Frameworks and Data Initiatives for Smart Grid and Cyber-Physical Systems

DEBS 2013 – July 2, 2013

David Wollman david.wollman@nist.gov

Deputy Director, Smart Grid and Cyber-Physical Systems Program Office,
Engineering Laboratory, National Institute of Standards and Technology

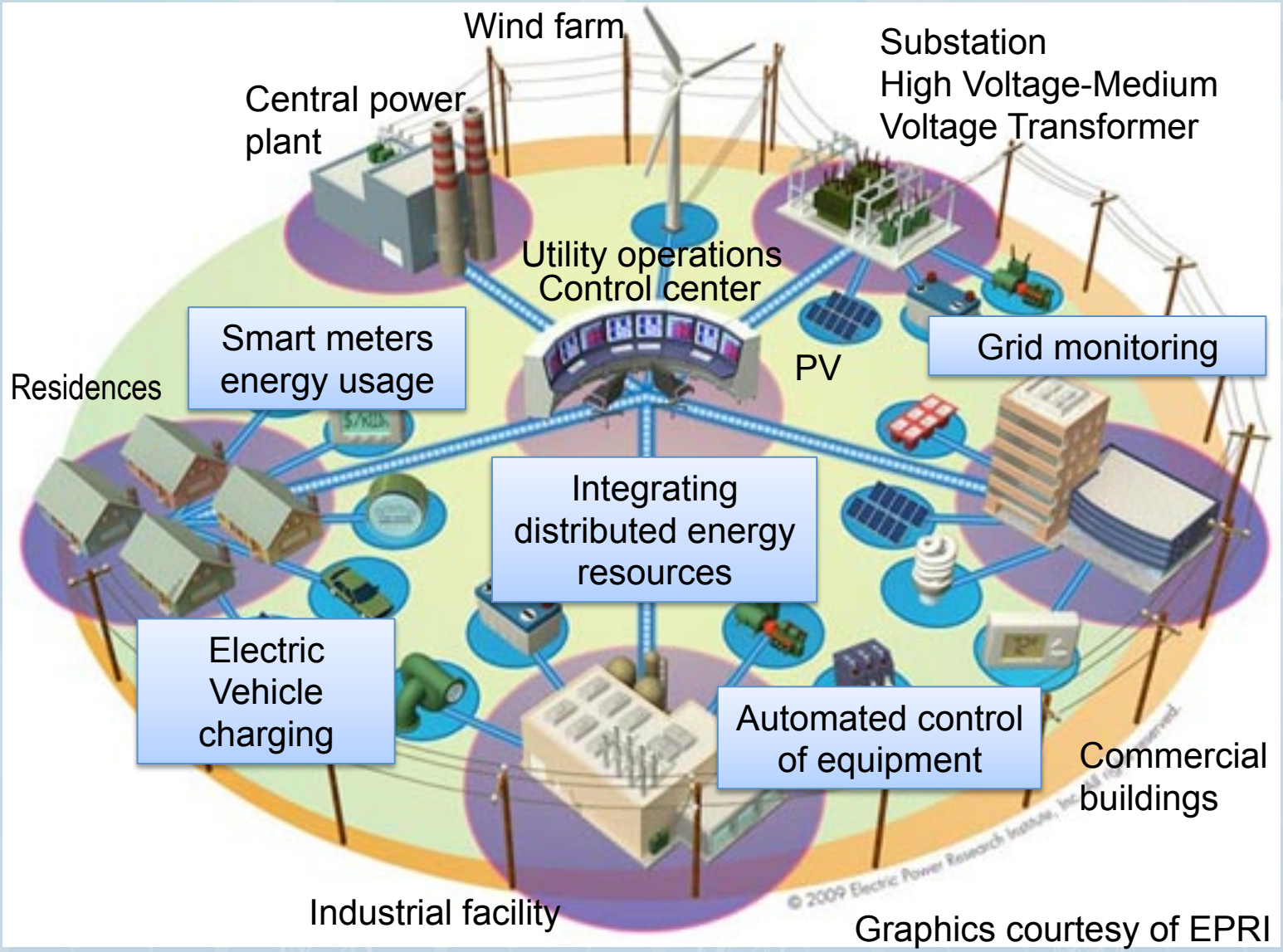
NIST National Institute of Standards and Technology U.S. Department of Commerce

engineering laboratory

Outline

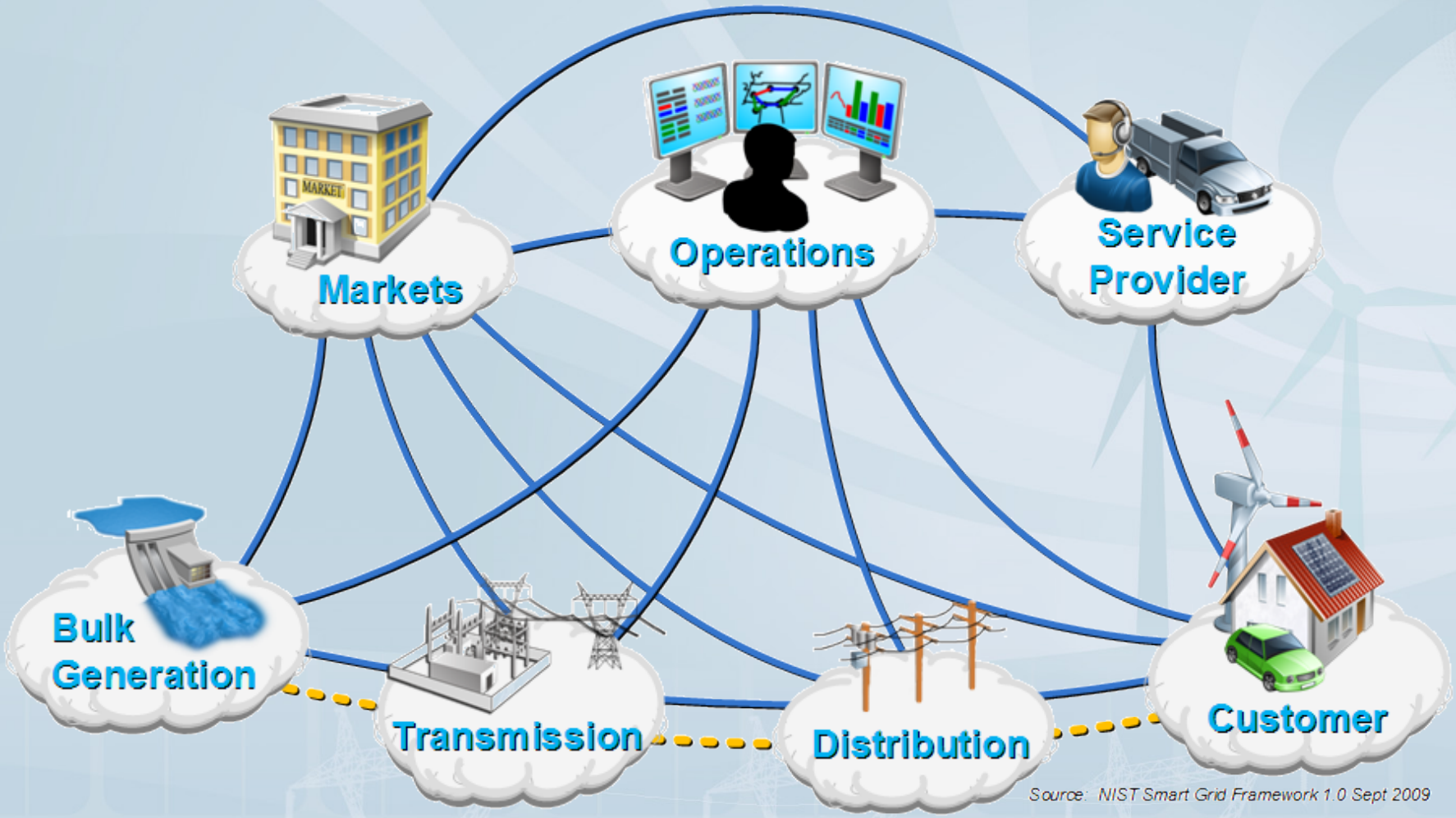
- Smart Grid introduction
  - Interoperability
  - NIST standards coordination
- Frameworks
  - Smart Grid
  - Cyber-Physical Systems
- Smart Grid Data Initiatives
  - Green Button Initiative
  - Data Challenges

Smart Grid



Graphics courtesy of EPRI

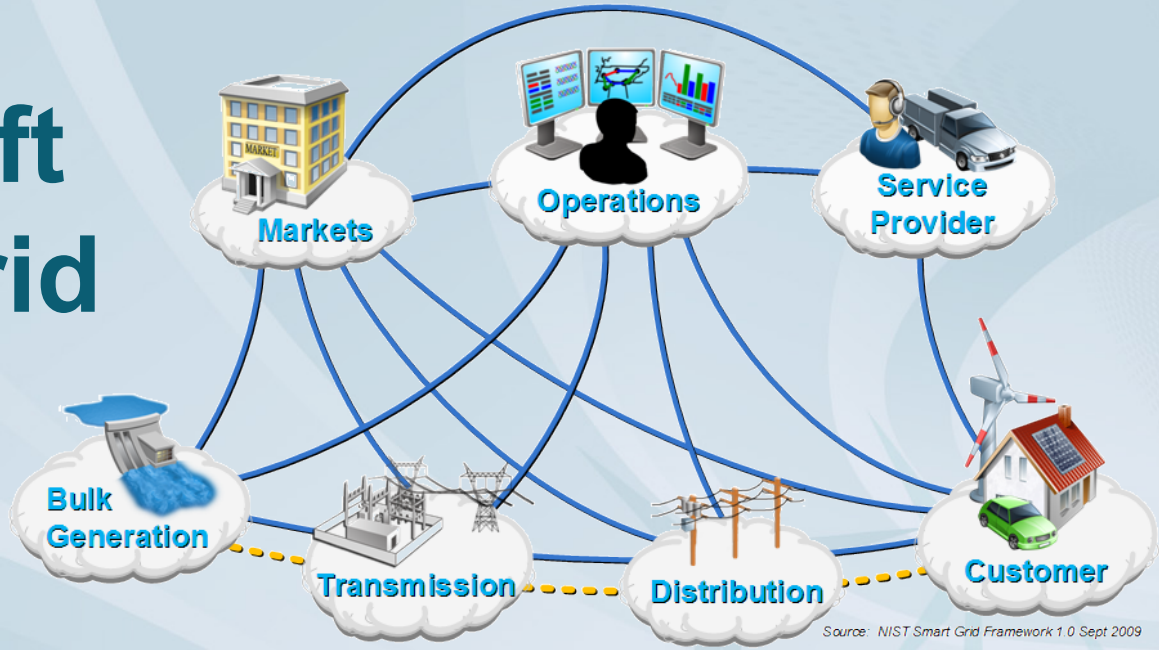
Smart Grid



Source: NIST Smart Grid Framework 1.0 Sept 2009

Paradigm Shift → Smart Grid

Drivers: Efficiency, Reliability, Resiliency, Sustainability



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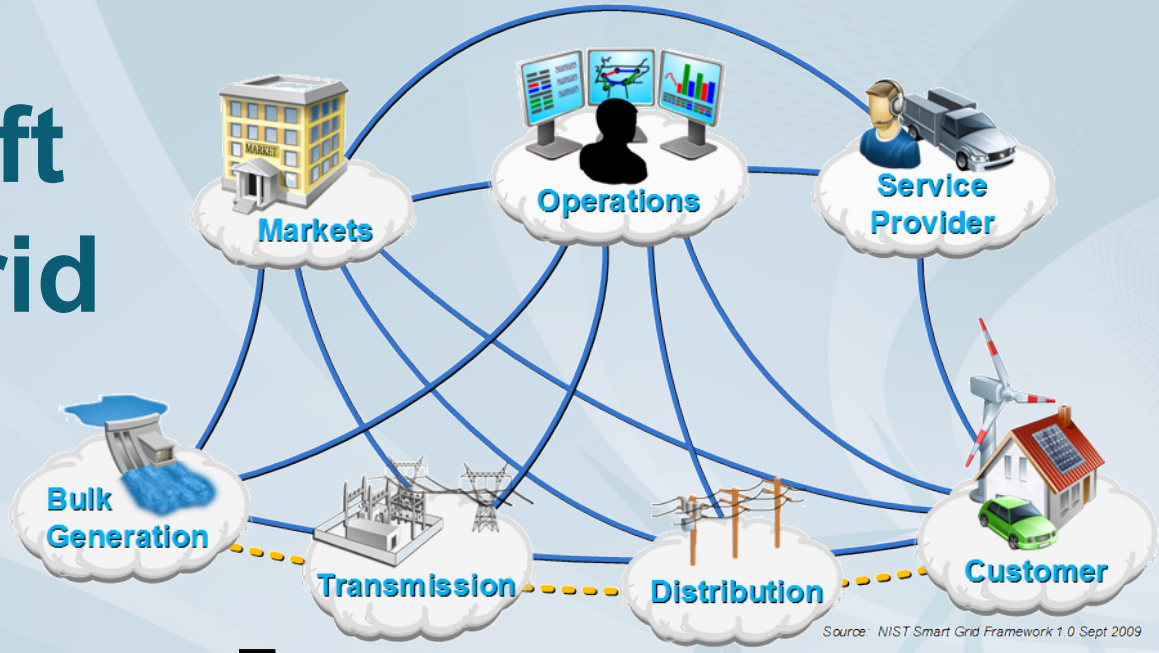
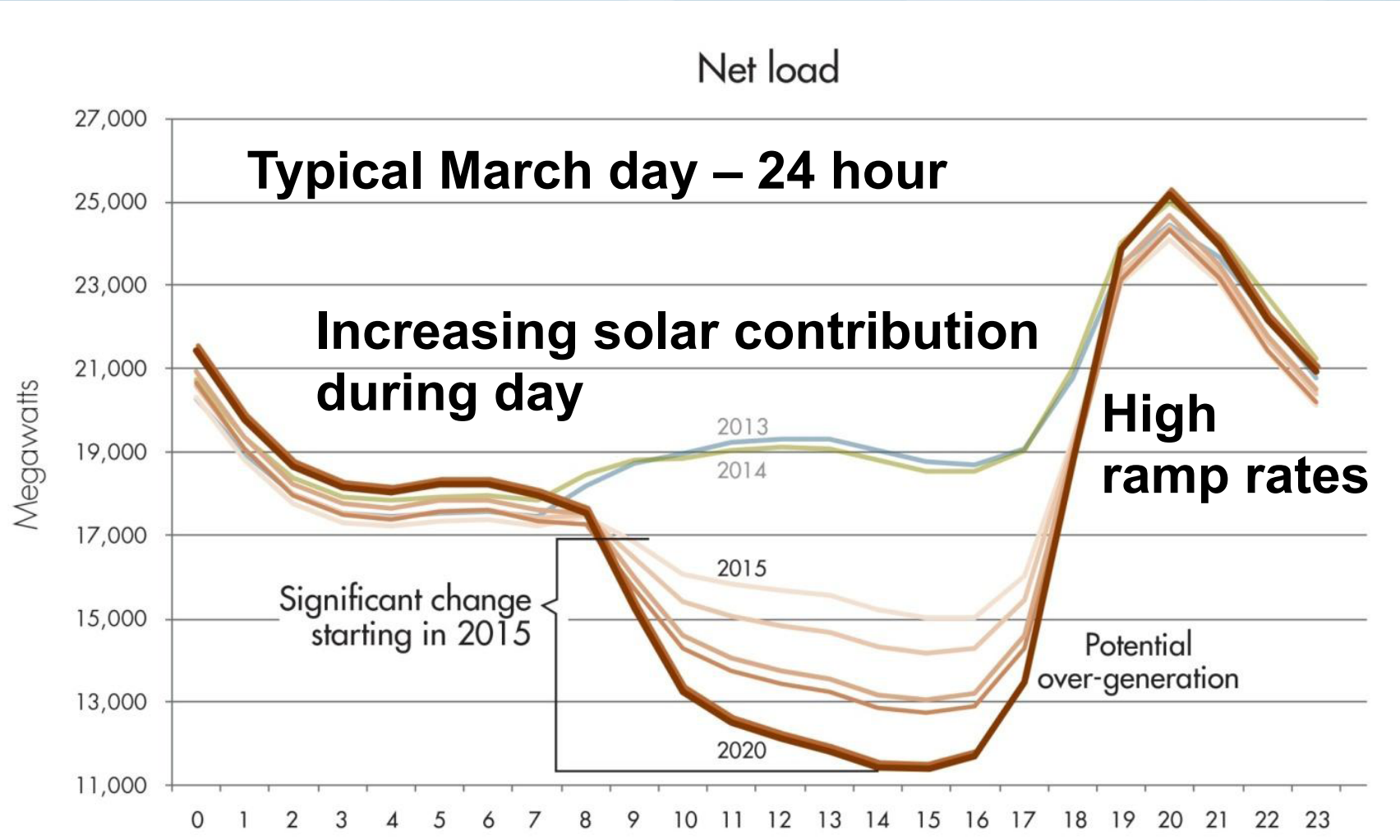


