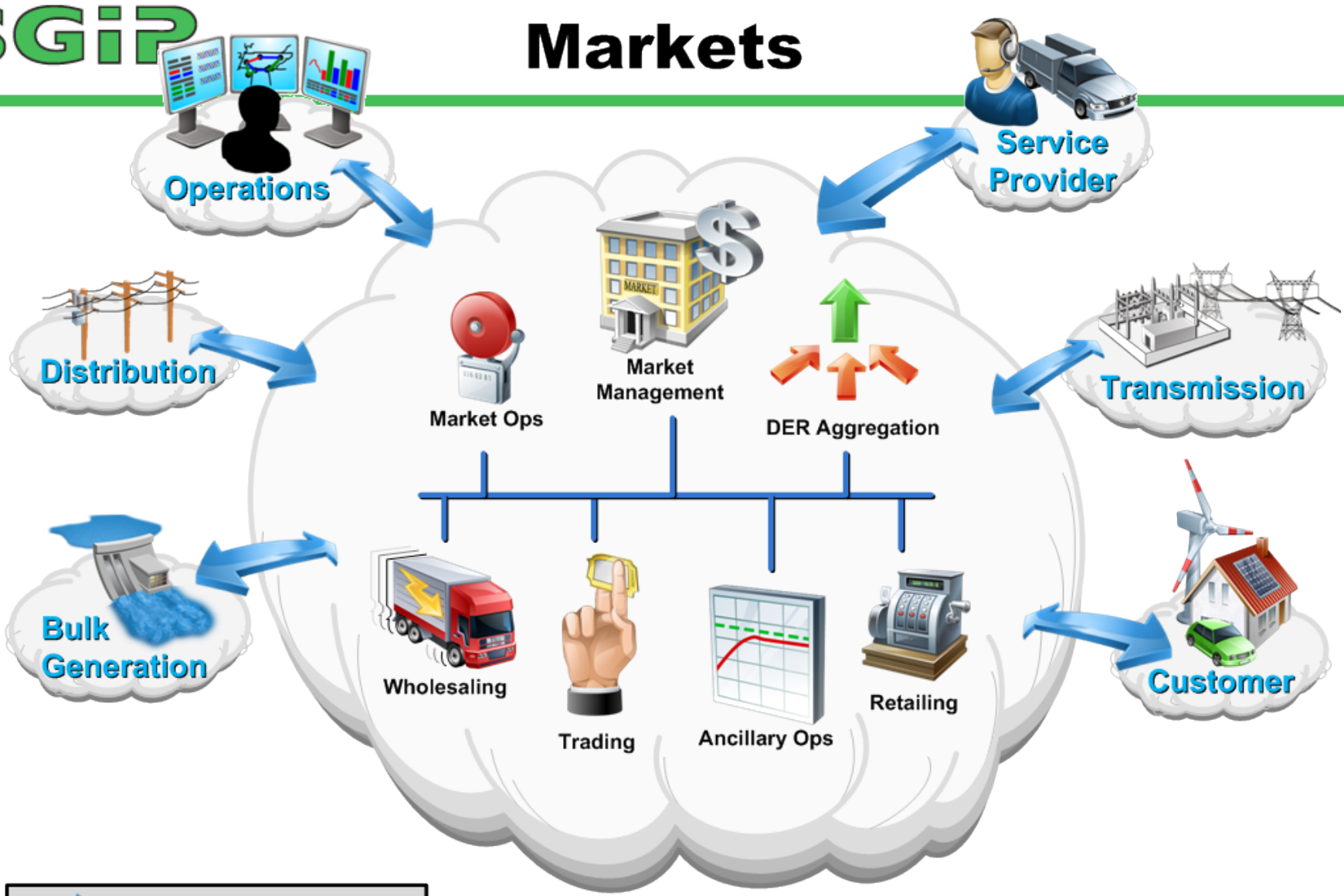
Transmission



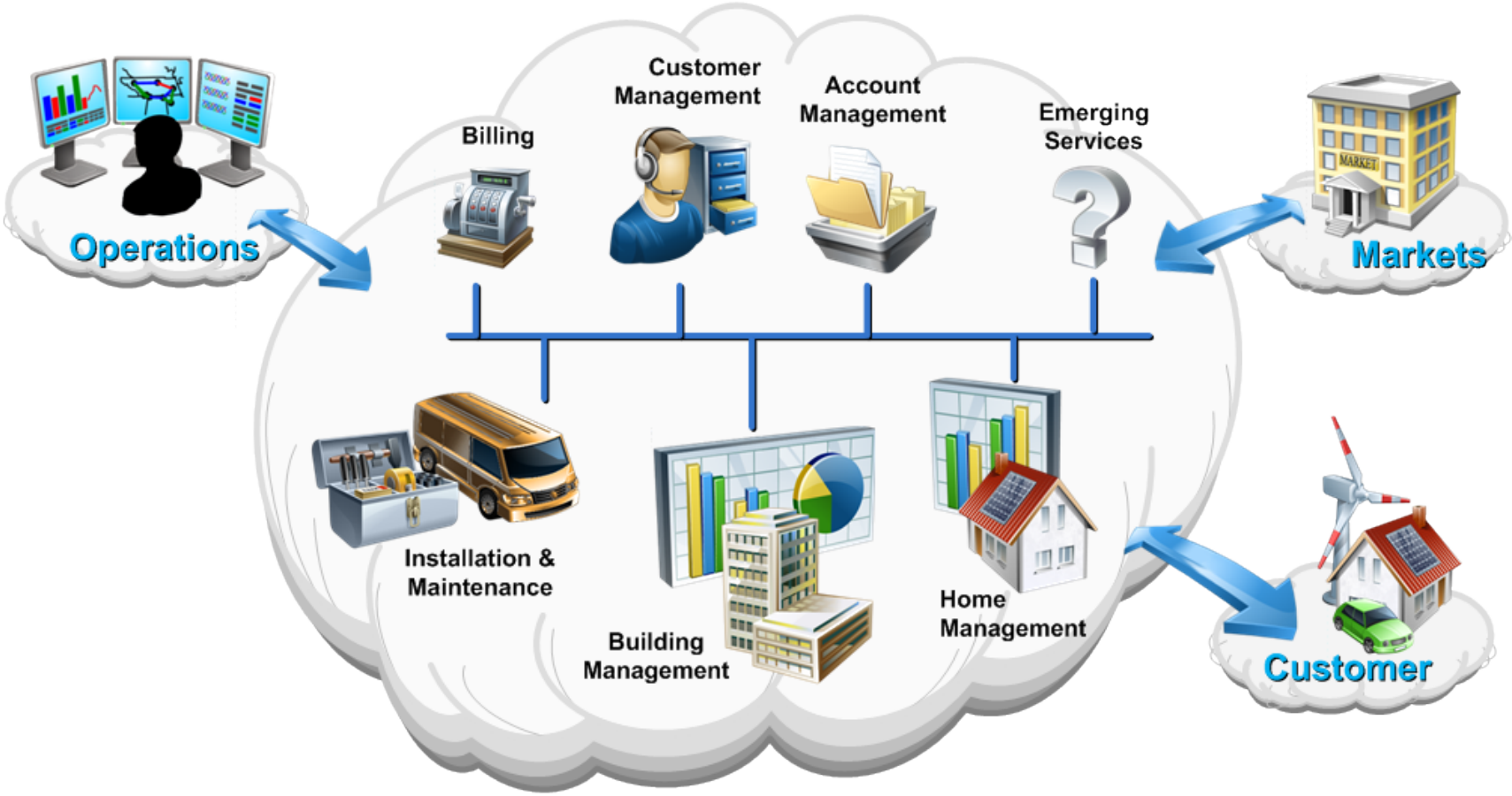
Distribution

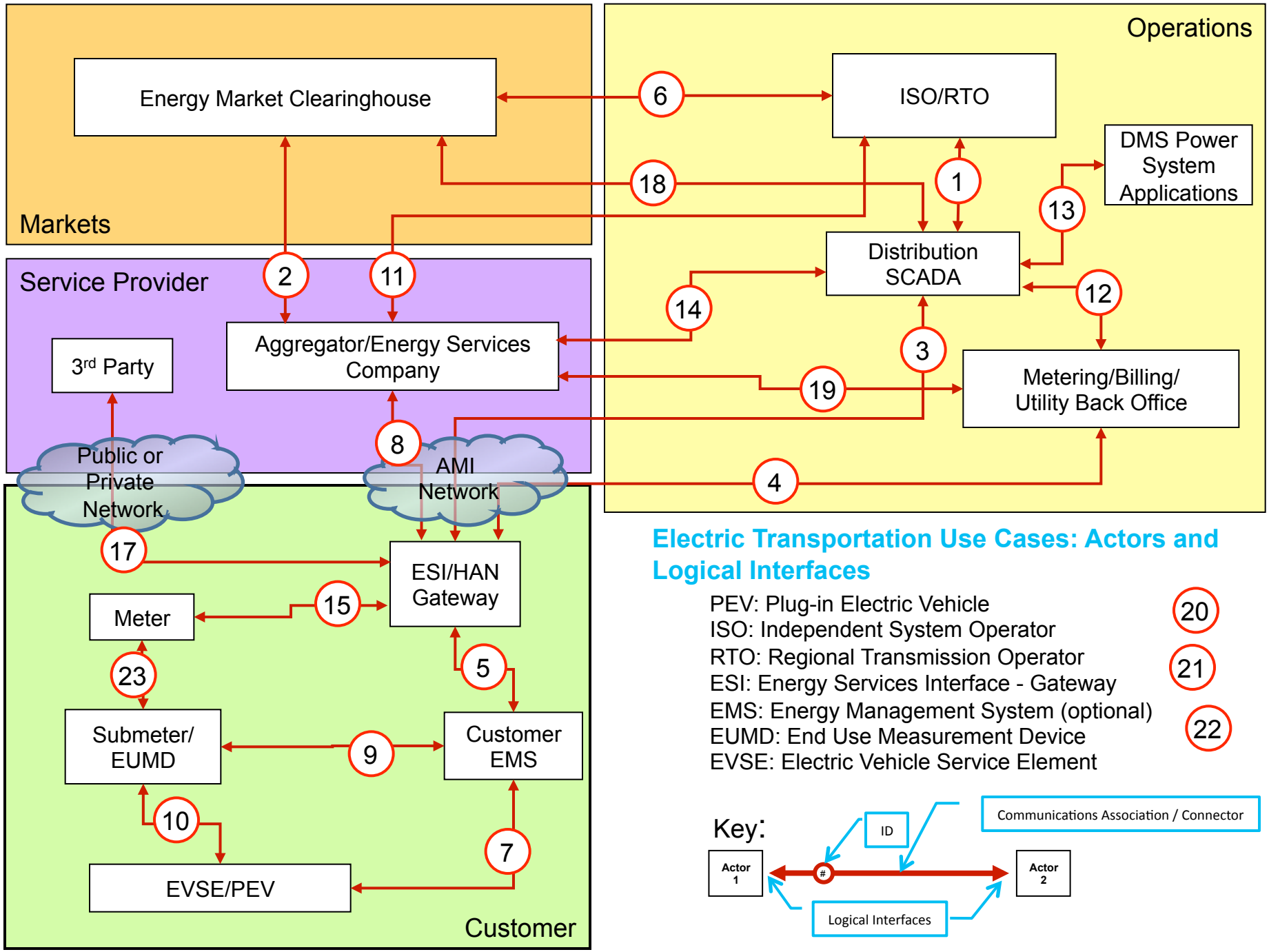


Markets


Operations
Service Provider
Distribution
Transmission
Market Ops
Market Management
DER Aggregation
Bulk Generation
Wholesaling
Trading
Ancillary Ops
Retailing
Customer
External Communication Interface
Internal Communication Interface
Electrical Interface
Domain

Service Provider



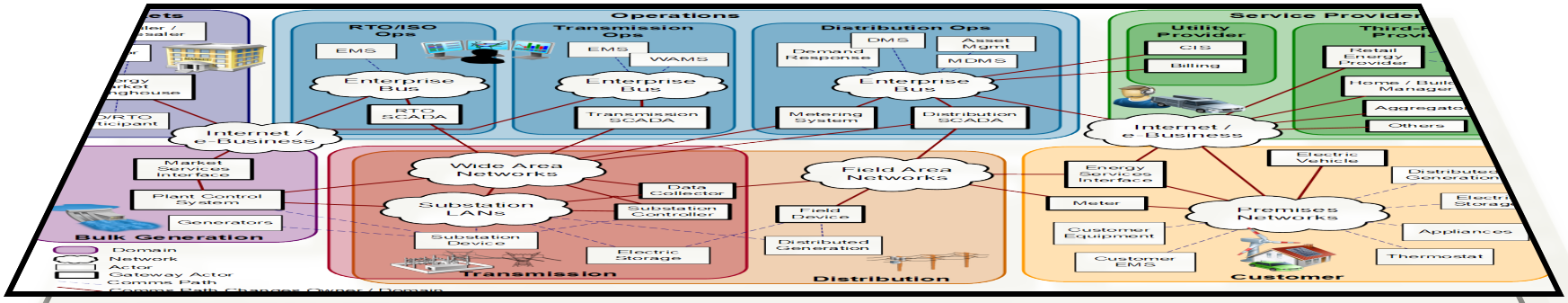


Electric Transportation Use Cases: Actors and Logical Interfaces

PEV: Plug-in Electric Vehicle
