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Reliability Considerations for the Integration of Smart Grid Devices and Systems on the Bulk Power System

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Engineer of Reliability
Assessments

to ensure
the reliability of the
bulk power system

About NERC: Mission

To ensure the reliability of the North American bulk power system

- Develop & enforce reliability standards
- Assess current and future reliability
- Analyze system events & recommend improved practices
- Encourage active participation by all stakeholders
- Pursue mandatory standards in all areas of the interconnection

Smart Grid Task Force Scope

- Identify and explain any BPS reliability issues and/or concerns of the Smart Grid
- Assess Smart Grid reliability characteristics
- Determine the cyber security and critical infrastructure protection implications
- Identify how the integration of Smart Grid technologies affects BPS planning, design and operational processes and the tools needed to maintain reliability
- Determine which existing NERC Reliability Standards may apply
- Provide recommendations for areas where Reliability Standards development work may be needed

Define Smart Grid

- *smart grid* - The integration and application of real-time monitoring, advanced sensing, communications, analytics, and control, enabling the dynamic flow of both energy and information to accommodate existing and new forms of supply, delivery, and use in a secure, reliable, and efficient electric power system, from generation source to end-user.

Key Findings of the Smart Grid Report

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Government initiatives and regulations promoting smart grid development and integration must consider bulk power system reliability implications.

Integration of smart grid requires development of new tools and analysis techniques to support planning and operations.

Smart grid devices and systems will change the character of the distribution system, potentially affecting bulk power system reliability.

Cyber security and control systems require enhancement to ensure reliability.

Research and development (R&D) has a vital role in successful smart grid integration.

The 21st Century Grid Emerges

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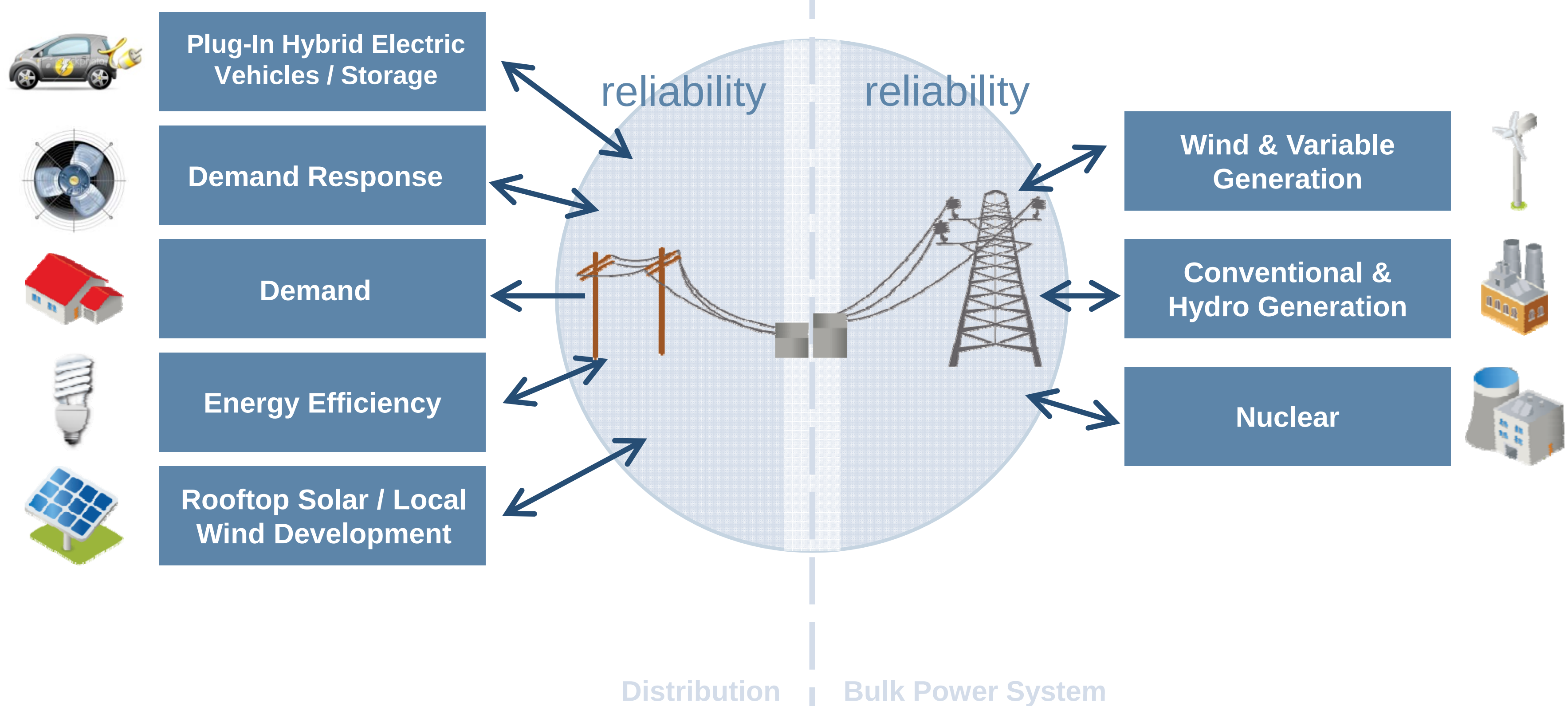
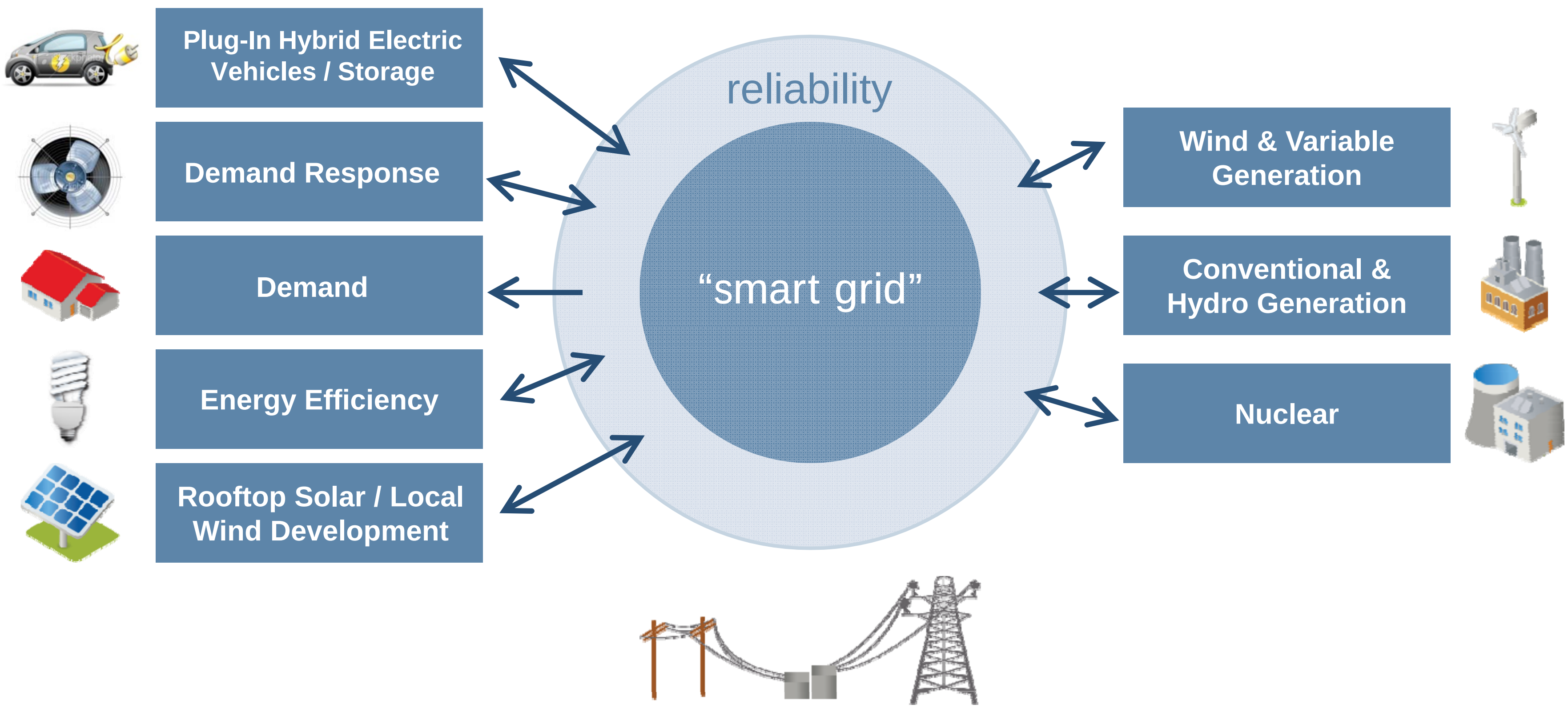
Islands of Automation