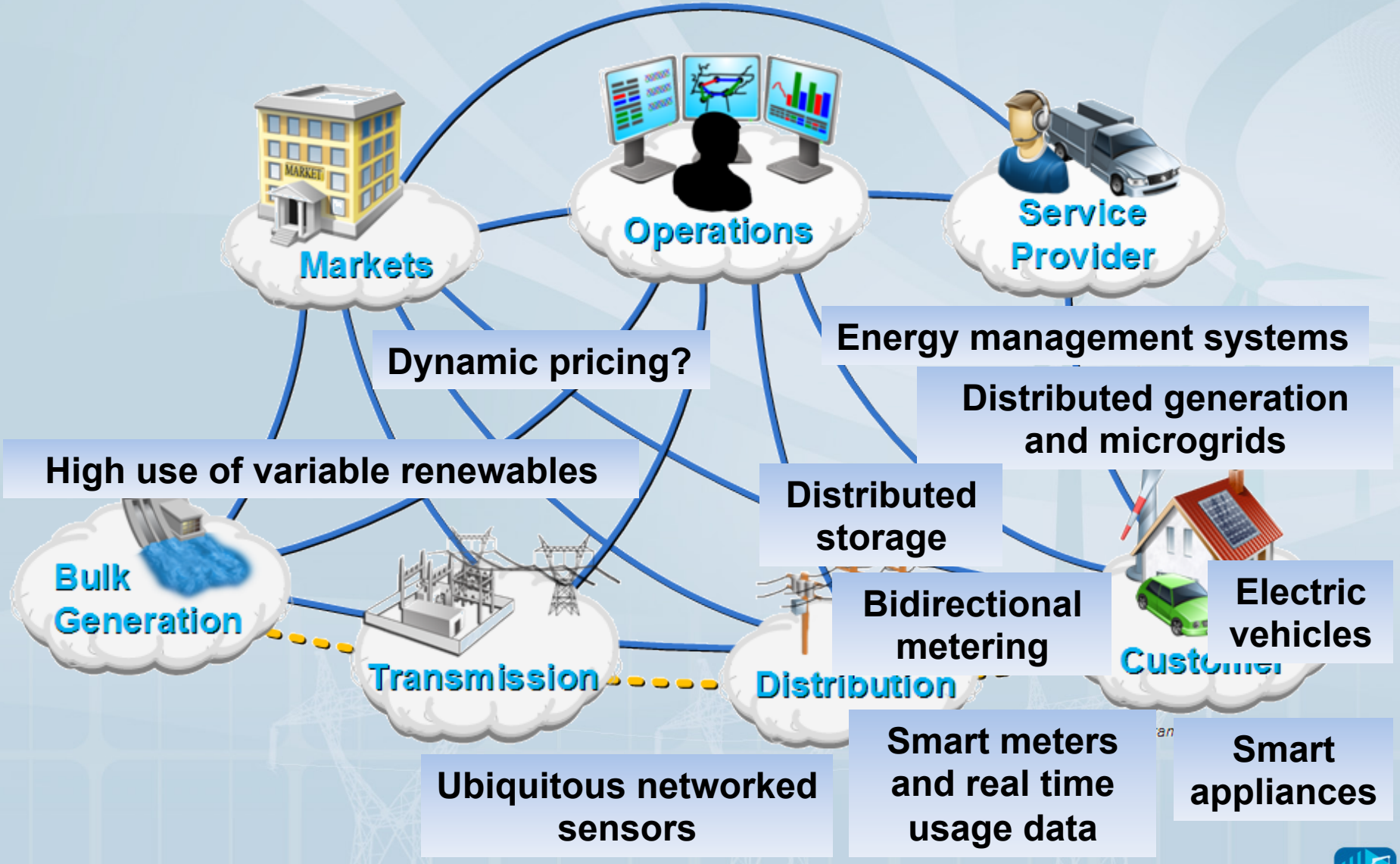
Trends – From:	To:
• Vertically integrated monopolies	• Restructured competitive markets
• Centralized generation	• More distributed generation
• Limited awareness	• Sensors everywhere
• Hierarchical network	• Interconnected microgrids
• Deterministic control	• Stochastic control
• Generation to meet demand	• Responsive demand and generation
• Proprietary architectures/interfaces	• Open standards
• Country-specific standardization	• International alignment & standards coordination

CAISO "Duck" Chart - California



- Reference: http://www.caiso.com/Documents/CEC_CPUC_ISO-Response-SenatorsPadilla_Fuller_Feb25_2013.pdf

Smart Grid Evolution



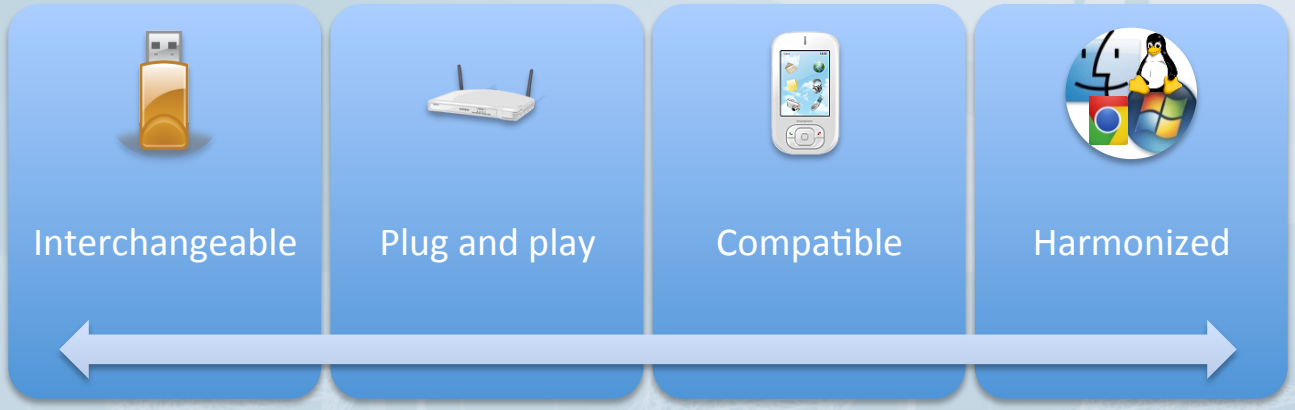
Energy Independence and Security Act

NIST has *"primary responsibility to **coordinate** development of a **framework** that includes protocols and model standards for information management to achieve **interoperability** of smart grid devices and systems…"*

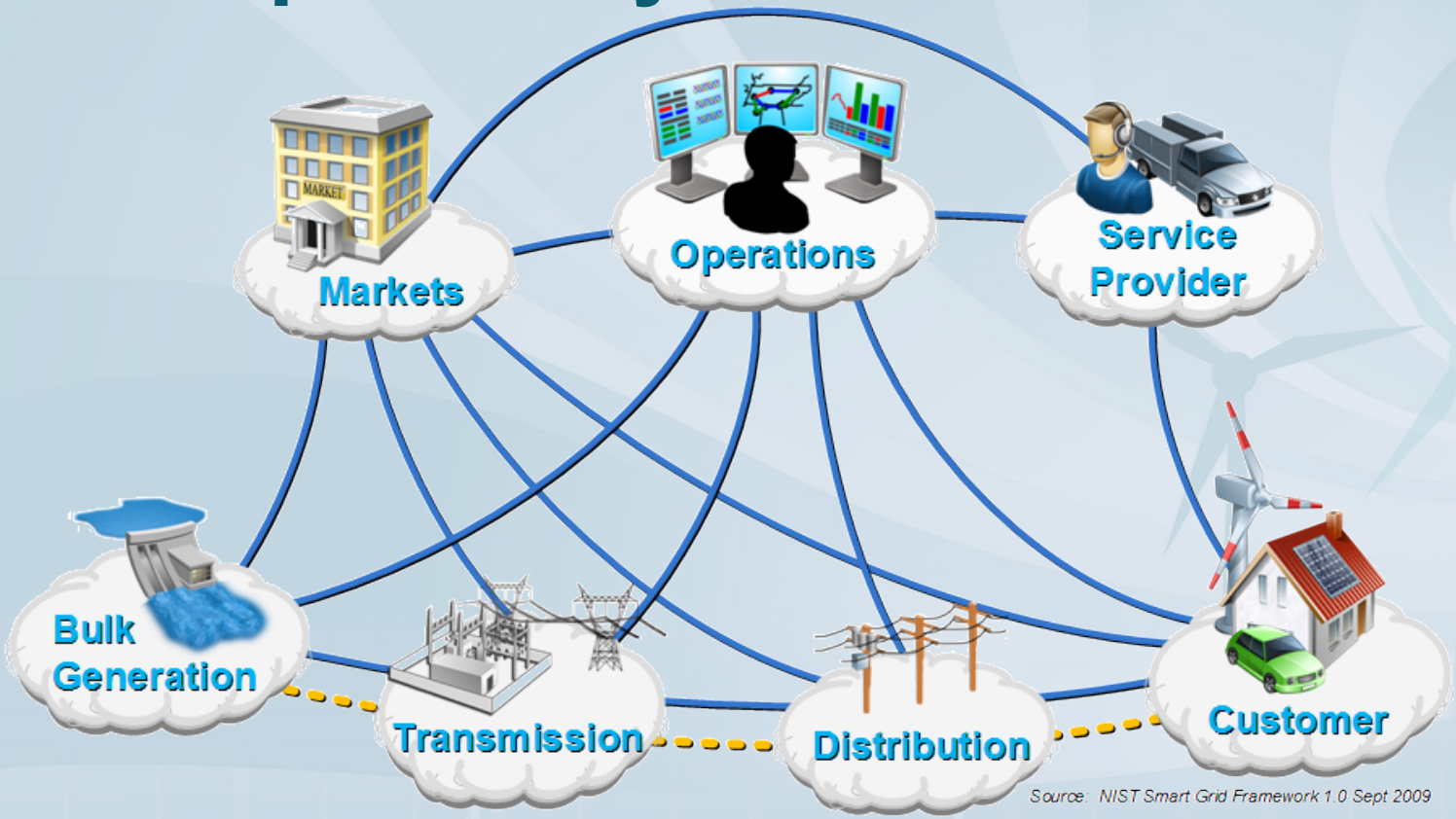
- Congress directed that the framework be "flexible, uniform, and technology neutral"
- NIST to seek input and cooperation from stakeholders
- Use of standards is a criteria for federal grants (DOE)
- Input to federal (and state) regulators
- EISA enacted December 2007

What is Interoperability?