ISO: Independent System Operator
RTO: Regional Transmission Operator
ESI: Energy Services Interface - Gateway
EMS: Energy Management System (optional)
EUMD: End Use Measurement Device
EVSE: Electric Vehicle Service Element

Key:

The "GWAC Stack" Underneath



Organizational: Policy, Business Objectives, Business Procedures

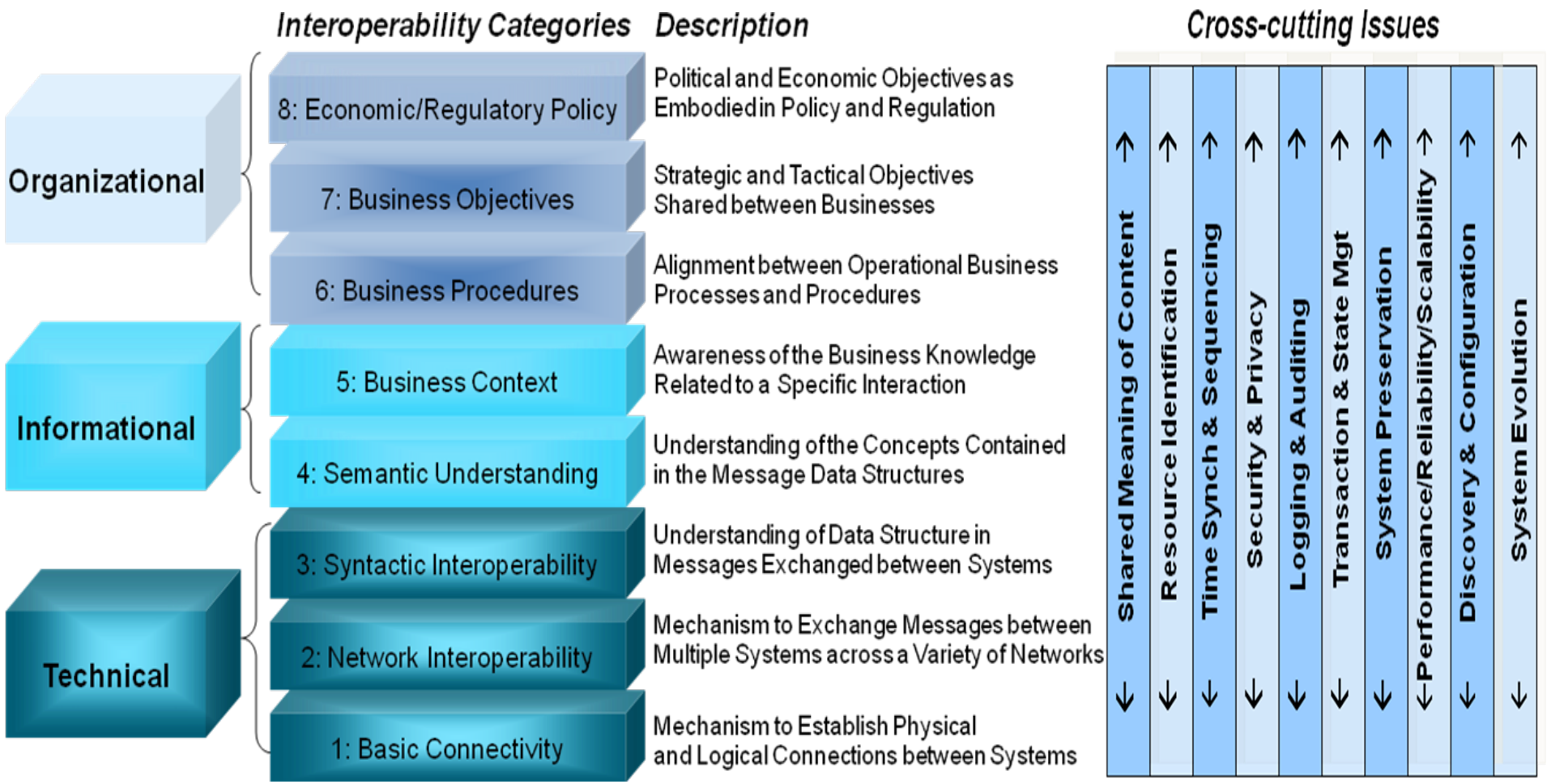
Informational: Business Context, Semantic Understanding

Technical: Syntactic Interoperability, Network Interoperability, Basic Connectivity

Cross-Cutting Issues: Security, Resource Identification, Time Synch, etc.