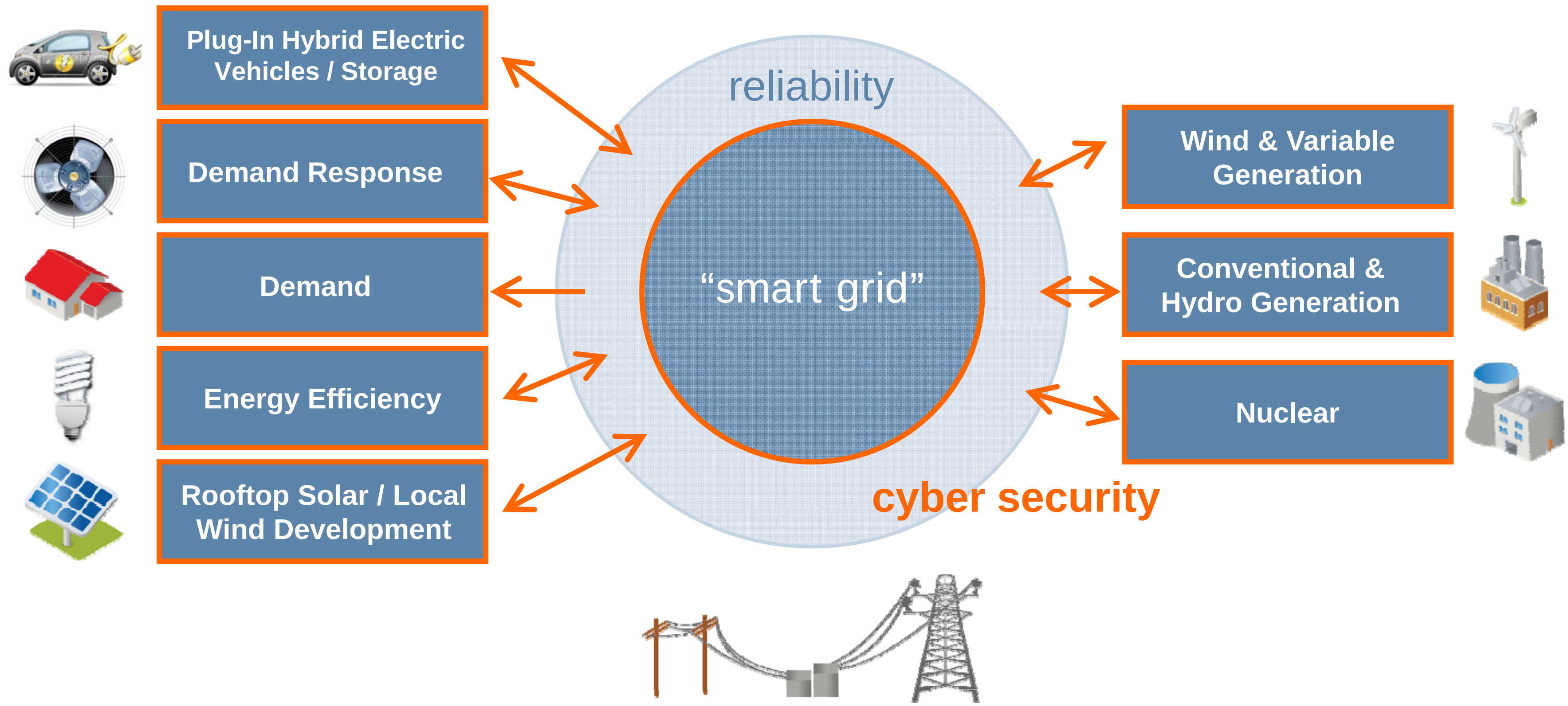
The development and successful integration of these resources will require the industry to break down traditional boundaries and take a holistic view of the system with reliability at its core.