- The capability of different systems and devices to communicate and work effectively together, ideally with minimal user intervention
- There are degrees of interoperability

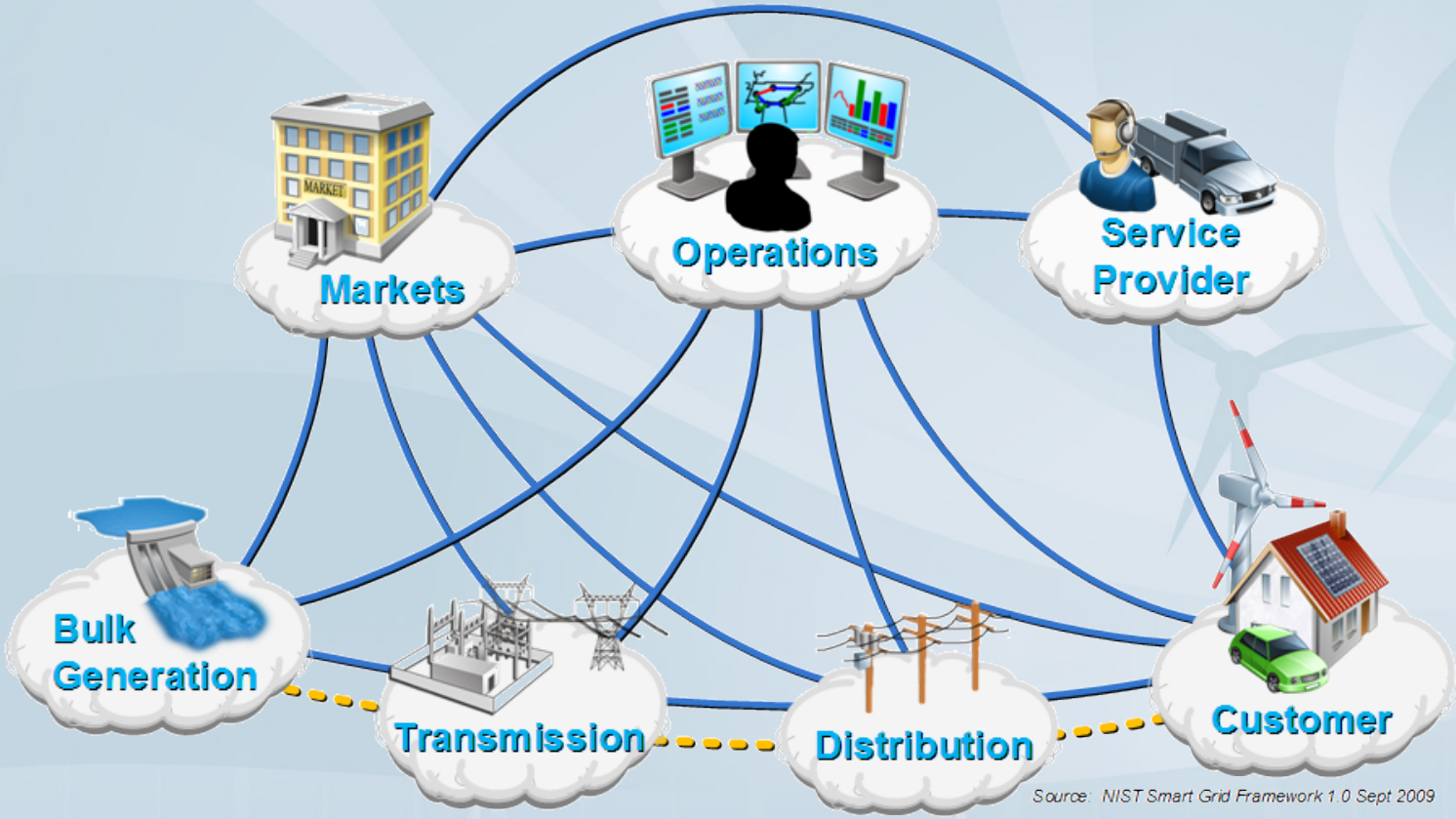


Interoperability in the Smart Grid



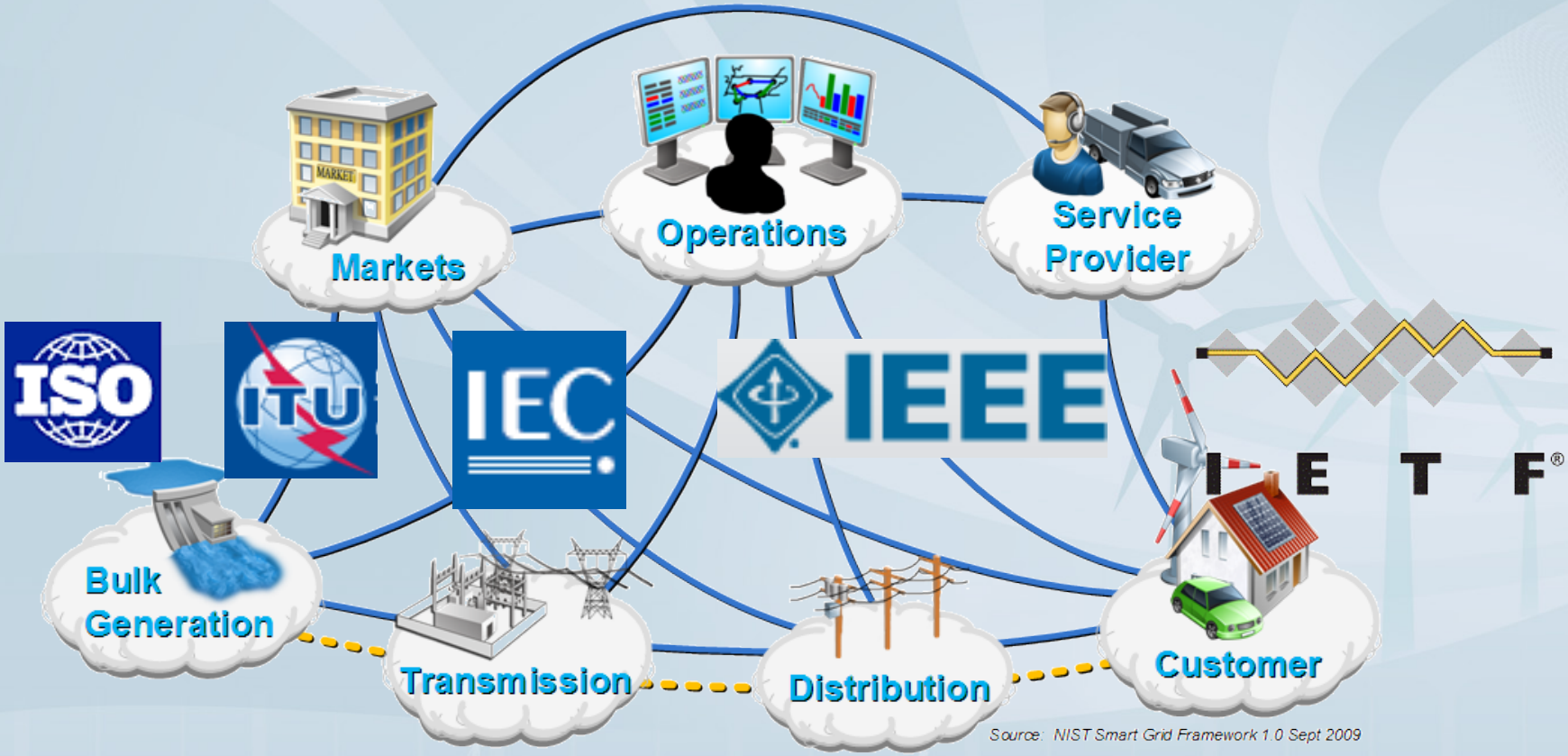
Standardized architectural concepts, data models and protocols are essential to achieve interoperability, reliability, security and evolvability.

Coordination in the Smart Grid



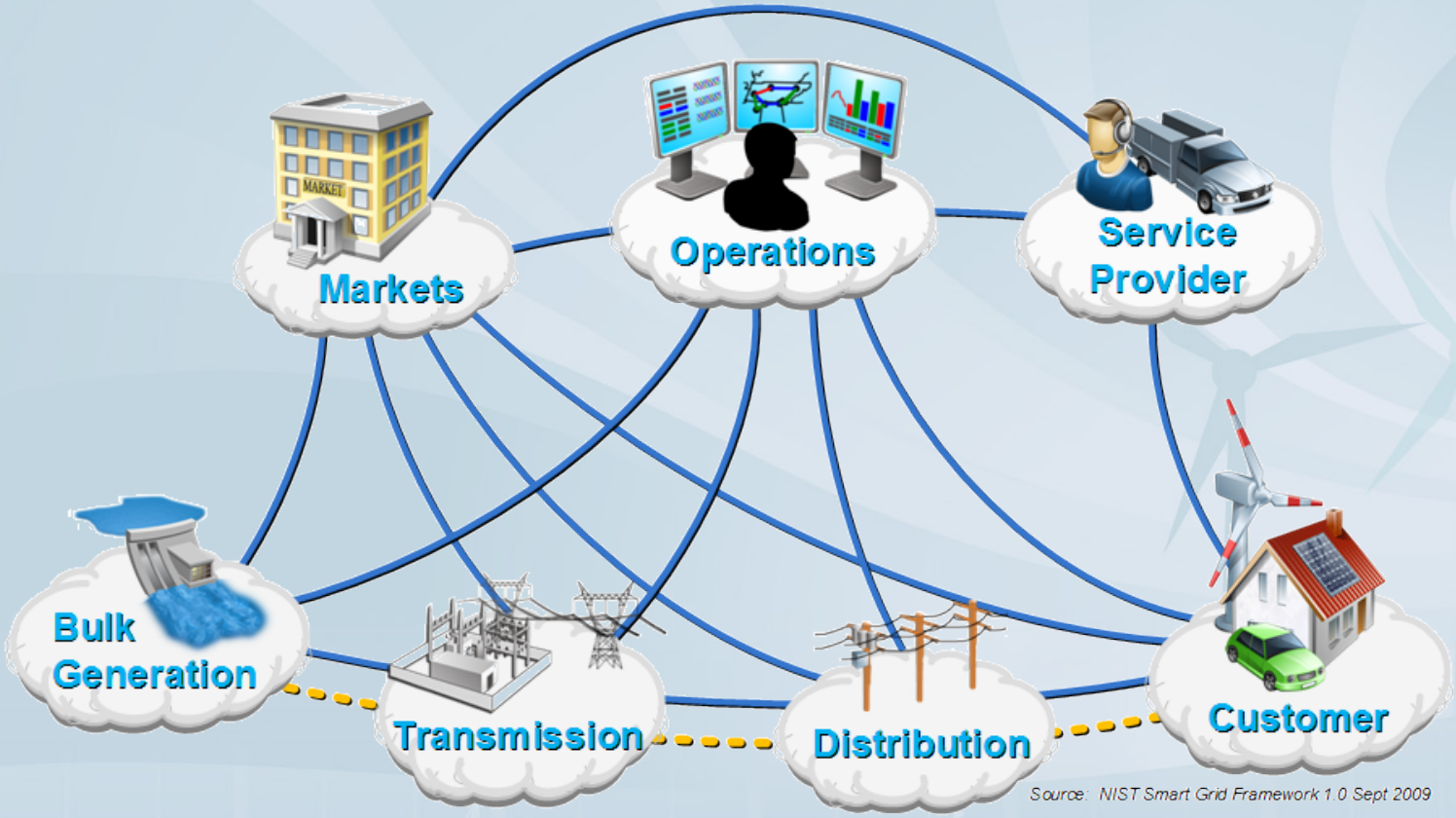
Coordination requires working effectively together in a team, aligned through good communications, timely decisions and meaningful actions, to deliver significant outcomes.

Coordination in the Smart Grid



SAE International
OGC® Open Geospatial Consortium, Inc.
OASIS
NAESB
SMWA
ANSI American National Standards Institute
NEMA
ZigBee® Alliance

Coordination in the Smart Grid



NIST
National Institute of Standards and Technology
U.S. Department of Commerce

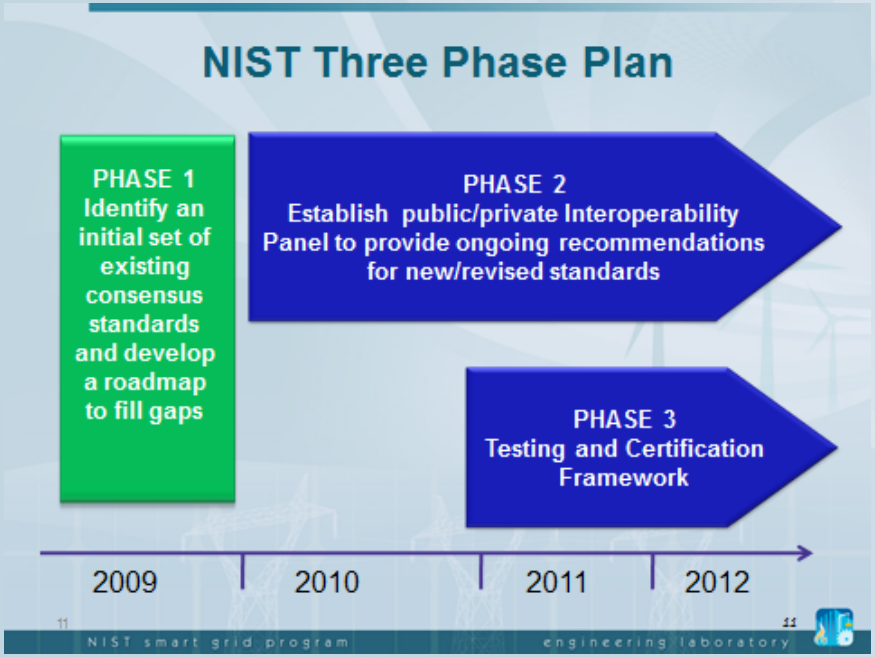
U.S. DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

State Regulators

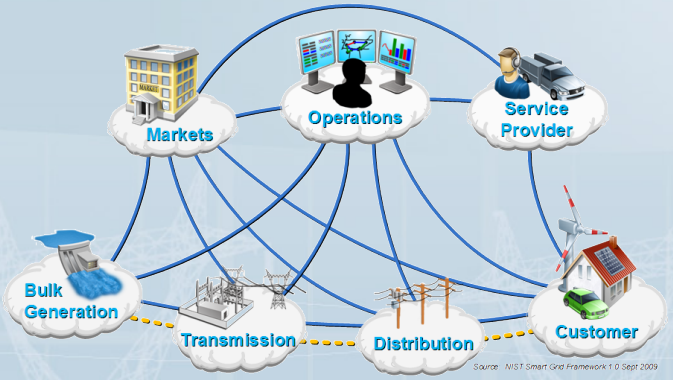
NARUC – National Association of Regulatory Utility Commissioners

Smart Grid Interoperability Standards Coordination



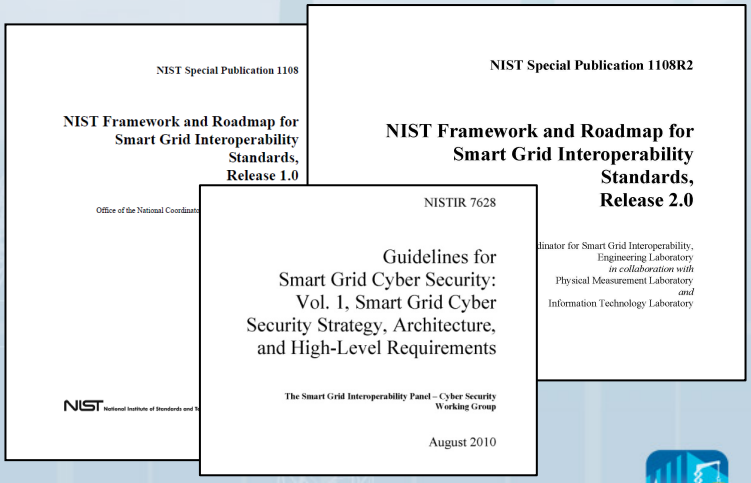
- **NIST Smart Grid Framework and Roadmap**
- **SGIP - Smart Grid Interoperability Panel**