Source: EnerNex

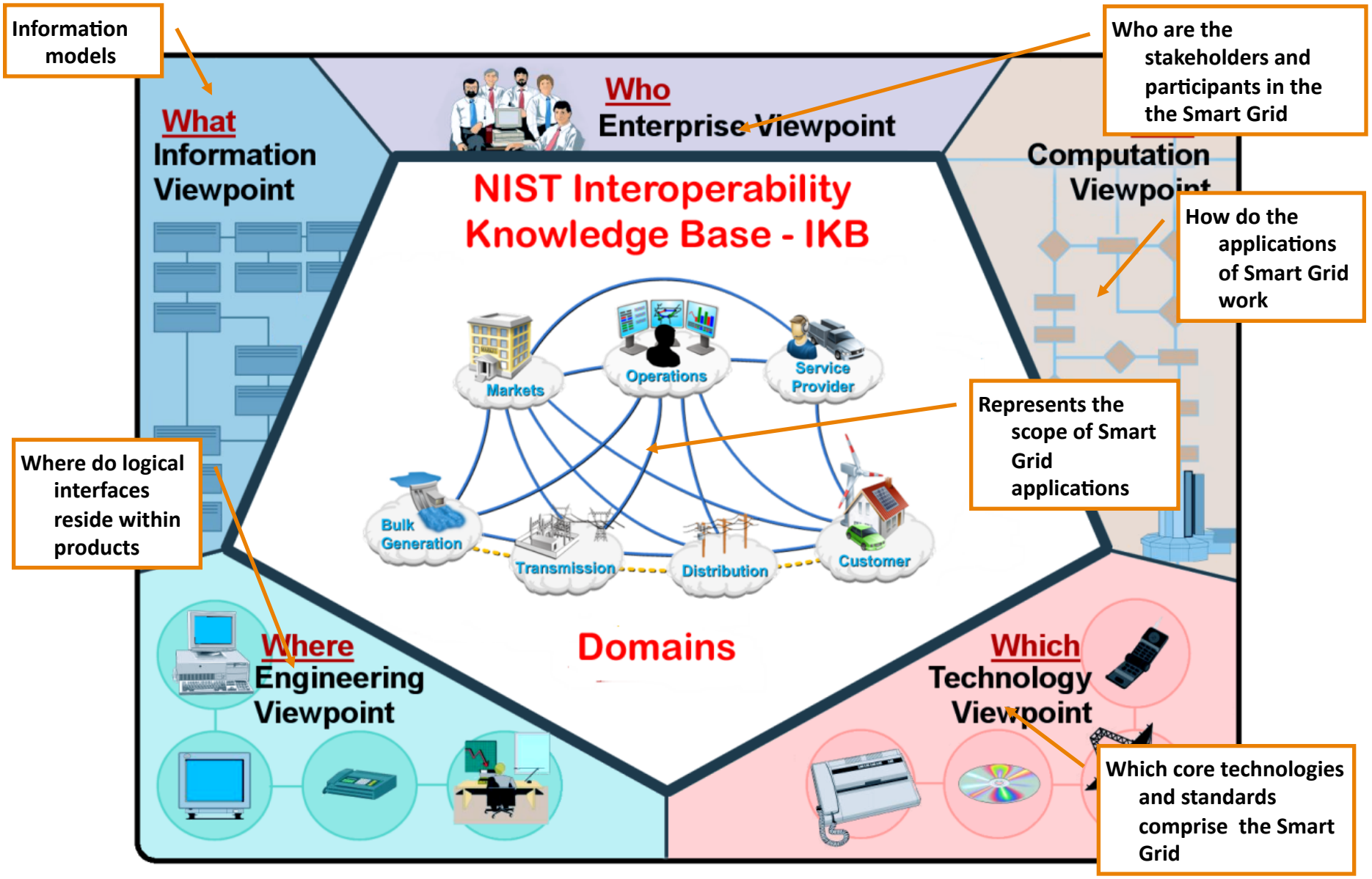
GWAC Stack – Levels of Interoperability



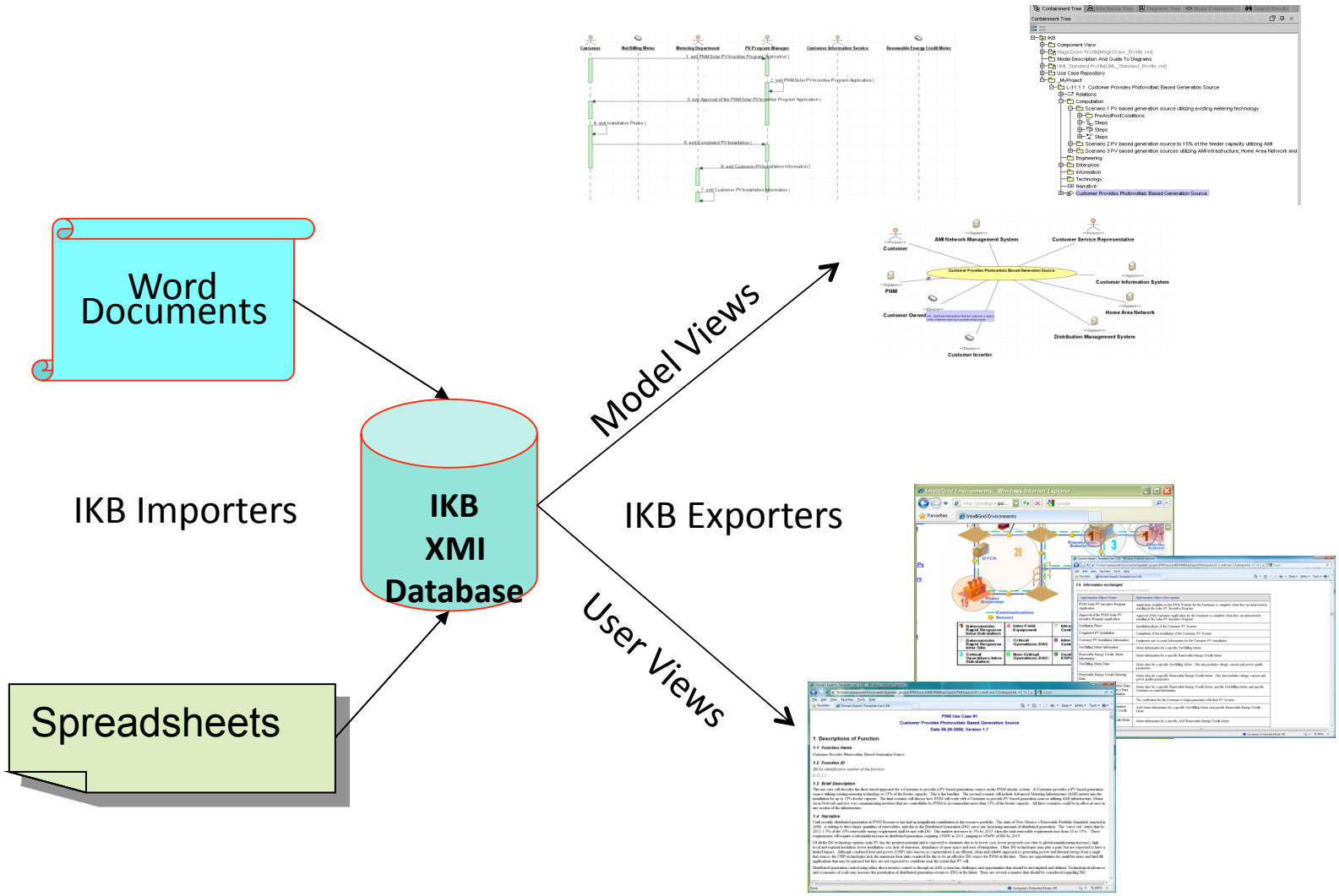
First 16 NIST Framework Standards

1	AMI-SEC System Security Requirements	✓	✓	✓			✓	✓
2	ANSI C12.19 End Device (Meter) Tables		✓	✓				✓
3	BACnet Building Automation & Control Net			✓	✓			✓
4	DNP3 – Distributed Network Protocol		✓		✓	✓	✓	
5	IEC 60870-6 – Inter-Control Center		✓					
6	IEC 61850 – Comms Nets in Substations		✓		✓	✓	✓	
7	IEC 61968/61970 – Common Info Model		✓	✓				
8	IEC 62351 – Data Comms Security		✓		✓	✓	✓	
9	IEEE C37.118 - Synchrophasors		✓			✓		
10	IEEE 1547 – Distributed Resources		✓		✓	✓	✓	
11	IEEE 1686 – IED Cyber Security				✓	✓	✓	
12	NERC Critical Infrastructure Protection	✓	✓	✓	✓	✓	✓	✓
13	NIST SP 800-53/82 Fed Info Sys Security	✓	✓	✓	✓	✓	✓	✓
14	Open Automated Demand Response	✓	✓	✓				✓
15	Open Home Area Network Requirements							✓
16	ZigBee/HomePlug Smart Energy Profile							✓