The Smart Grid



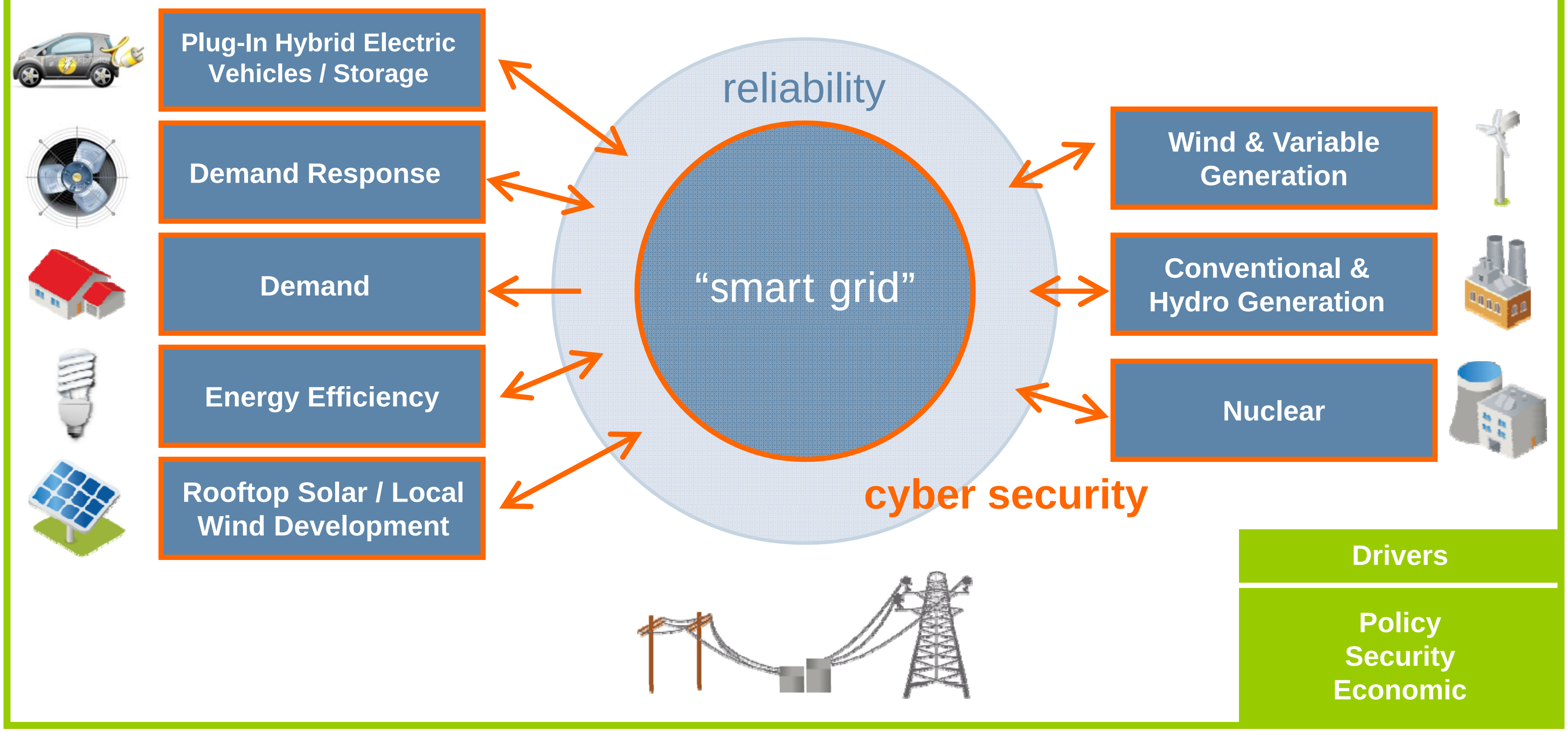
The "Smart Grid" completes the picture of a fully integrated system without boundaries. Stretching from synchro-phasors on the transmission system to smart appliances in the home, these systems will enable the visualization and control needed to maintain operational reliability.

Common Challenges



Cyber security is one of the most important concerns for the 21st century grid and must be central to policy and strategy. The potential for an attacker to access the system extends from meter to generator.

Common Drivers



Building the 21st century grid requires a comprehensive and coordinated approach to policy and resource development – looking at the grid as a whole, not as component parts.

Electric Power: Players, Drivers, Etc.