White House kickoff and NIST stakeholder meetings



NIST Smart Grid Domains

http://www.nist.gov/smartgrid/

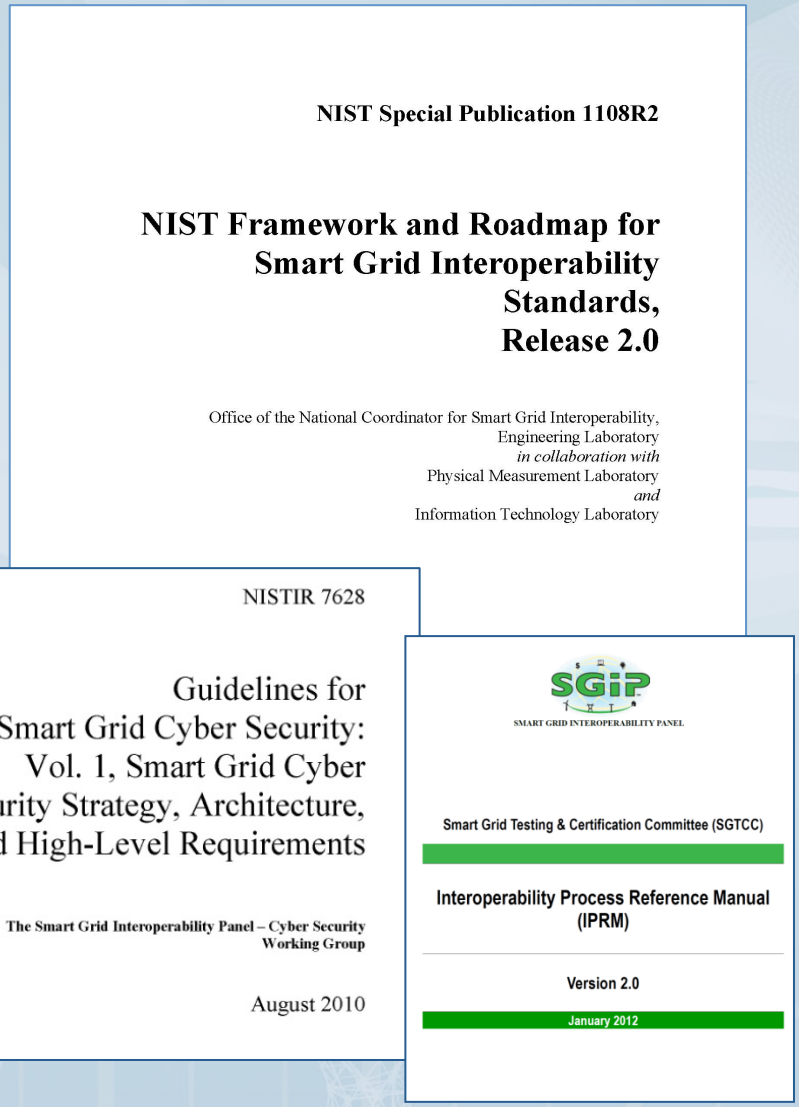


Priority Use Cases

- Demand Response and Consumer Energy Efficiency
- Wide Area Situational Awareness
- Electric Storage
- Electric Transportation
- Advanced Metering Infrastructure
- Distribution Grid Management
- Cybersecurity
- Network Communications

NIST Smart Grid Framework and Roadmap

- Release 1 - January 2010
- Release 2 - February 2012
- Release 3 - under development
- Smart Grid vision and conceptual architectural framework
- Identifies 100 key standards
- Cybersecurity risk management framework
- Conformance testing and certification framework
- Priority Action Plans
- Provided a foundation for IEC, IEEE, ITU, and other standardization efforts



http://www.nist.gov/smartgrid/

NIST Smart Grid Conceptual Model

A framework for discussing the characteristics, uses, behavior, interfaces, requirements and standards of the smart grid.

- Systems of systems
  - Multiple architectures
- General Concepts
  - Loose Coupling
  - Layered Systems
  - Shallow Integration
- Interface Related
  - Symmetry
  - Transparency
  - Composition
  - Cybersecurity (risk management)

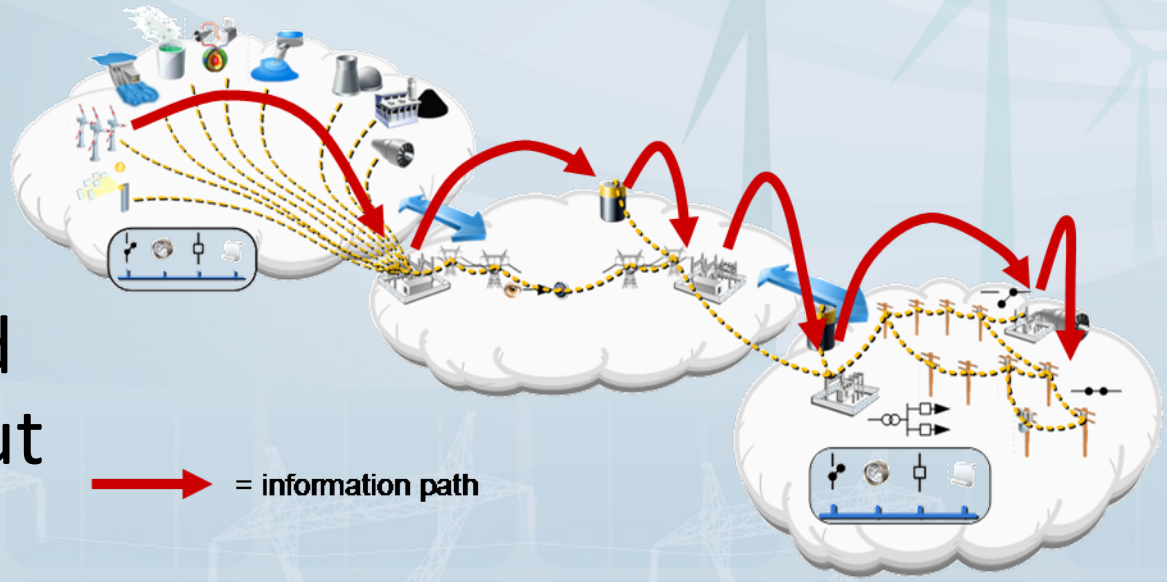
NIST and SGIP Smart Grid Architecture Committee: continued development and international harmonization

Use Case Methodology

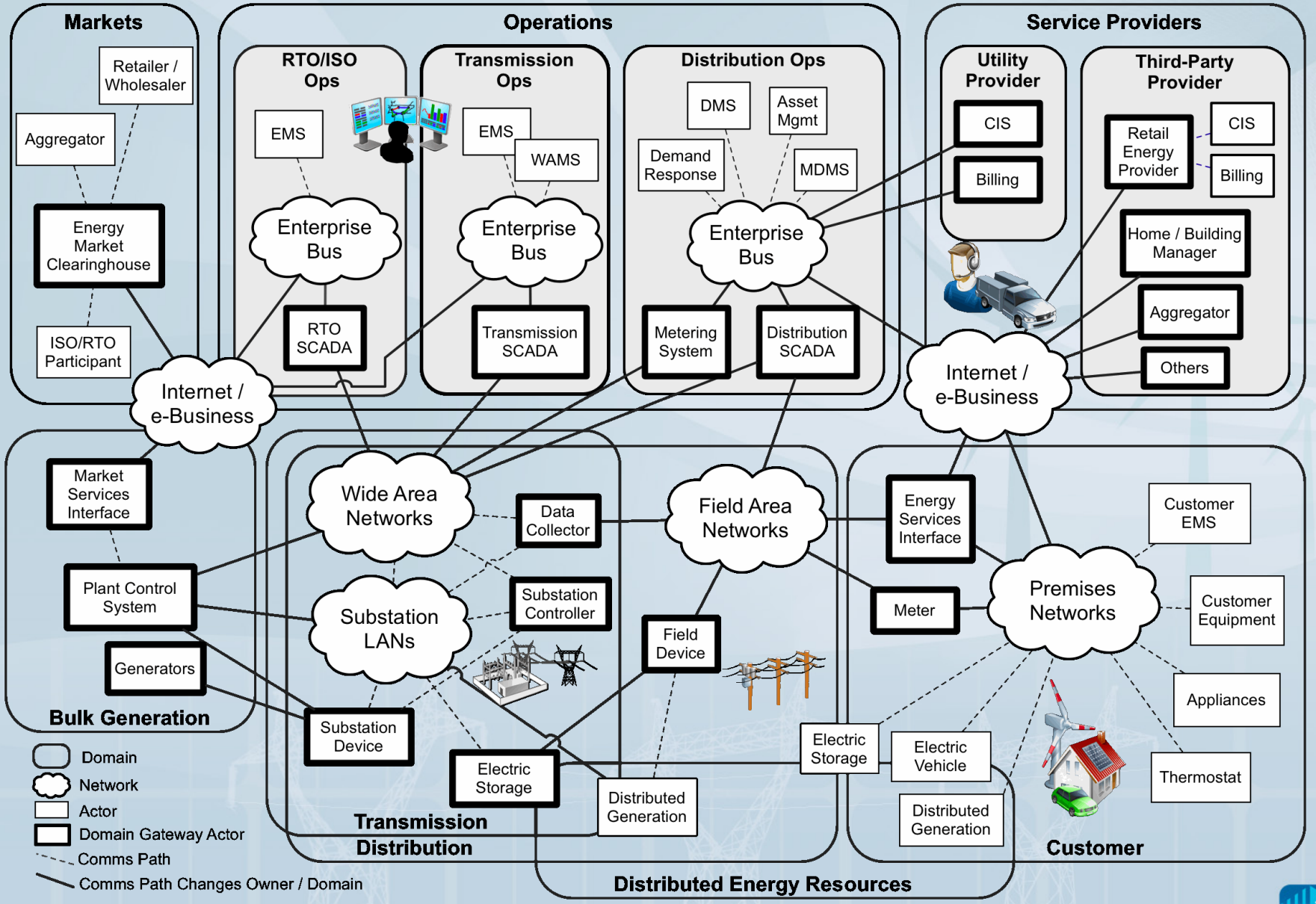
Clarifies how a Smart Grid requirement is envisioned to work and provides the overarching:

- Functional requirements
- Non-Functional requirements
- Interfaces
- Sequence
- Actors (roles)

They are used and refined throughout the architectural process



NIST Smart Grid Conceptual Reference Diagram



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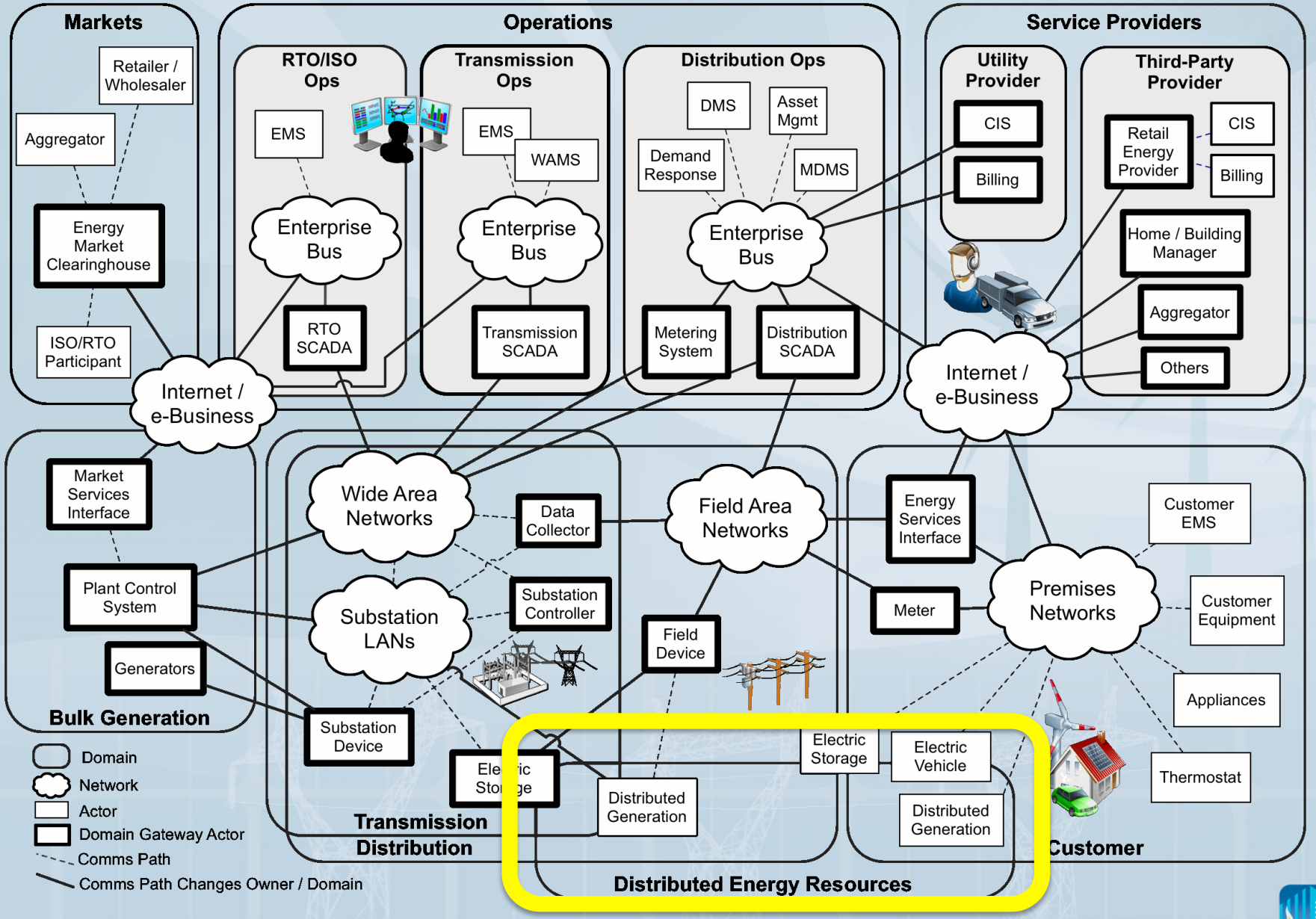
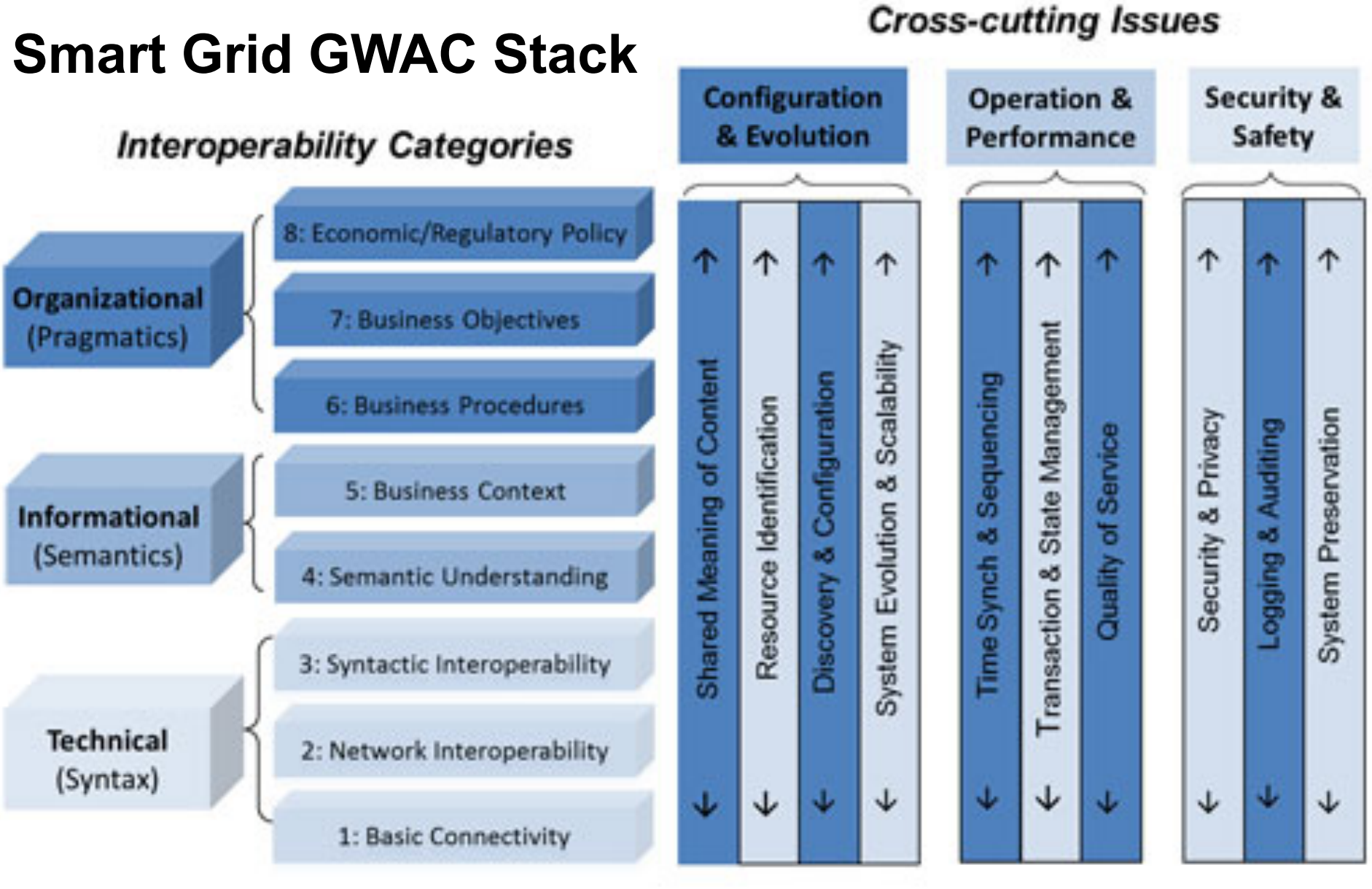