Conceptual Model as Architectural View



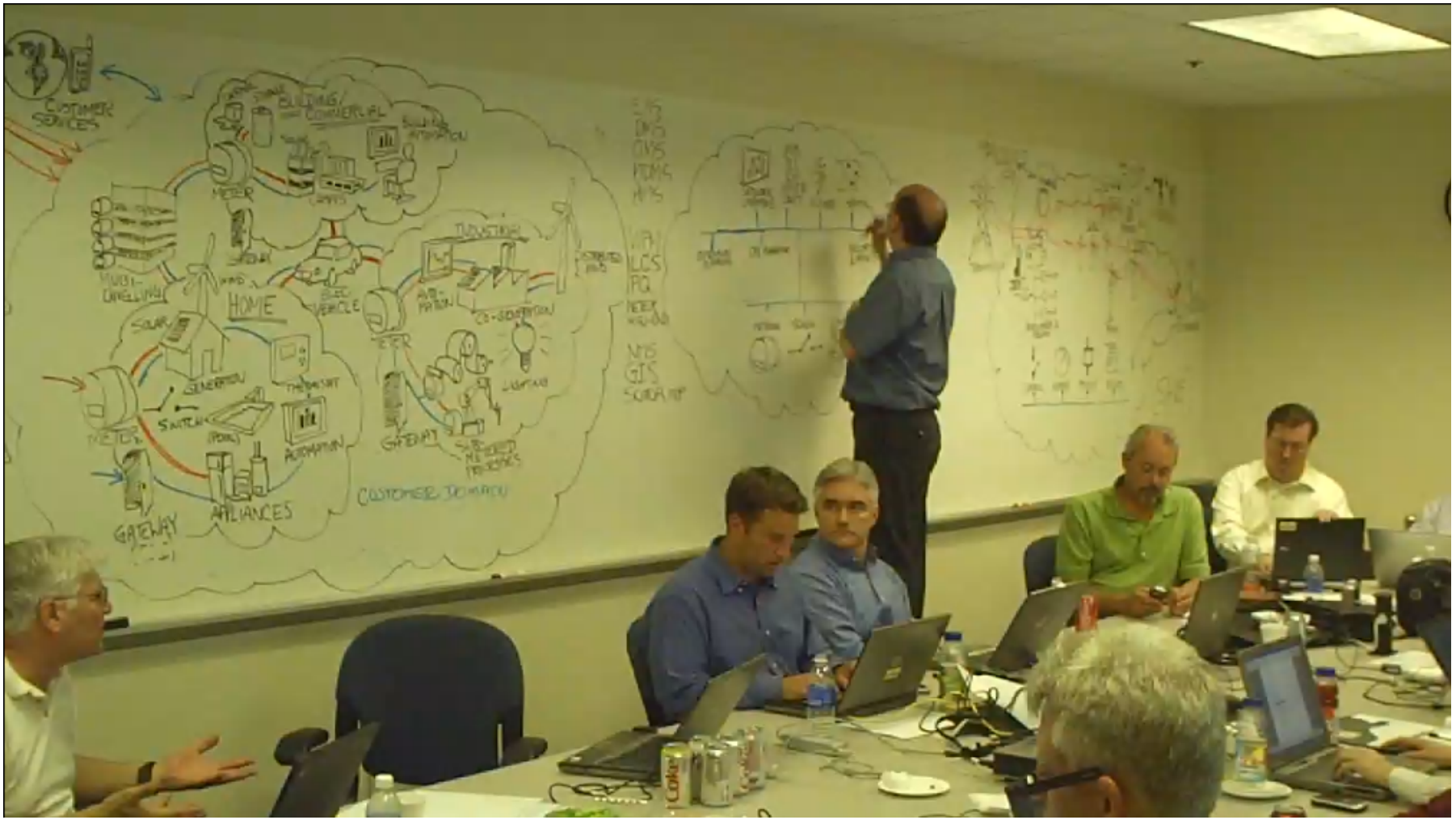
NIST Interoperability Knowledge Base



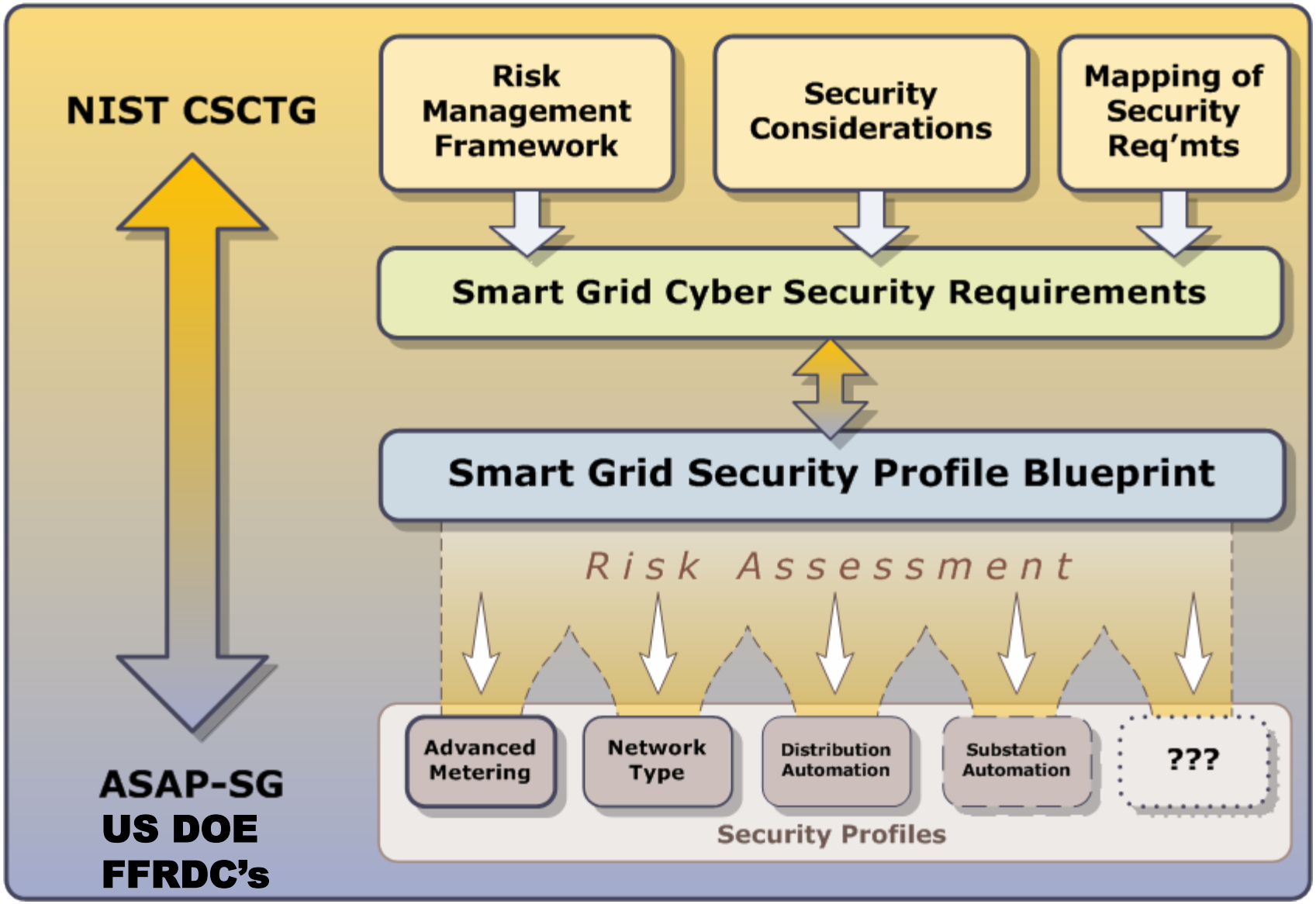
Model Usage

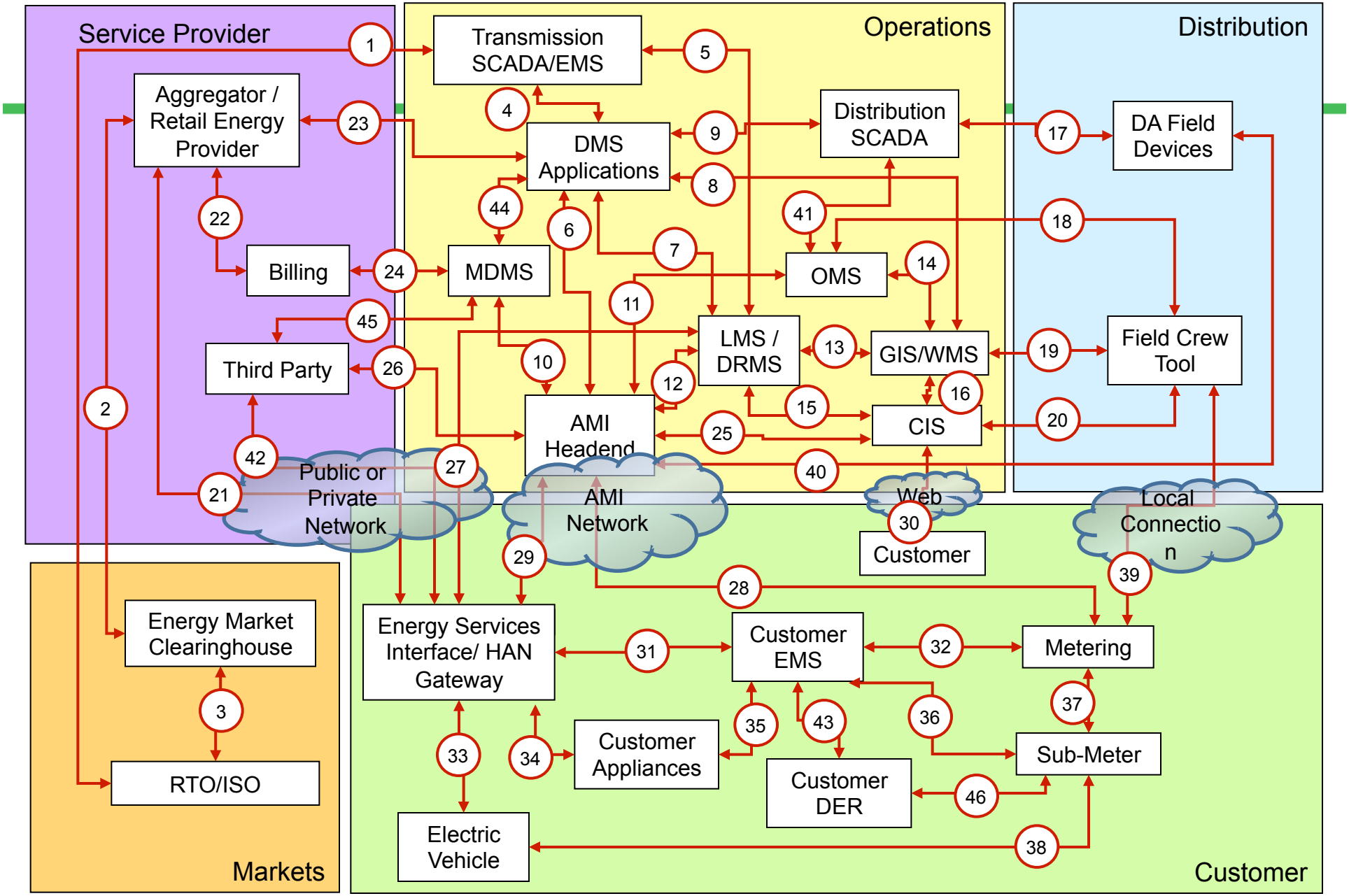
- Please use the model! Ask us for the PPT!
- Intended to be adopted widely as a consistent means of discussing and analyzing the smart grid and its applications
- Example – The IEEE PES will use the model as a means to:
  - Organize the IEEE PES smart grid web site
  - Ensure topic coverage for new publication – Transactions on Smart Grid
  - Organize smart grid symposia topics and sessions
  - Categorize inventory of existing standards and projects
  - Categorize a smart grid bibliography and reference set