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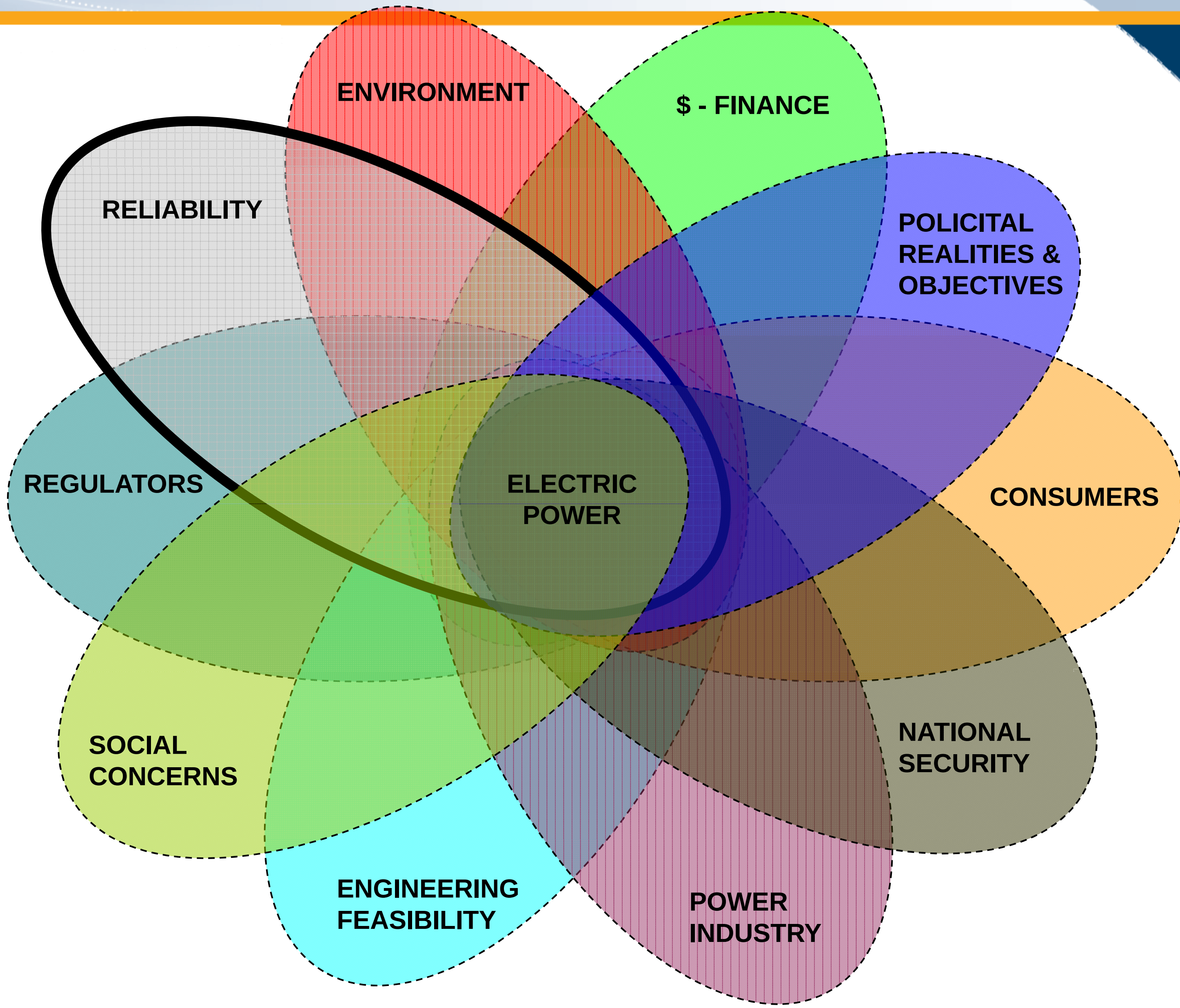

Smart Grid – Everybody has a vision…

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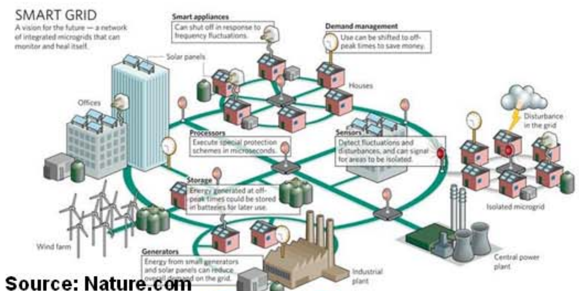
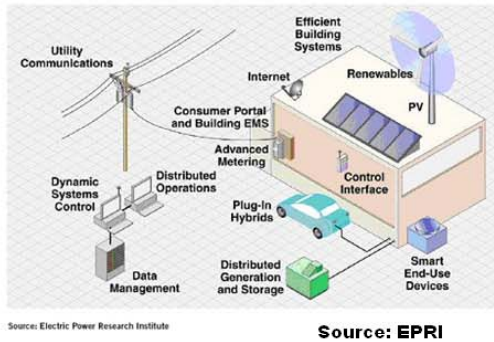
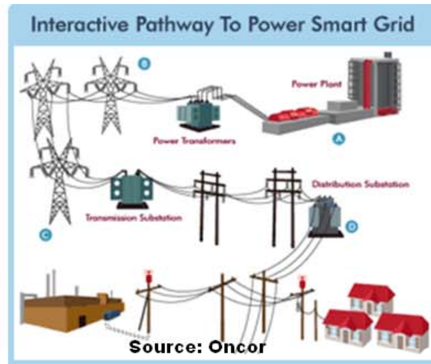


Source: Nature.com



Source: EPRI



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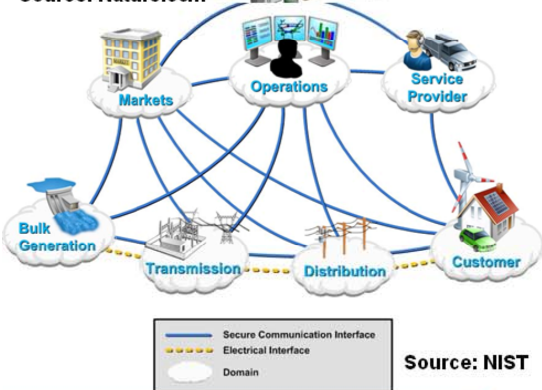
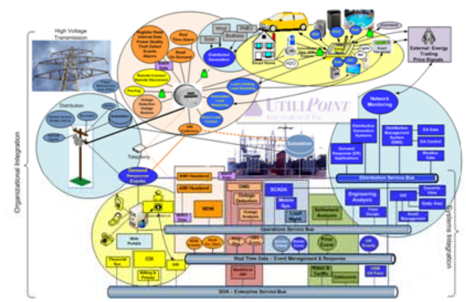