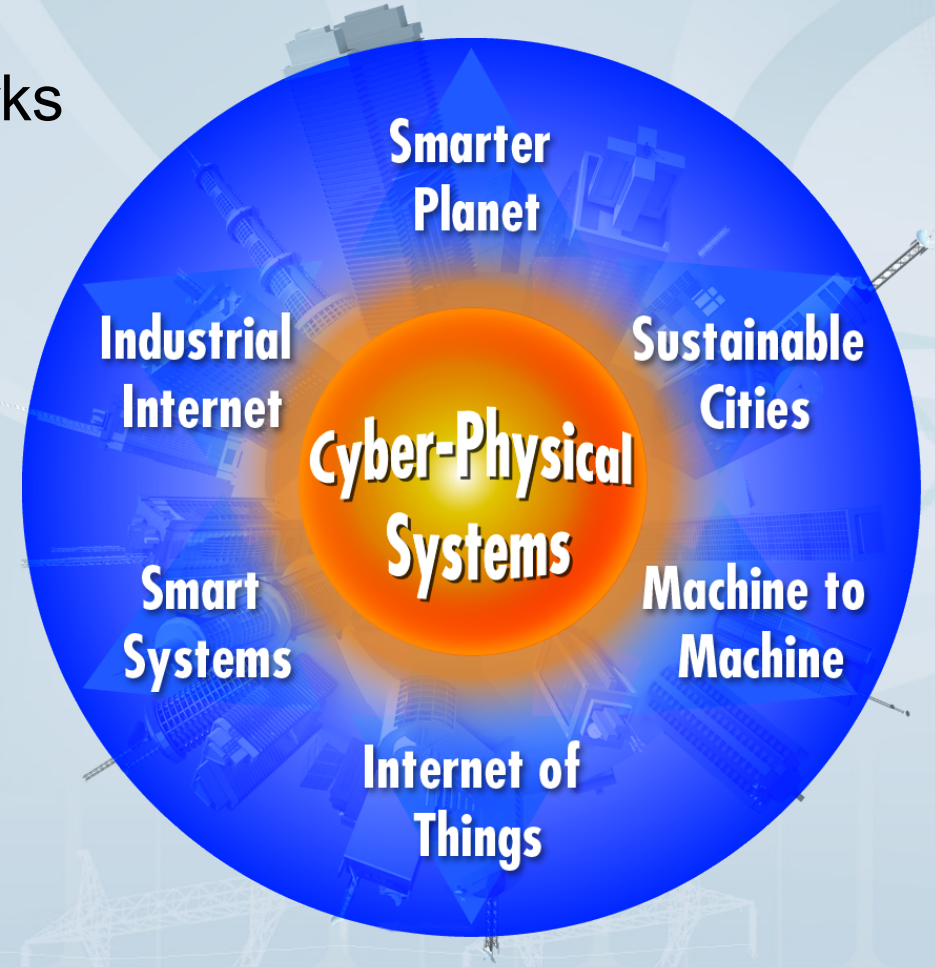
GWAC Stack (GridWise Architecture Council)

Smart Grid GWAC Stack



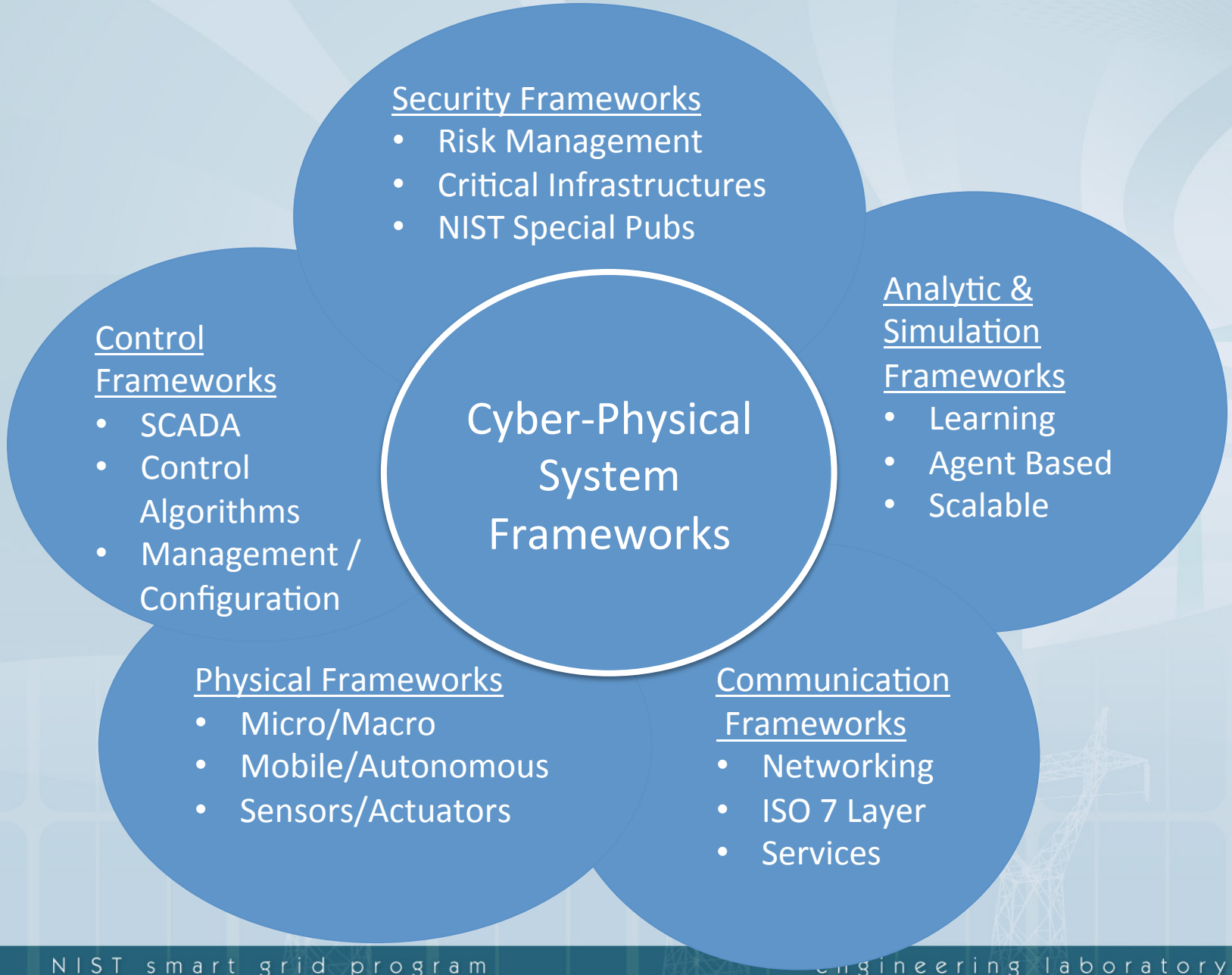
What are Cyber-Physical Systems?

- Integrated, hybrid networks of cyber and engineered physical elements
- Co-designed and co-engineered to create adaptive and predictive systems
- Respond in real time to enhance performance



- Key metrics include: efficiency and sustainability, agility and flexibility, reliability and resilience, safety and security

Heterogeneous Integration of Frameworks for CPS

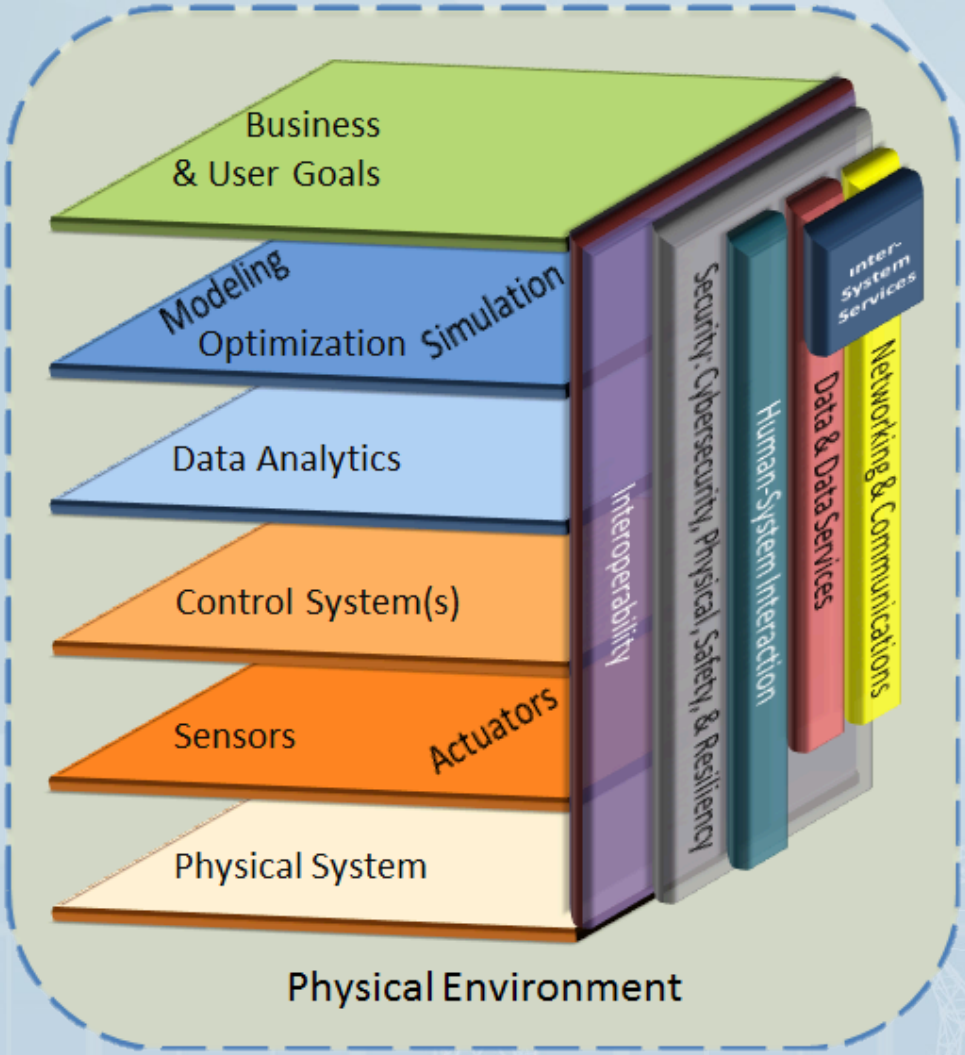


CPS Frameworks and Architectures

- Opportunity to generalize at a useful level of abstraction
  - Organizing principles and lessons learned can be shared between CPS domains, taking into account domain-specific requirements, constraints, and ecosystem conditions
  - Example: systems and infrastructures