Panel Discussion – “LA 15”



DOE / NIST / UCAIug / ASAP-SG Effort



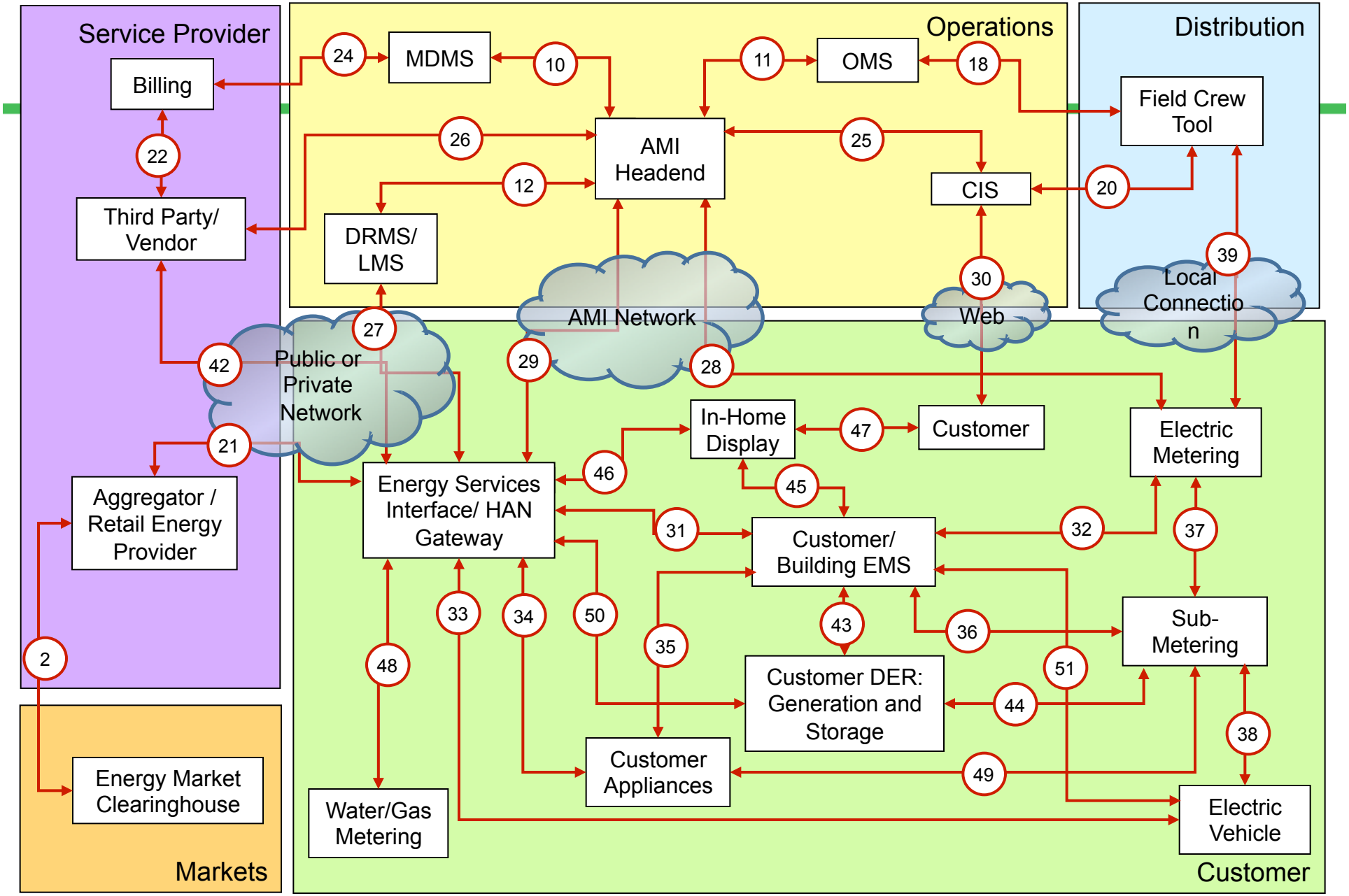


AMI Systems Use Cases: Actors, Logical Interfaces, and Networks

AMI: Advanced Metering Infrastructure
SCADA: Supervisory Control and Data Acquisition
WMS: Work Management System

DRMS: Demand Response Management System
MDMS: Meter Data Management System
DMS: Distribution Management System
EMS: Energy Management System

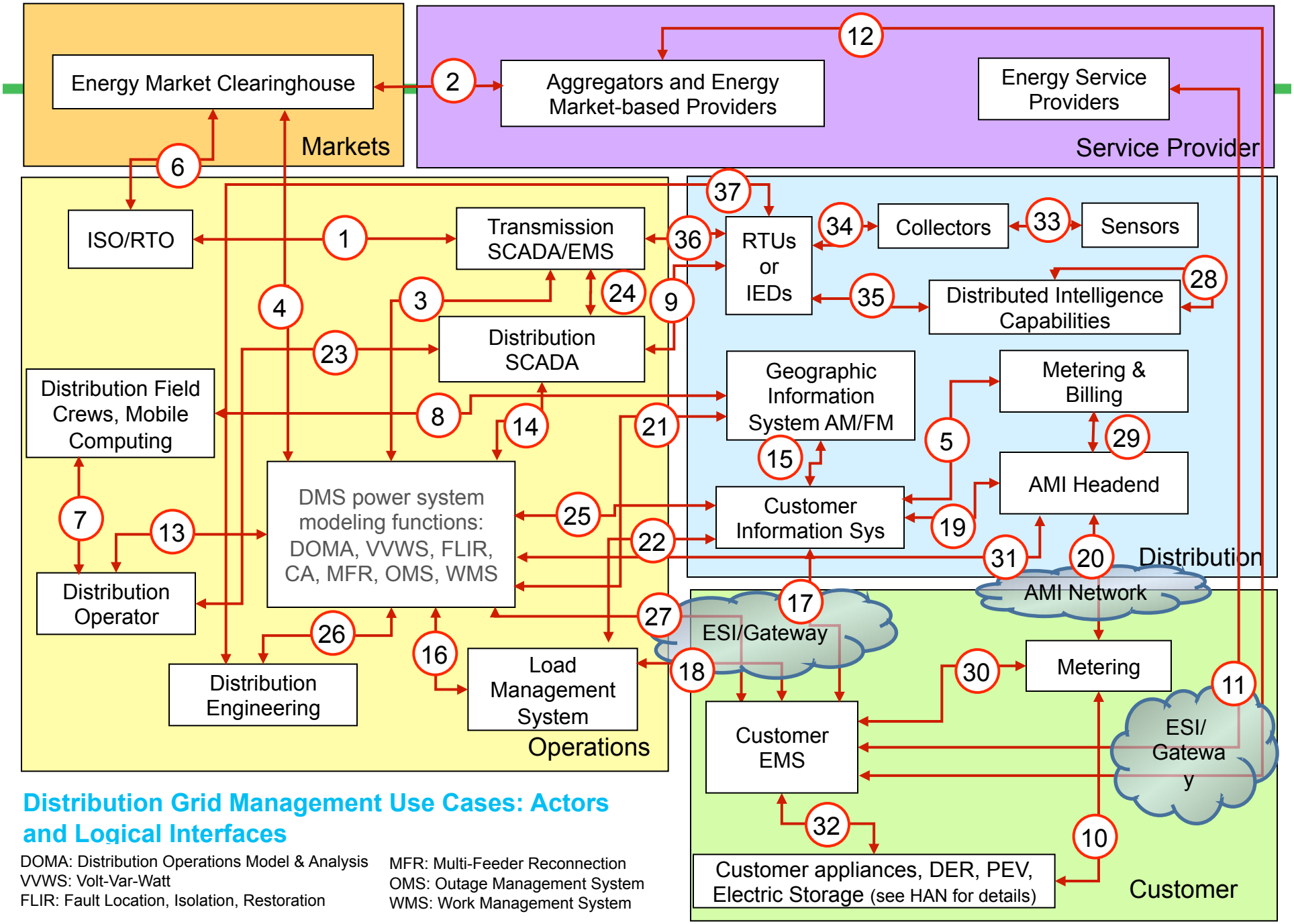
LMS: Load Management System
GIS: Geographic Information System
CIS: Customer Information System
OMS: Outage Management System