Source: NIST

Source: US DOE



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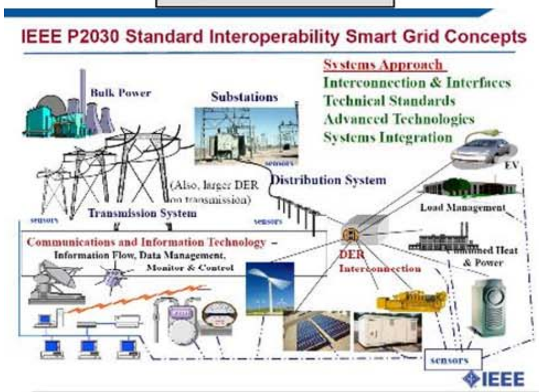
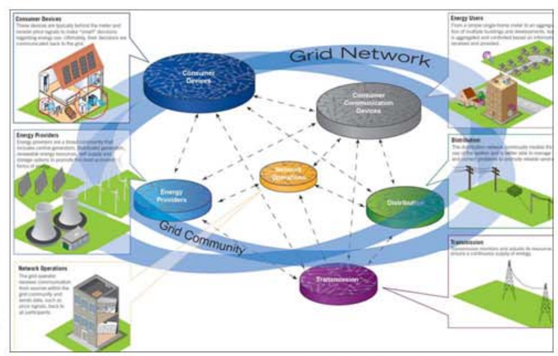
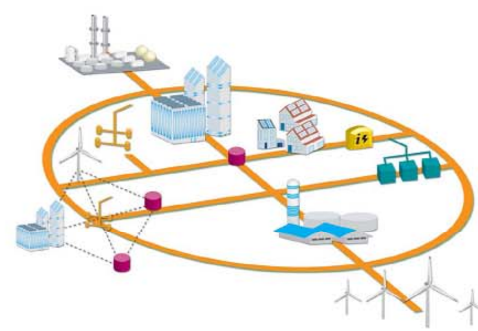




Source: Carbonmetrics



Source: Smartgirds.eu

Smart Grid Vision

- Reduce electric sector greenhouse gas emissions;
- Enable consumers to better manage and control their energy use and costs;
- Improve energy efficiency, demand response, and conservation measures;
- Interconnect renewable energy resources;
- Improve bulk power and distribution system reliability;
- Manage energy security; and
- Provide a platform for innovation and job creation.

Smart Grid Landscape

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Concepts

- Interconnection-wide reliability coordinator
- Interconnection-wide state estimator
- Multi-Region data collection and correlation
- Smart grid cyber security and definitions
- Interoperability
- Electricity storage
- Emergency control
- Substation automation
- Device and end-to-end testing
- Training
- Wind generation

Devices

- Synchrophasors and PMU Concentrators
- Wholesale and customer smart meters
- Intelligent end devices (IEDs)
- Switched/controllable capacitor banks
- Digital fault recorders
- Plug-in electric vehicles
- Power quality meters
- Direct control load management
- DLR for operations
- Tension and Sag measurement

Applications

- State Estimator and Contingency Analysis
- Wide-area situational awareness
- Event detection
- Disturbance location
- Dynamic Ratings
- Pattern recognition
- Protection systems
- Remedial action
- Demand Response
- Automatic meter Reading
- Voltage/reactive control
- Operator training simulator
- Data storage and retrieval

Measurement/Data

- Voltage and current angle differences
- Voltage and current phasors and DLR
- Frequency
- Three-phase AC voltage and/or current waveforms
- Power system modeling data and real-time data from DLR
- Meter data common profiles
- Dynamic Line Ratings

Communications

- Precision time protocols
- Information management protocols
- Wide-area networks and communications
- Field area networks and communications
- Premises networks and communications
- Wireless communications
- Substation LANs
- Global Positioning System
- Encryption
- Phasor Management Networks