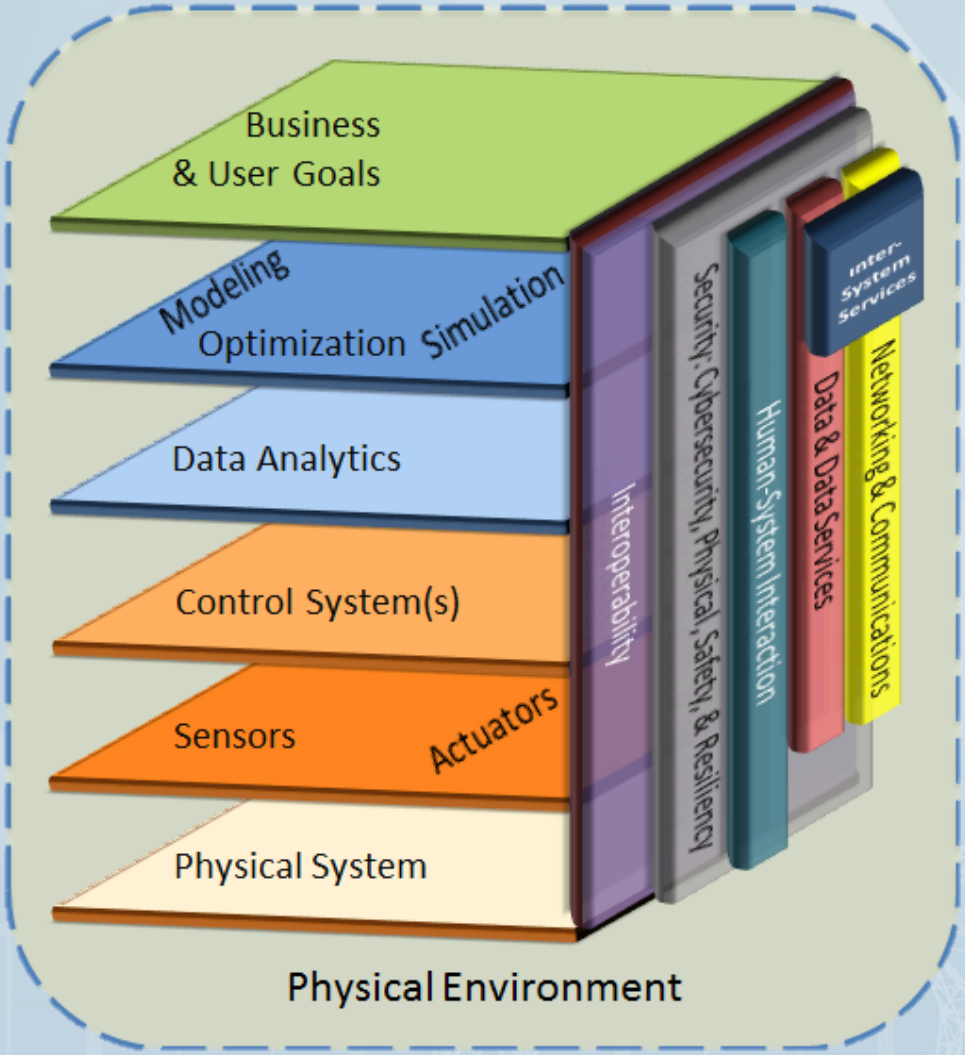
- Need for a CPS Reference Architecture:
  - Provide a common lexicon and taxonomy that can apply across cyber-physical systems
  - Show a common architectural vision to help facilitate interoperability between components and systems
  - Enable creation of reusable CPS components and tools to measure and evaluate their performance
  - Promote communication across diverse stakeholder community

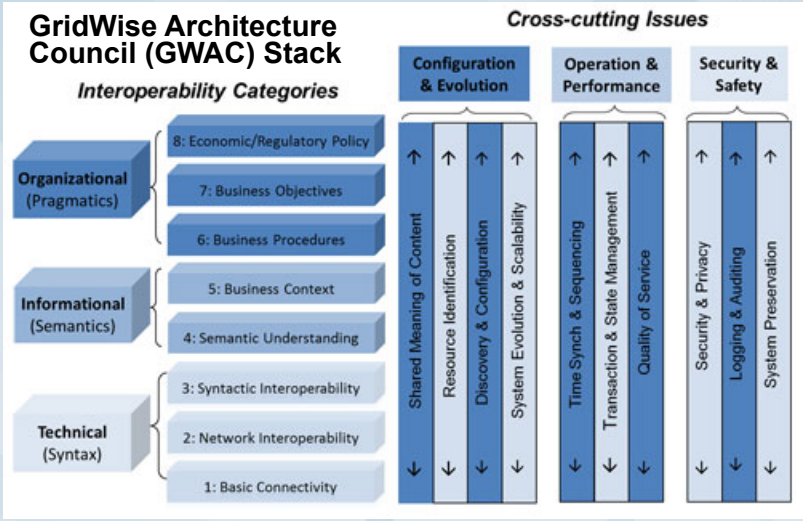
Notional CPS Reference Architecture (draft, work in progress, notional, draft, …)

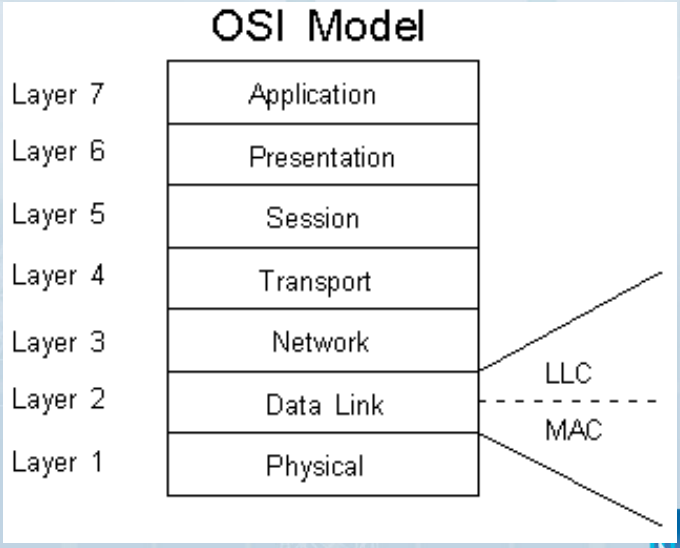


- Functional, multi-stack architecture
- All layers should be co-designed in the context of the Physical Environment
- Management function, not depicted, provides oversight and ensures coordination and composability

Notional CPS Reference Architecture (draft, work in progress, notional, draft, …)







Presidential Innovation Fellows at NIST (CPS and Green Button – June 2013)

Vision Vignettes for CPS – Rapidly Reconfigurable Factories Driven by Networked Robots, …

What is the equivalent of the LAMP stack for CPS? …

SMART GRID DATA INITIATIVES

Federal Government Interest in Data Access

- Smart Disclosure
  - Timely release of complex information and data in standardized, machine readable formats in ways that empower and enable consumers to make informed decisions
- Open Data Initiatives
  - Make government data and other public information widely available and useful – data is a fuel for innovation
  - Energy Data Initiative, …
- My Data Initiatives
  - Support consumers and others to access their own data, preserving privacy and maintaining security
  - Blue Button, industry-led
    Green Button, …

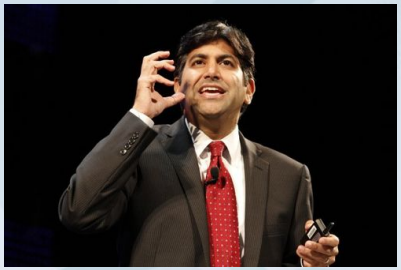
Let's Directly Empower Consumers with Data

A Challenge – Design a "Green Button"

A Challenge to Industry: How can we safely and securely provide customers electronic access to their energy information, thereby supporting the continuing development of innovative new products and services in the energy sector?

Key Principles

- Use SGIP standards
- Open, Collaborative
- Multi-Stakeholder
- "Lean Startup"
- Easy-to-use



Aneesh Chopra

U.S. Chief Technology Officer – Office of Science and Technology Policy

Todd Park

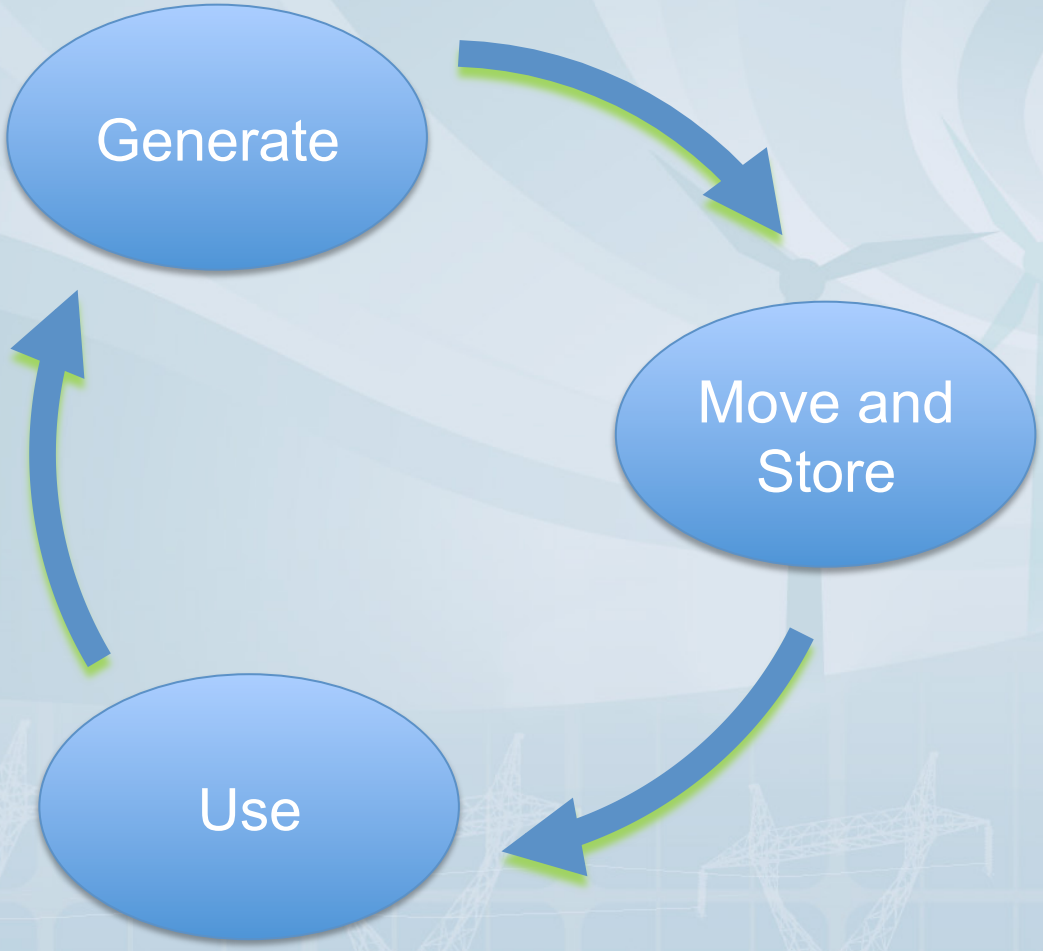
Green Button Initiative

- *Common-sense idea that electricity customers should be able to download their own energy usage information in a consumer- and computer-friendly electronic format from their utility's secure website*
- *Result of collaboration among White House, DOE, NIST, state regulators, utilities, vendors, SGIP, and North American Energy Standards Board*

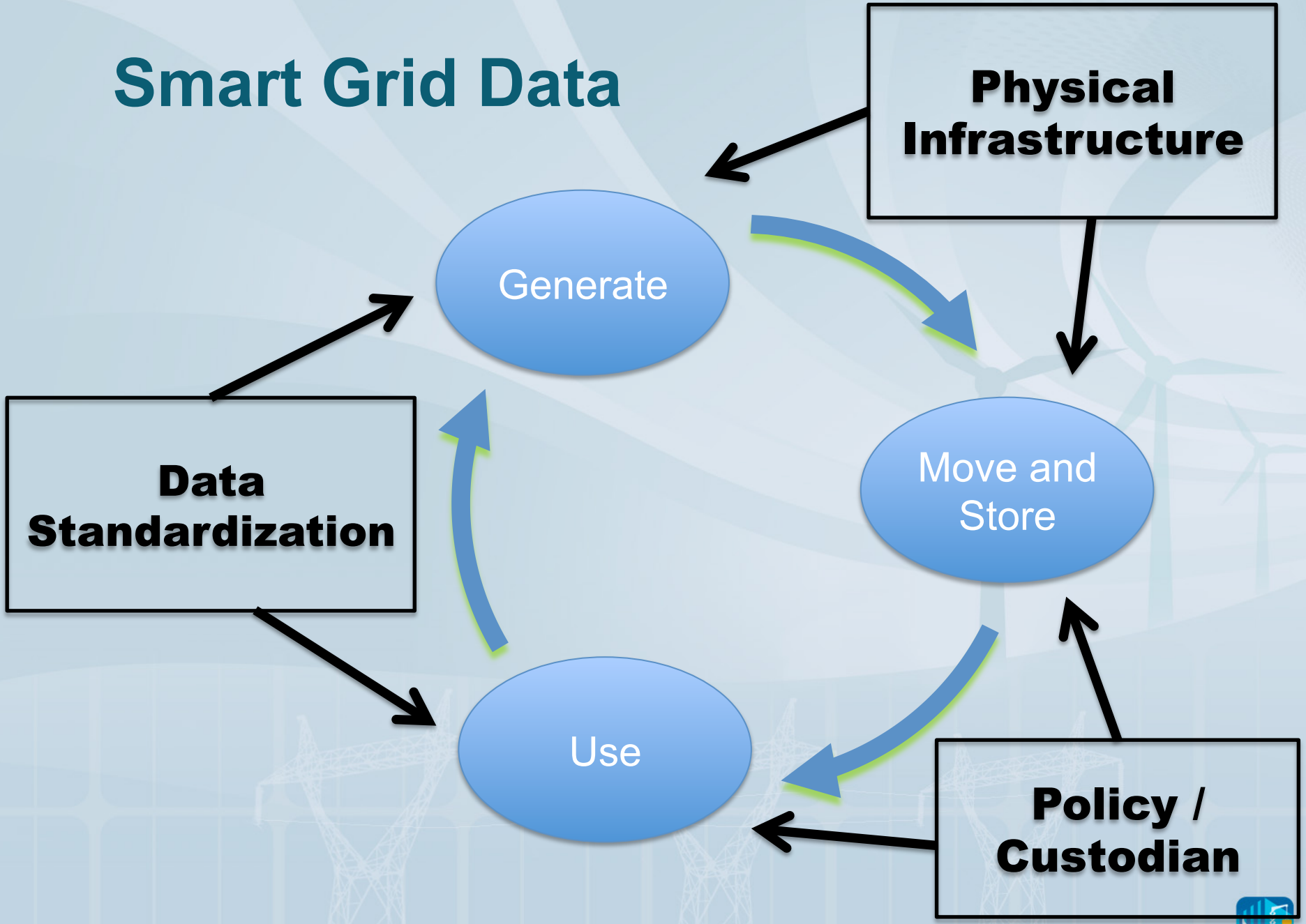
19 million consumers have access to Green Button data NOW, and 30+ million will by 2013-14