HAN/BAN Use Cases: Actors, Logical Interfaces, and Networks

DRMS: Demand Response Management System
LMS: Load Management System
CIS: Customer Information System
OMS: Outage Management System

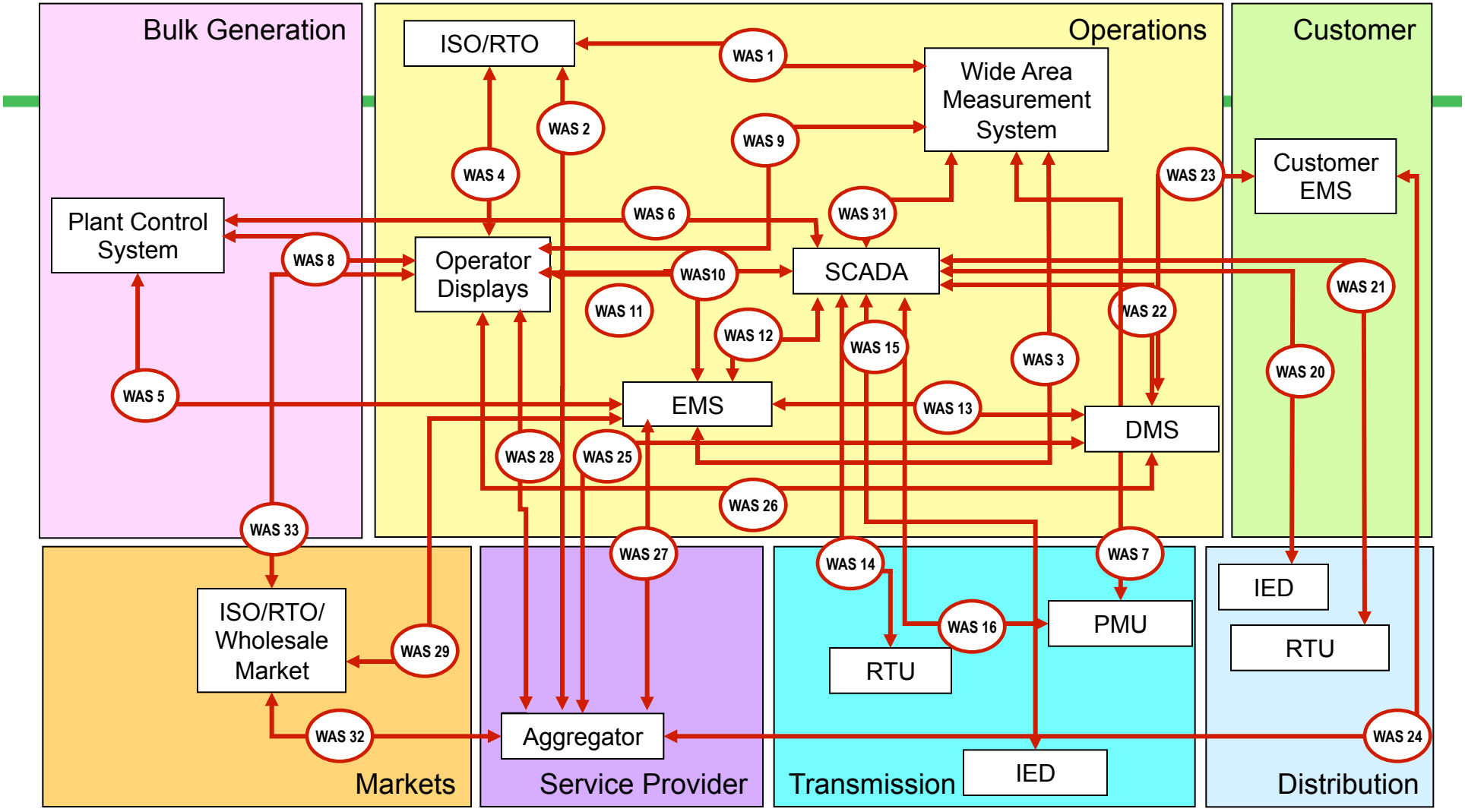
HAN: Home Area Network
DER: Distributed Energy Resources
MDMS: Meter Data Management System
EMS: Energy Management System



Distribution Grid Management Use Cases: Actors and Logical Interfaces

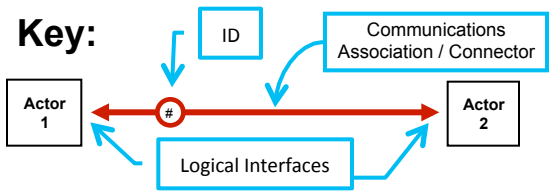
DOMA: Distribution Operations Model & Analysis
VVWS: Volt-Var-Watt
FLIR: Fault Location, Isolation, Restoration

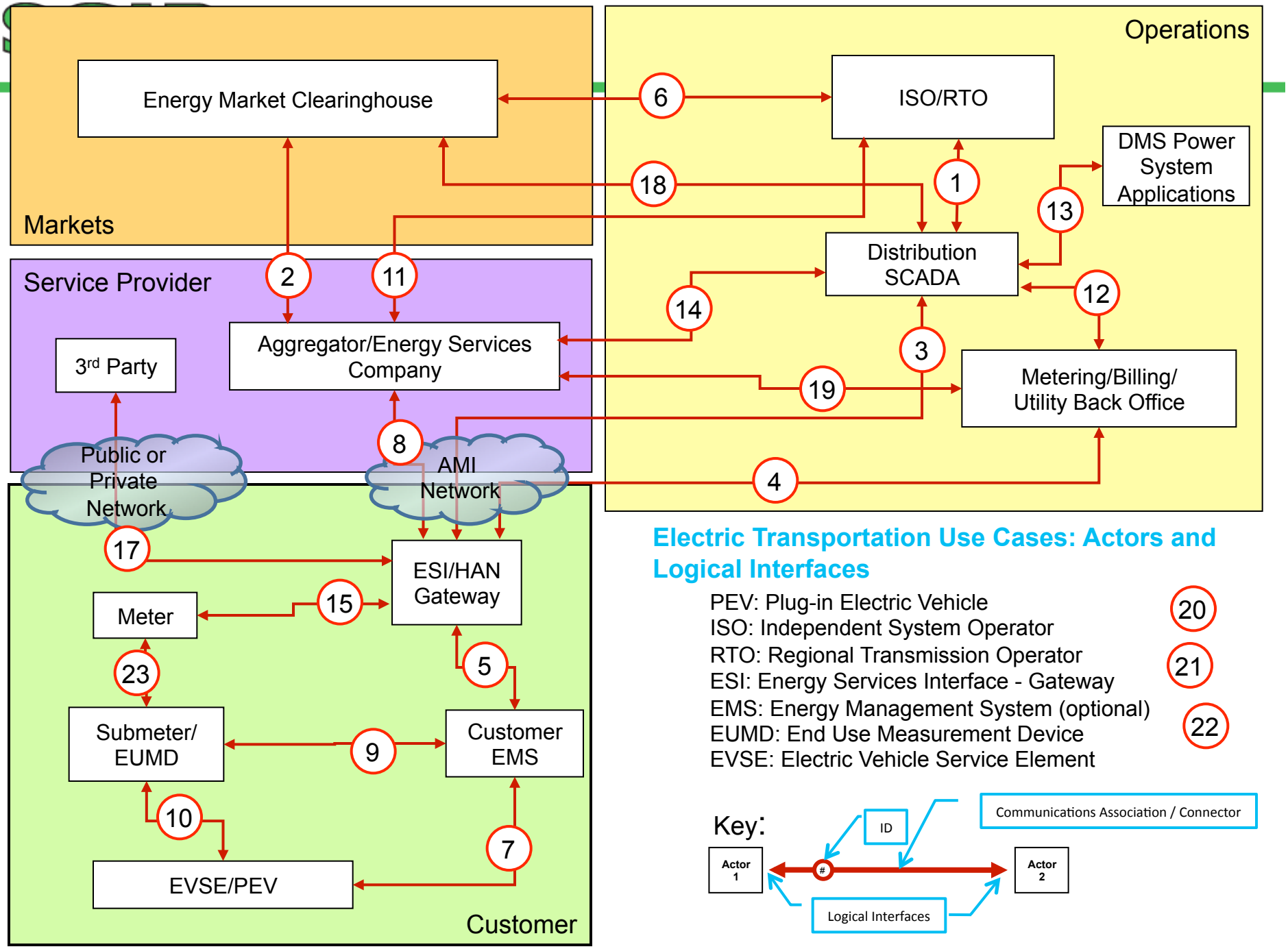
MFR: Multi-Feeder Reconnection
OMS: Outage Management System
WMS: Work Management System