The Smart Grid Landscape: Devices & Systems

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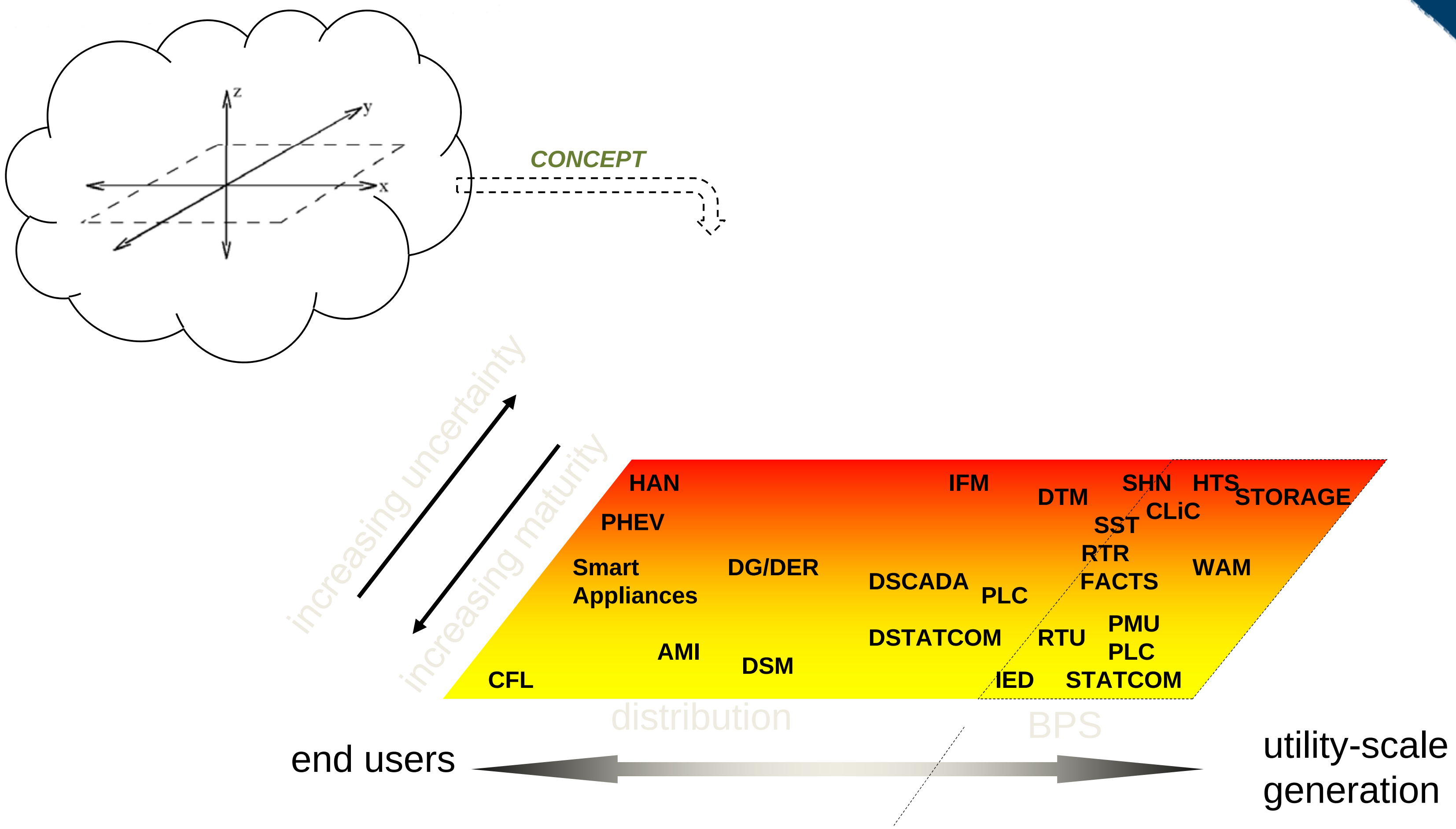
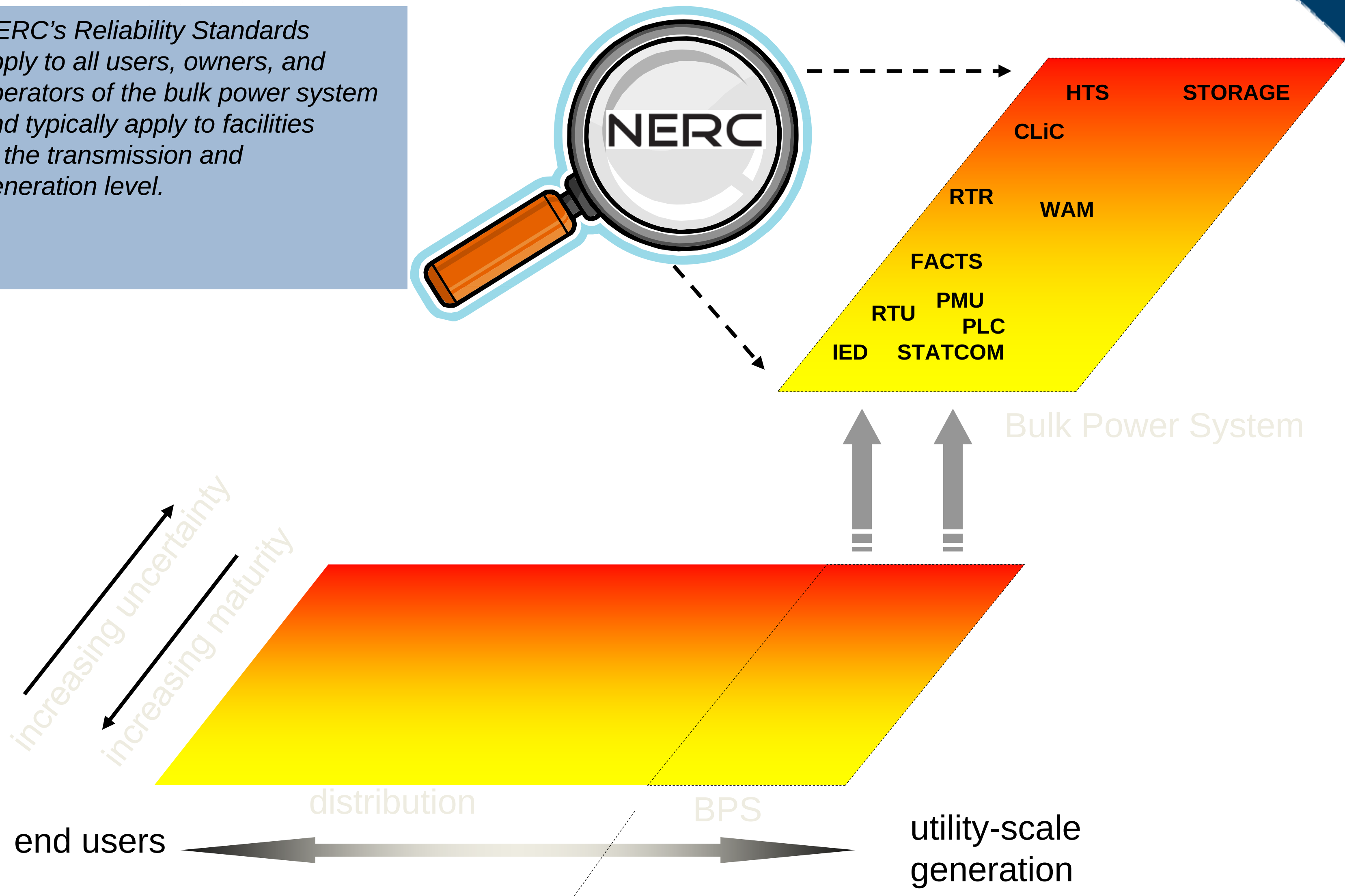


NOTE: Placement of items in the plane above is for concept discussion purposes.