www.greenbuttondata.org & www.nist.gov/smartgrid/greenbutton.cfm

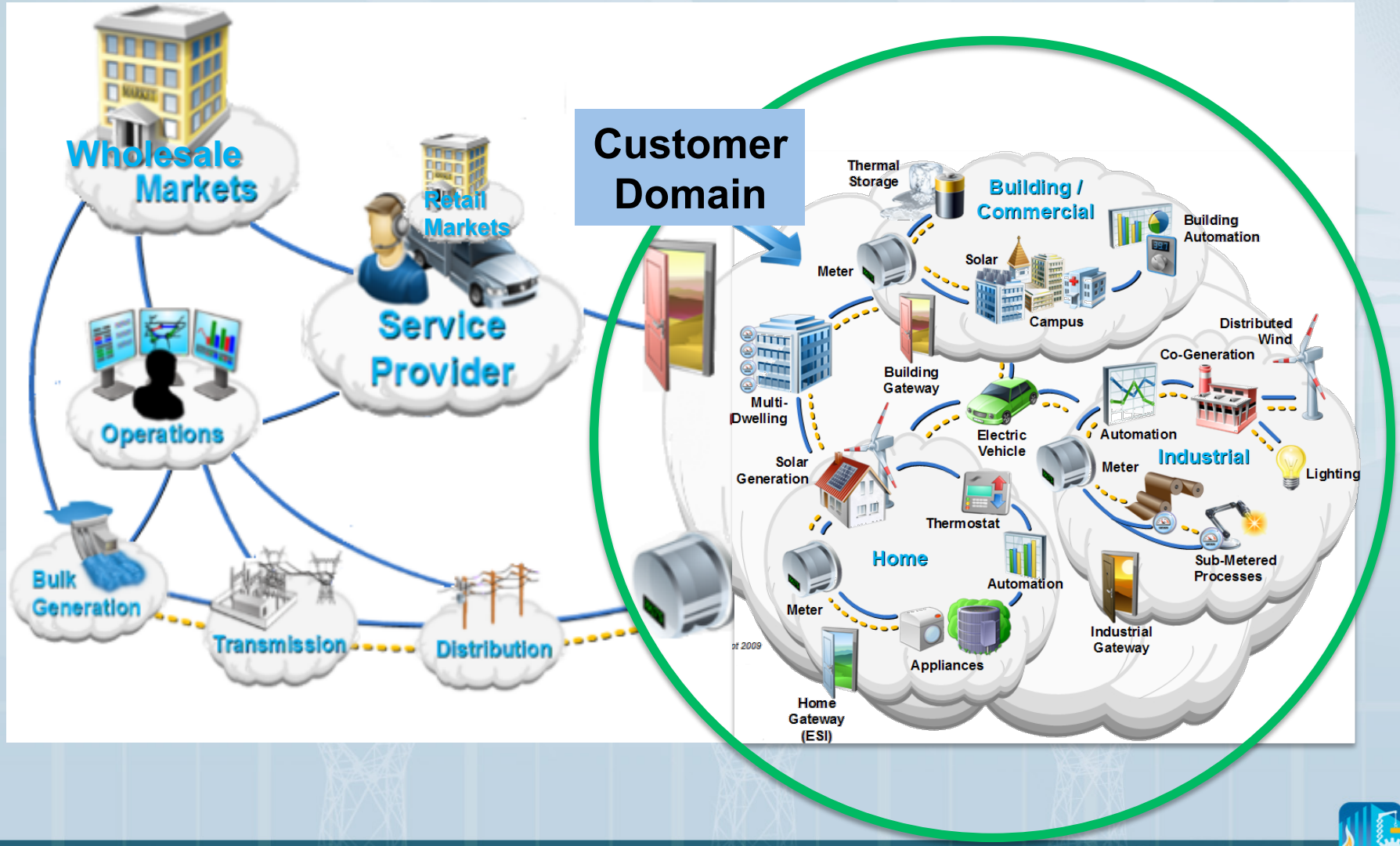
Smart Grid Data



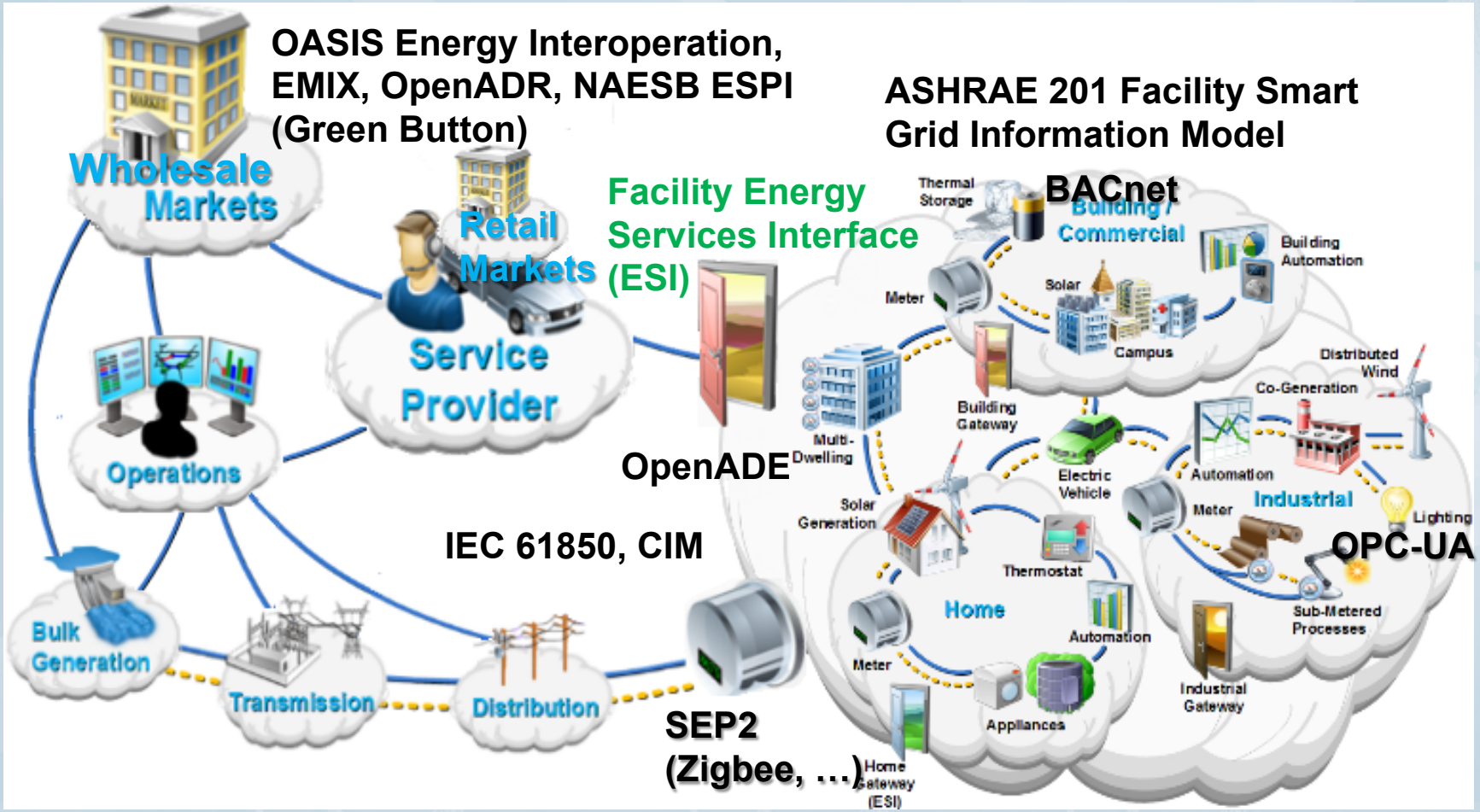
Smart Grid Data



Energy Usage Information



Consumer Domain – Standards



Security applied as required to all communications

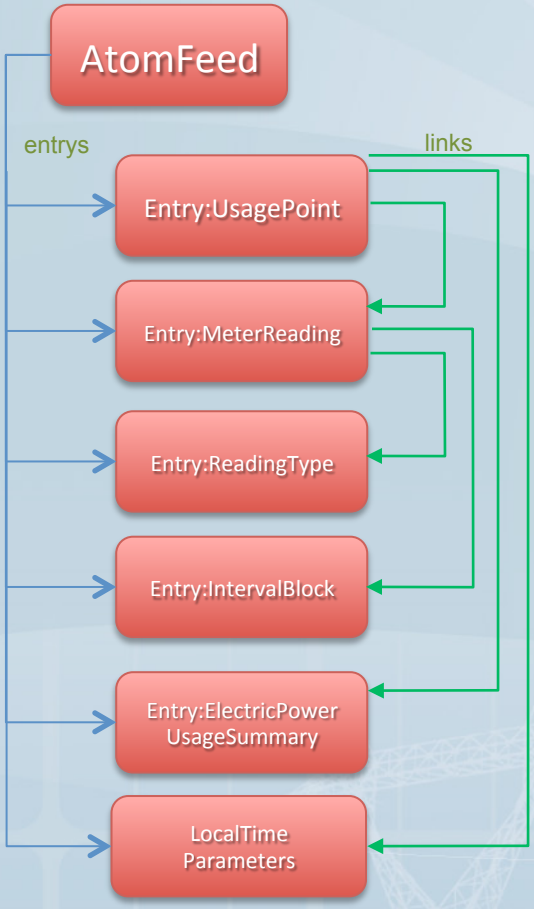
Smart Grid Data – Energy Usage Information

- Physical Infrastructure
  - Smart Meters
  - Meter Communications and Utility Back-end Systems
- Privacy / Custodian
  - US privacy blueprint and privacy efforts
  - US States policies on data access
  - SGIP Cybersecurity Committee, NISTIR 7628
  - DOE-led Privacy Voluntary Code of Conduct stakeholder effort
- Standardization
  - North American Energy Standards Board standards:
  - REQ-18 Energy Usage Information
  - REQ-21 Energy Service Provider Interface
  - REQ-22Third Party Access to Smart-Meter-based Information

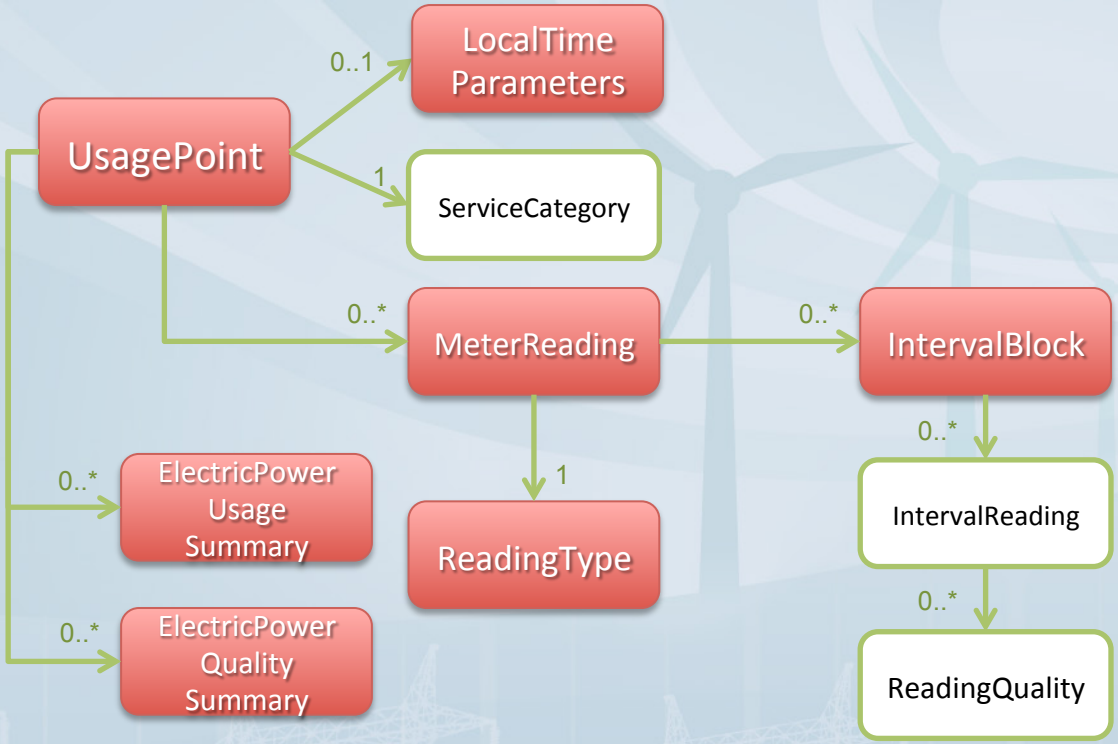
Goal: Ecosystem of innovative smart grid products and services based on energy usage data