Wide-Area Situational Awareness (WASA) Use Cases: Actors and Logical Interfaces

IED: Intelligent Electronic Device
DMS: Distribution Management System
EMS: Energy Management System
SCADA: Supervisory Control and Data Acquisition
AMI: Advanced Metering Infrastructure



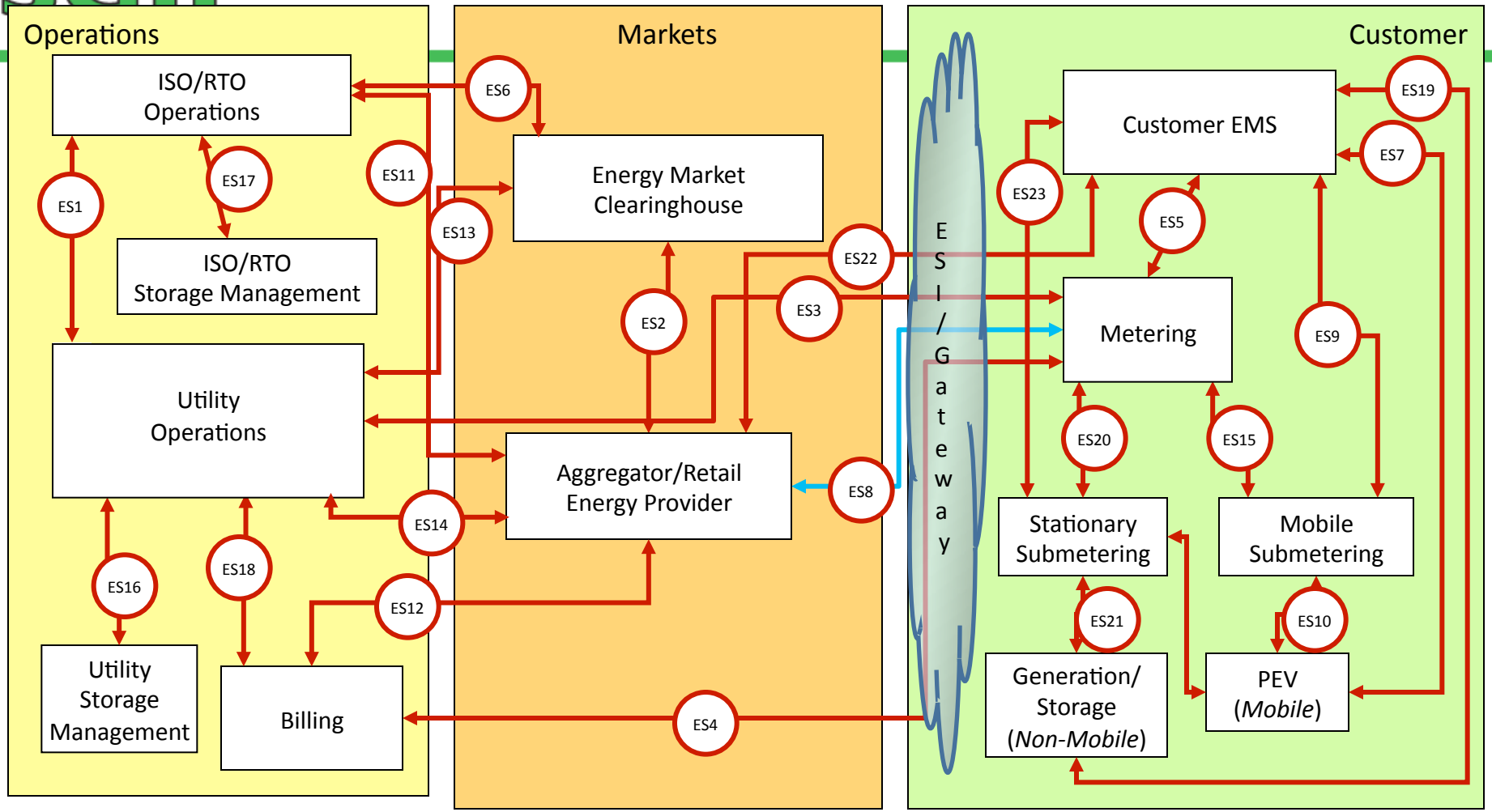


Electric Transportation Use Cases: Actors and Logical Interfaces

PEV: Plug-in Electric Vehicle
ISO: Independent System Operator
RTO: Regional Transmission Operator
ESI: Energy Services Interface - Gateway
EMS: Energy Management System (optional)
EUMD: End Use Measurement Device
EVSE: Electric Vehicle Service Element

Key:

Electric Storage Use Cases: Actors and Logical Interfaces



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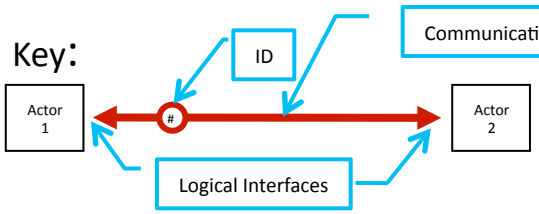
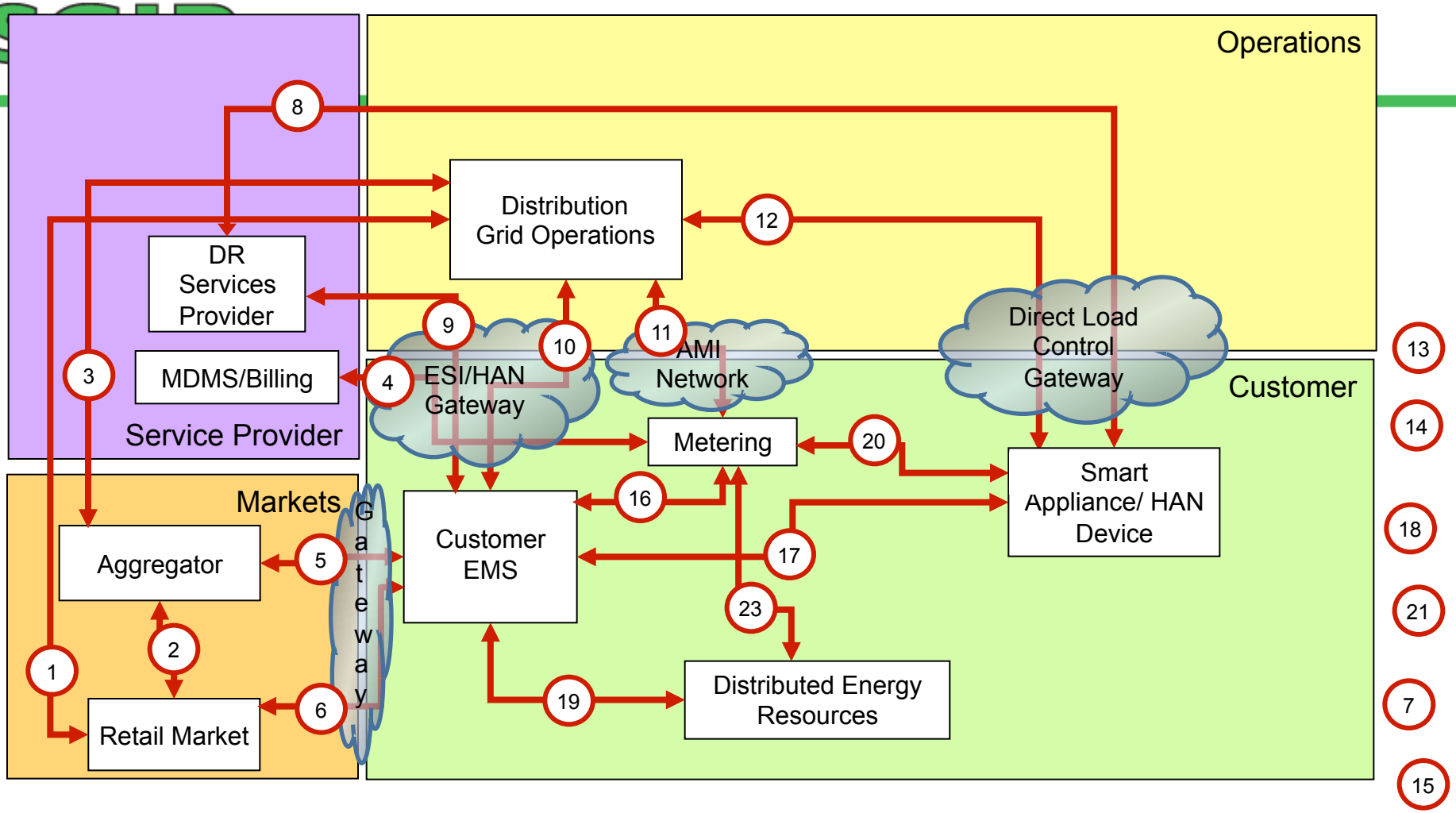


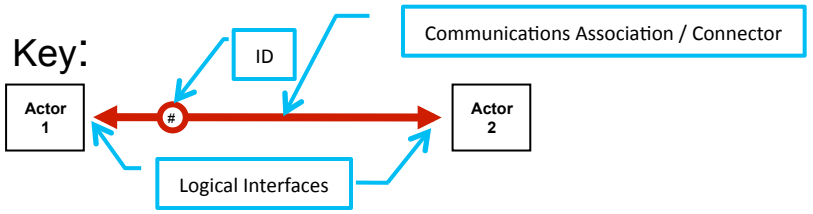
EMS: Energy Management System
ESI: Energy Services Interface
EUMD: End Use Measurement Device
ISO: Independent System Operator
PEV: Plug-in Electric Vehicle
RTO: Regional Transmission Operator