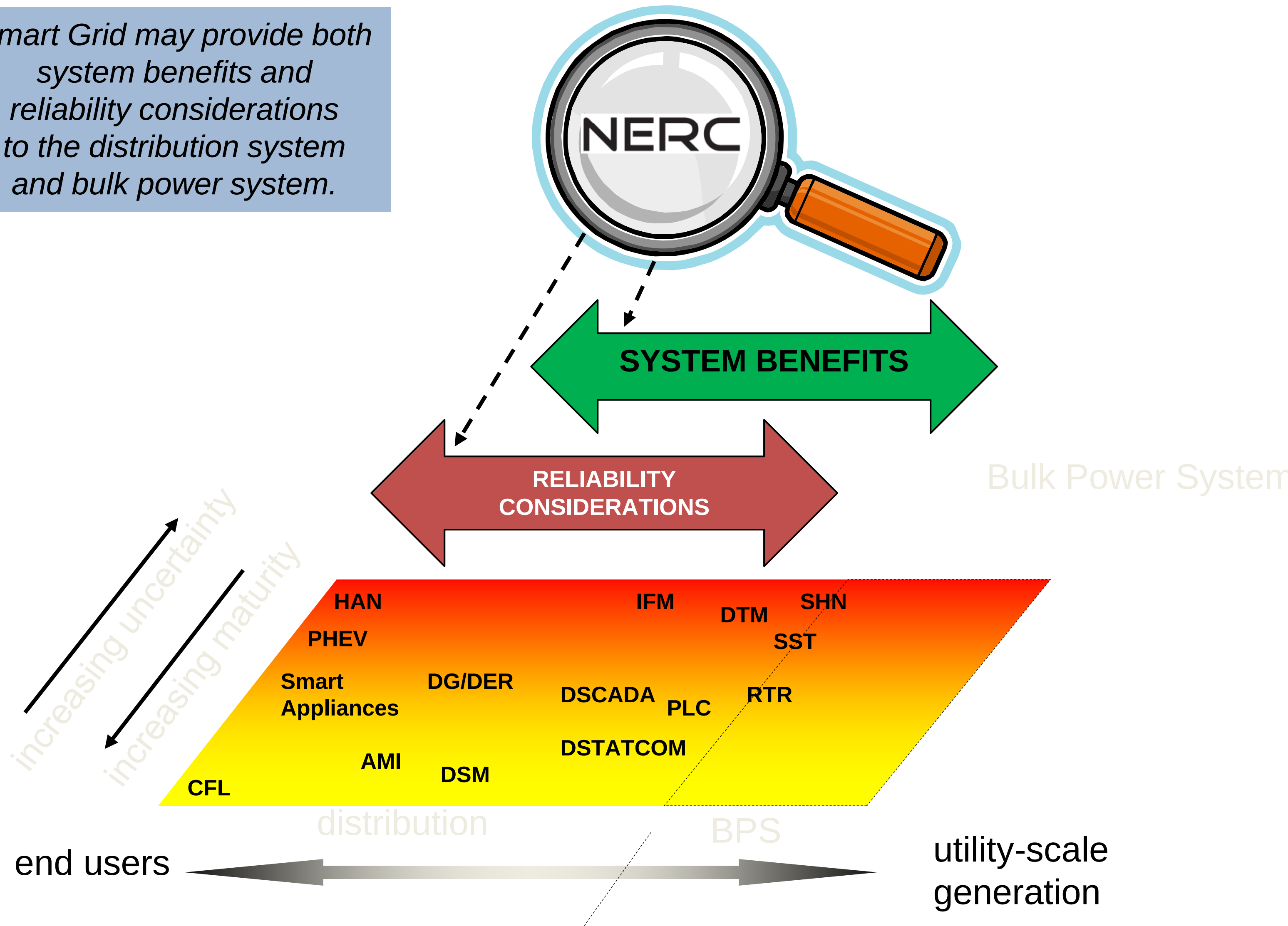
The Smart Grid Landscape:
Bulk Power System Devices and Systems

NERC's Reliability Standards apply to all users, owners, and operators of the bulk power system and typically apply to facilities at the transmission and generation level.



The Smart Grid Landscape: Distribution System Devices and Systems

Smart Grid may provide both system benefits and reliability considerations to the distribution system and bulk power system.



The Smart Grid Landscape: Distribution System Devices and Systems

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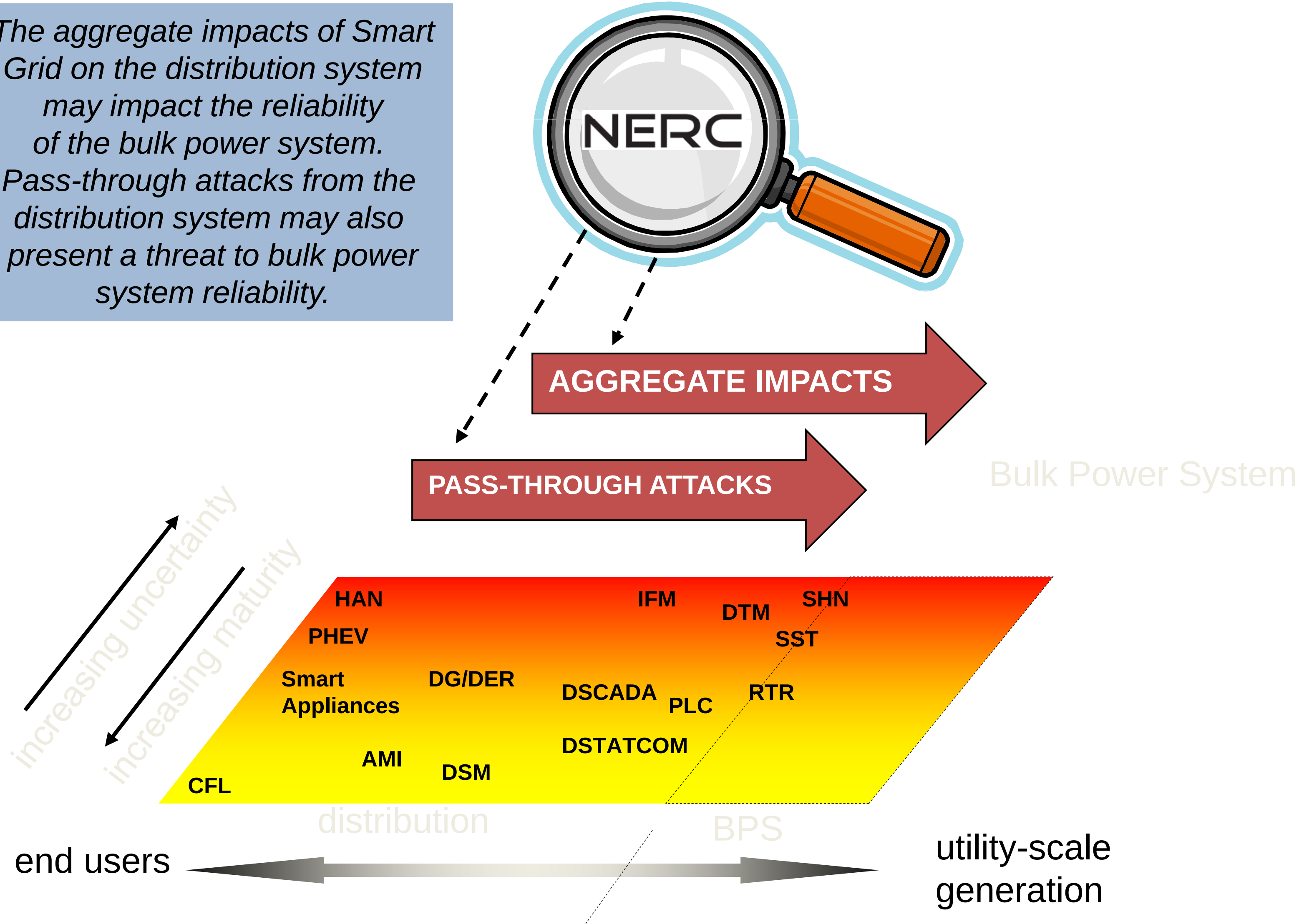
The aggregate impacts of Smart Grid on the distribution system may impact the reliability of the bulk power system. Pass-through attacks from the distribution system may also present a threat to bulk power system reliability.



Reliability Considerations

- Coordination of controls and protection systems
- Cyber security in planning, design, and operations
- Ability to maintain voltage and frequency control
- Disturbance ride-through (& intelligent reconnection)
- System inertia – maintaining system stability
- Modeling harmonics, frequency response, controls
- Device interconnection standards
- Increased reliance on distribution-level assets to meet bulk system reliability requirements

System Reliability Benefits

- Two-way flow of energy and communications enabling new technologies to supply, deliver and use electricity.
- Functions
  - Enhanced flexibility and control
  - Balancing variable demand & resources (storage, PHEV, etc.)
  - Demand response integration
  - Large deployment of sensor & automation technologies (wide-area situational awareness)
  - Congestion management
  - Voltage stability (transient & post-transient stability)
  - Frequency regulation, oscillation damping
  - Disturbance data monitoring/recording
  - Integrating increased amounts of distribution-level assets (residential solar panels, PHEV, etc.)

Identification of Risk on Bulk Power System

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Input into Certification Process

Likelihood – Threats	*Likelihood - Vulnerabilities*	*Impact Areas*
Naturally occurring events (regardless of how infrequent)	Communications	Generation sensors
Untrained and/or distracted personnel	The internet	Generation actuators
Insiders with malicious intent	Grid complexity	Transmission sensors
Cyber attack — lone actors (thrill seekers, script kiddies, etc.)	Grid control system complexity	Transmission actuators
Cyber attack — terrorism	New systems	Distribution sensors
Cyber attack — nation-states	New device	Distribution actuators
		Distributed generation
		Microgrids
		Communications networks
		Intelligent or autonomous systems

Despite the technical advances expected from smart grid, the greatest potential risk factor remains the individual with access to high-level control system privileges.

How to Address Cyber Risks?

- Need a systematic approach to vulnerability management
  - One-off vulnerability mitigation with little context
- Intrusion Tolerant Systems
  - Networks are already a contested territory
- Advanced scenario training platform for operators and responders
- Greater State Awareness
  - Detect system thrifts and changes (Security inclusive situational awareness)
- Remove implicit data and system trust
  - Monitoring philosophy “guilty until proven innocent”

Effects on NERC Standards

- Balancing
  - DSM proliferation, Frequency Bias and Response Improvements
- Critical Infrastructure Protection
  - Identification of Critical Cyber Assets, Device/System Awareness, Recovery Plans
- Communication
  - Data exchange, loss of communication, communication with load
- Emergency Operating Procedures
  - Self-healing applications, PMU data for restoration, Storage for blackstart
- Facility Design, Connections, and Maintenance
  - Dynamic Ratings, Operating Limits, Transfer Capabilities
- Personnel Performance, Training, and Qualification
  - Enhanced real-time data to improve simulator-based training
- Voltage and Reactive Support
  - SVCs and STATCOMs to automatically be inserted to provide VAR support.

2011 Follow-on Action Plan

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- Bulk Power System & Distribution System
  - Control System Interfaces
  - System Stability
  - Modeling Requirements
  - Critical Infrastructure Protection Requirements
- Standard Development Organizations -
  - Continue to provide input on standards development
- Develop Risk Metrics

Questions?

Integrating Smart Grid Technologies: Bulk Power System

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Devices

- Disturbance Monitoring Equipment
- Phasor Measurement Units
- Intelligent Electronic Devices
- Transmission Line Sensors
- Storage

Systems

- Transmission Dynamic Line Rating
- Special Protection Systems/Schemes
- Advanced Relaying Systems
- State Estimators
- Wide Area Management Systems

Integrating Smart Grid Technologies: Distribution System

Devices

- **Advanced Metering Infrastructure**
- **Power Factor Correction Devices**
- **Integrated Volt/VAr Control**
- **Storage**

Systems

- **Demand-Side Management Programs**
- **Under-Frequency/Voltage Load Shedding**
- **Electric Transportation Supply/Demand (V2G)**
- **Industrial Automation Systems**

Background Slide #1

Abbreviations:

- AMI – Advanced Metering Infrastructure
- CFL – Compact Fluorescent Light bulb
- CLiC – Current Limiting Conductors
- DG / DER – Distributed Generation / Distributed Energy Resources
- DSCADA – Distribution Supervisory Control and Data Acquisition
- DSTATCOM – Distributed Static Synchronous Compensator
- DSM – Demand-Side Management
- DTM – Distribution Transformer Monitoring
- FACTS – Flexible Alternating Current Transmission Systems
- HAN – Home Area Networks
- IED – Intelligent Electronic Devices
- IFM – Intelligent Fault Management
- HTS – High-temperature Superconducting cables/devices
- PHEV – Plug-In Hybrid Electric Vehicle
- PLC - Power line carrier/communication
- PMU – Phasor Measurement Units
- RTU – Remote Terminal Units
- SHN – "Self-Healing" Networks
- SST – Solid State Transfer Switches
- STATCOM - Static Synchronous Compensator
- WAM – Wide-Area Management