Composition of Energy Usage Information

Syntactic Model
Atom Feed View

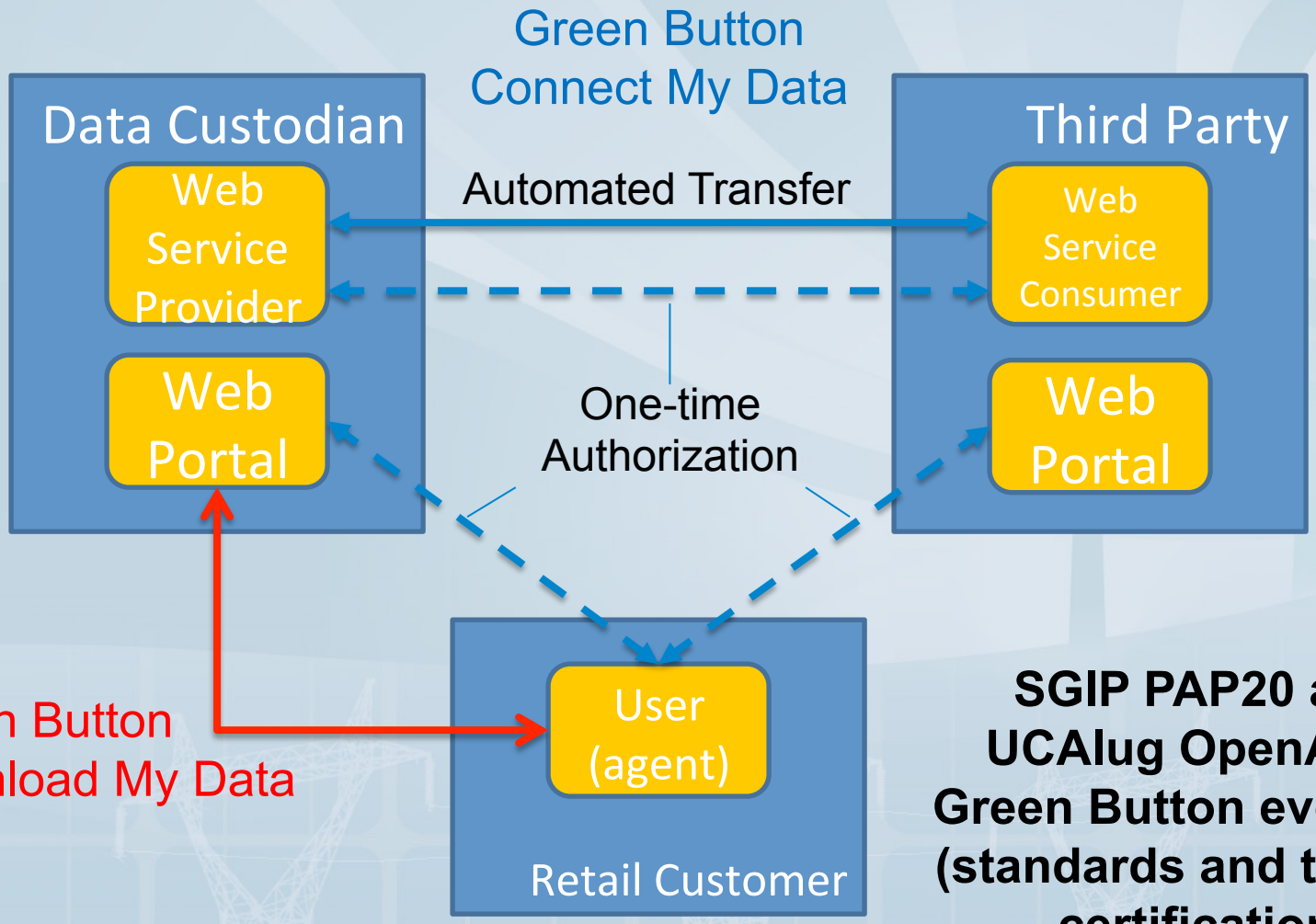


Information Model
Profile View



Note: This information is multidimensional. Many different reading types, summaries, and readings possible. i.e. not "flat"

Green Button Data Exchange



SGIP PAP20 and UCAIug OpenADE: Green Button evolution (standards and testing/ certification)

EPA Home Energy Yardstick with Green Button

ENERGY STAR®

Home Energy Yardstick

Assess the energy efficiency of your home and see how it measures up:

EPA's Home Energy Yardstick provides a simple assessment of your home's annual energy use compared to similar homes. By answering a few basic questions about your home, you can get:

- Your home's Home Energy Yardstick score (on a scale of 1 to 10);
- Insights into how much of your home's energy use is related to heating and cooling versus other everyday uses like appliances, lighting, and hot water;
- Links to guidance from ENERGY STAR on how to increase your home's score, improve comfort, and lower utility bills; and
- An estimate of your home's annual carbon emissions.

Learn more about how the Home Energy Yardstick works.

See a sample results page.

Getting Started:

To calculate your Yardstick score, all you need is some basic information about your home:

- Your ZIP code;
- Your home's square footage;
- Number of full time home occupants;
- A list of all the different fuels used in your home (e.g., electricity, natural gas, fuel oil); and
- Your home's last 12 months of utility bills (usually found in the 12 month summary provided on your bill or through a Green Button file ?).

Having trouble with the Home Energy Yardstick? Contact us at yardstick@energystar.gov.

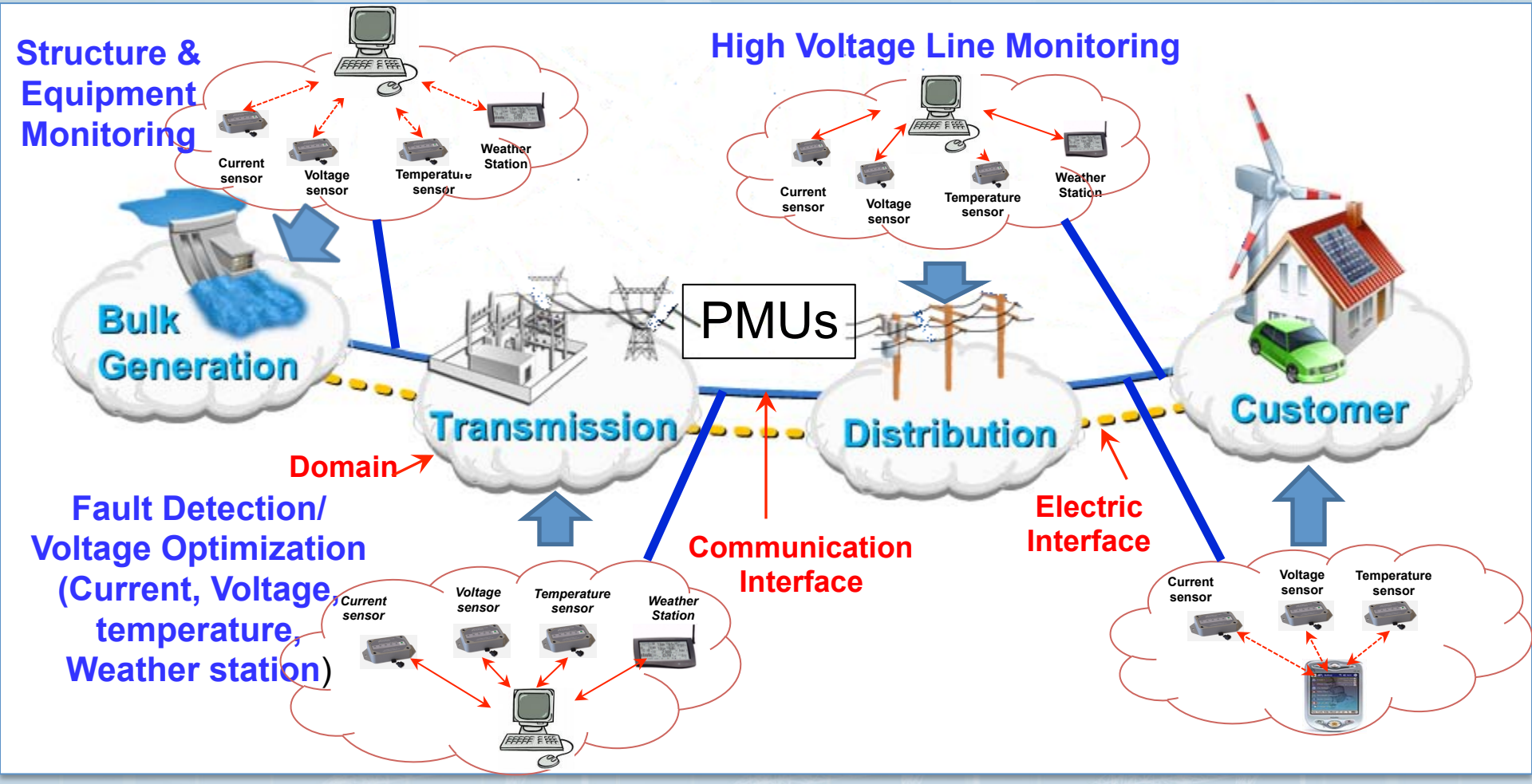
Green Button application areas

- Growing ecosystem of Green Button utilities, third party application providers, aggregators, …
- Commercial buildings interest
- President's Climate Action Plan
  - Finally, the Administration will leverage the "Green Button" standard – which aggregates energy data in a secure, easy to use format – within federal facilities to increase their ability to manage energy consumption, reduce greenhouse gas emissions, and meet sustainability goals.
- Extendable to gas, water, …
- greenbuttondata.org, OpenEI.org, …

Smart Grid Data Challenges

- Phasor Measurement Units (real-time wide area situational awareness) and other distributed sensors
- Accurate time synchronization
- Smart meter infrastructure
- Data Analytics
- Customer Engagement and Microsegmentation
- Many more …

Real time monitoring using sensor networks

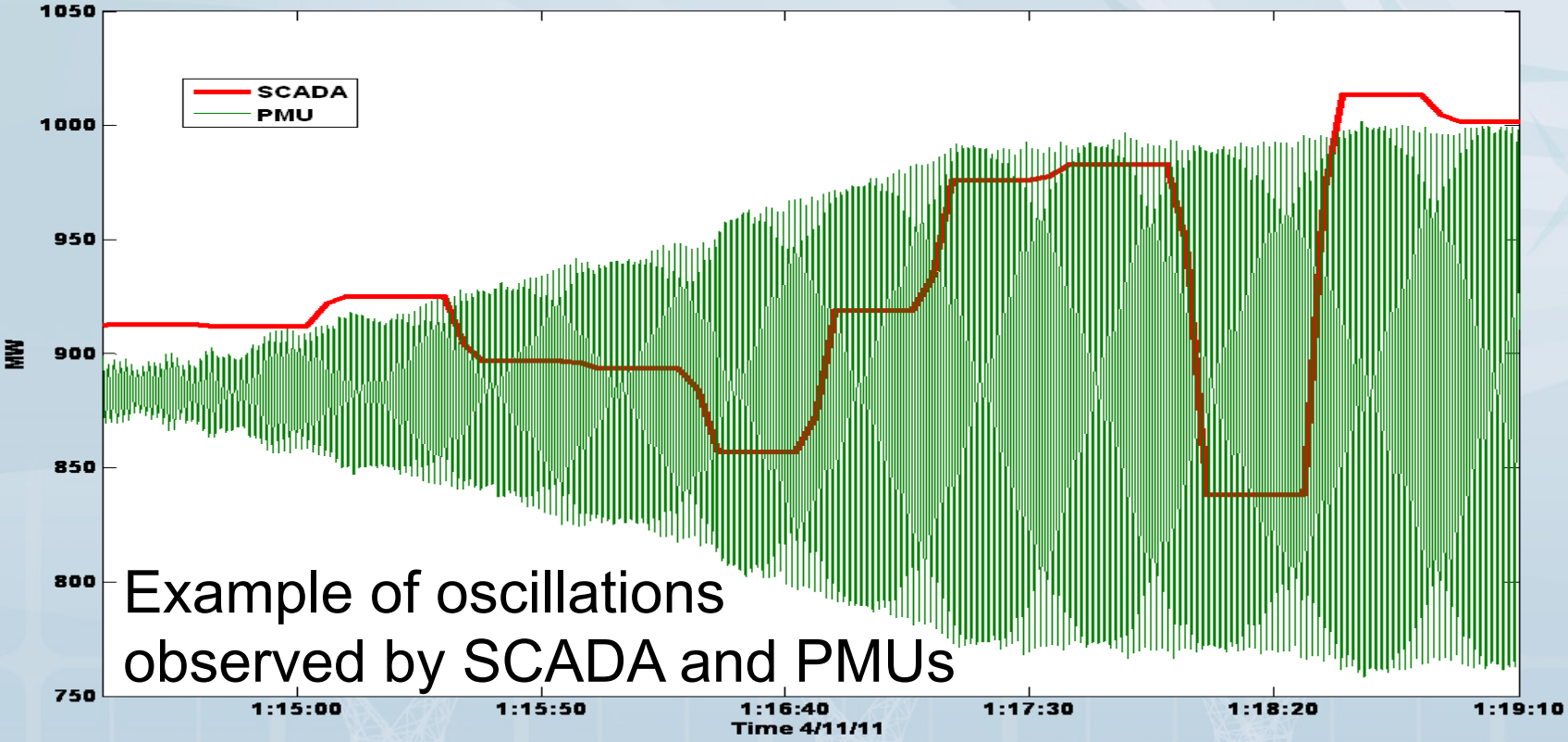


Need: Metrology for sensor networks and accurate timestamping

Need: Phasor measurement units accurate in dynamic environment

Reduce wide area blackouts (2003, $6B losses) using better sensor data and predictive models

- SCADA measurements cannot see most oscillations, can be misleading
- PMUs are needed to observe oscillations - faster data sampling, greater data resolution, and wide-area synchronization



Example of oscillations observed by SCADA and PMUs

Source: Mahendra Patel at PJM

Smart Grid Data Challenges

- Phasor Measurement Units (real-time wide area situational awareness) and other distributed sensors
- Accurate time synchronization
- Smart meter infrastructure
- Data Analytics
- Customer Engagement and Microsegmentation
- Many more …

Priority Crosscutting Challenges

The NIST-RASEI Smart Grid R&D Needs workshop identified a number of crosscutting challenges, including

- **Decision tools for operators** to increase visibility and situational awareness, enable planning and forecasting, and provide logic for decision-making
- **Communications infrastructure** to enable interconnections among various components and systems, public networks, and devices, as well as operations and planning functions
- **Performance metrics** to better understand, manage, and control manage performance, flexibility, and a host of other elements
- **Data management and analytics** for effectively collecting, storing, and interpreting the massive amounts of data that are now possible
- **Robust operational and business models** to enable effective operations and planning and that can incorporate diverse generation sources, storage options, and models for flexibility

Big Data

- Hot topic area – lots of activity
- NIST Big Data Working Group
  - Chairs: Chaitan Baru, Robert Marcus, and Wo Chang
  - Big Data Definitions, Taxonomies, Reference Architectures and Technology Roadmap
- NIST Cloud/Big Data Workshop Jan2013
  - Definition version 1: Big Data refers to digital data volume, velocity and/or variety [,veracity] that:
    - enable novel approaches to frontier questions previously inaccessible or impractical using current or conventional methods; and/or
    - exceed the capacity or capability of current or conventional methods and systems.
- Multiple workshops, use cases (including smart grid)

Smart Grid Success Factors

- **Champions**: identification of smart grid as national priority by Congress and Administration
- **Active Coordination**: within Federal Government and with private sector, standards developing organizations, and regulatory community
- **Leadership and Visibility**: NIST Three-Phase Plan with White House kickoff
- **Planning, Organization and Governance**: NIST standards process including NIST Framework and Smart Grid Interoperability Panel
- **Funding**: ARRA plus appropriations (including DOE)
- **Federal Government convening function**: workshops, stakeholder input, targeted activities
- **Expertise**: leverage existing expertise, build new, address longer-term measurement science/R&D needs

Conclusion

- Momentum towards smart grid has been supported by the NIST framework/standards coordination process, but much work remains to enable and harness new data streams
- Additional questions?
- Contact info:

David Wollman
Deputy Director, Smart Grid and CPS Program Office
Engineering Laboratory, NIST
david.wollman@nist.gov
301-975-2433

- Work presented includes contributions from many experts (government, industry, academia)