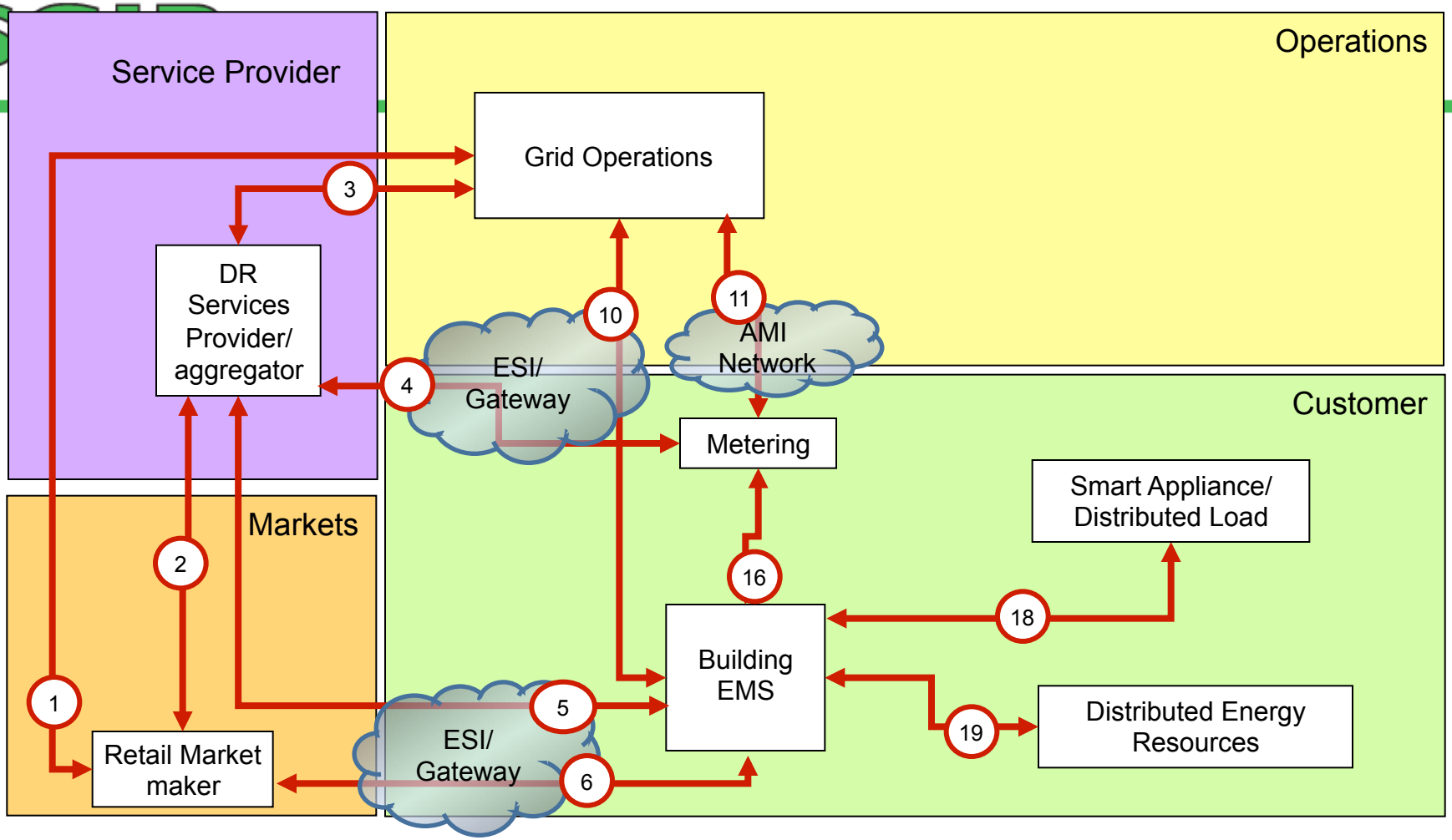


H2G Demand Response Use Cases: Actors and Logical Interfaces

HAN: Home Area Network
EMS: Energy Management System
DR: Demand Response

Key:





Removed Interfaces: 7 (meter doesn't get market signals), 8 (SP talks to devices through ESI), 12 (no grid op cnx to HAN device), 14 (not sure on this one), 17 (same as 18), 20-21 (meter doesn't talk to devices, but for AMI case ESI can be put in meter)

B2G Demand Response Use Cases:

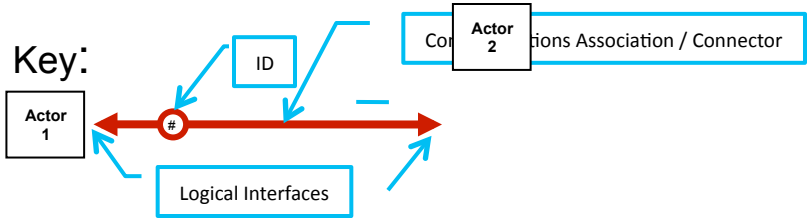
Actors and Logical Interfaces

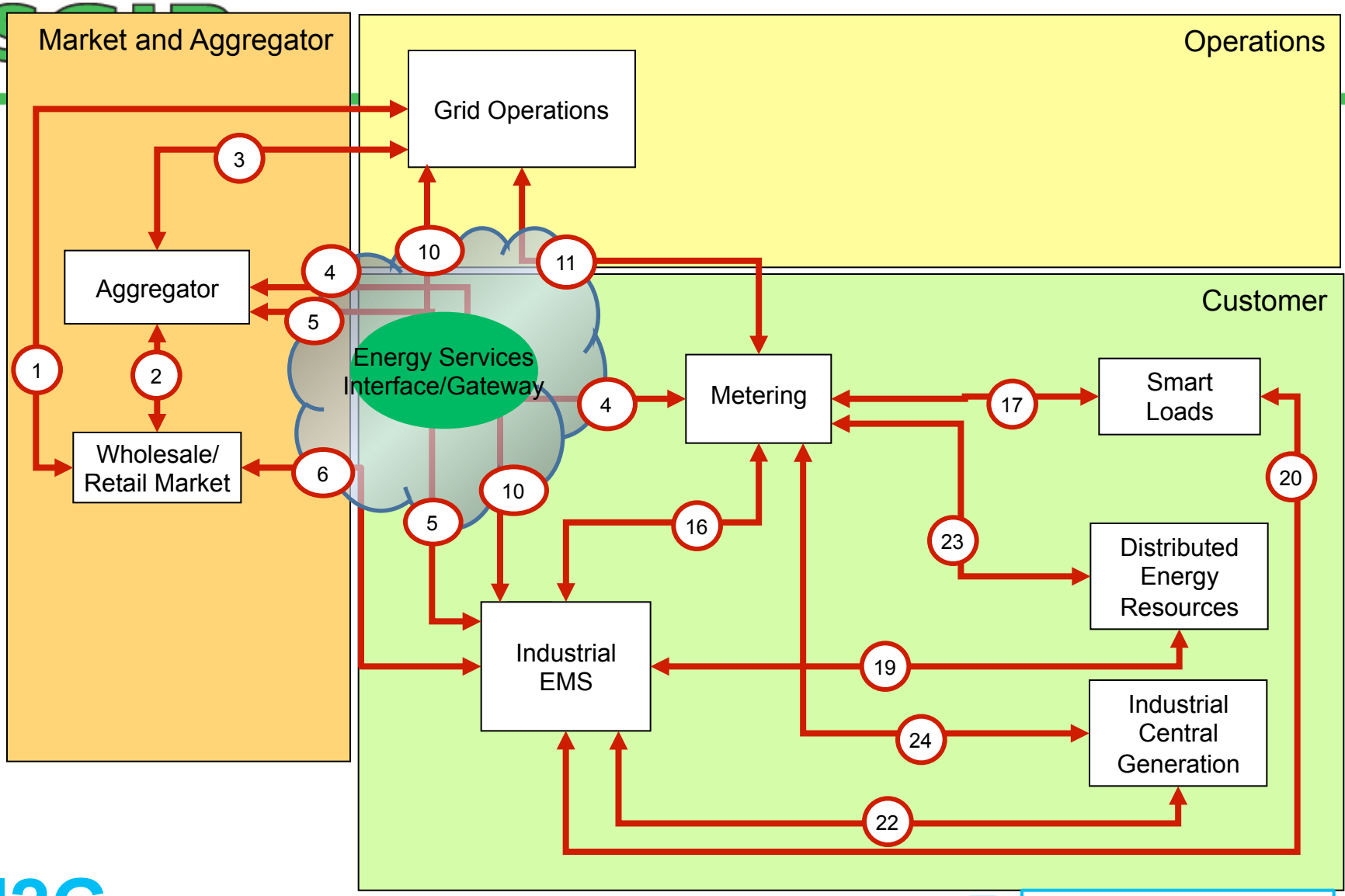
HAN: Home Area Network
EMS: Energy Management System
DR: Demand Response

15

13

Key:





I2G Demand Response Use Cases: Actors and Logical Interfaces

13 14 25

ESI: Energy Services Interface
EMS: Energy Management System
DR: Demand Response

Key: