Smart Grid:
Vision, Status, Challenges

NIST VCAT Meeting

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Topics

- Smart grid: a vision
  - Scope
  - Examples and demonstrations
  - Deployment status
- DOE's smart grid program
- Interoperability & the GridWise Architecture Council

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Part I:

Smart Grid Concept, Vision, and Status

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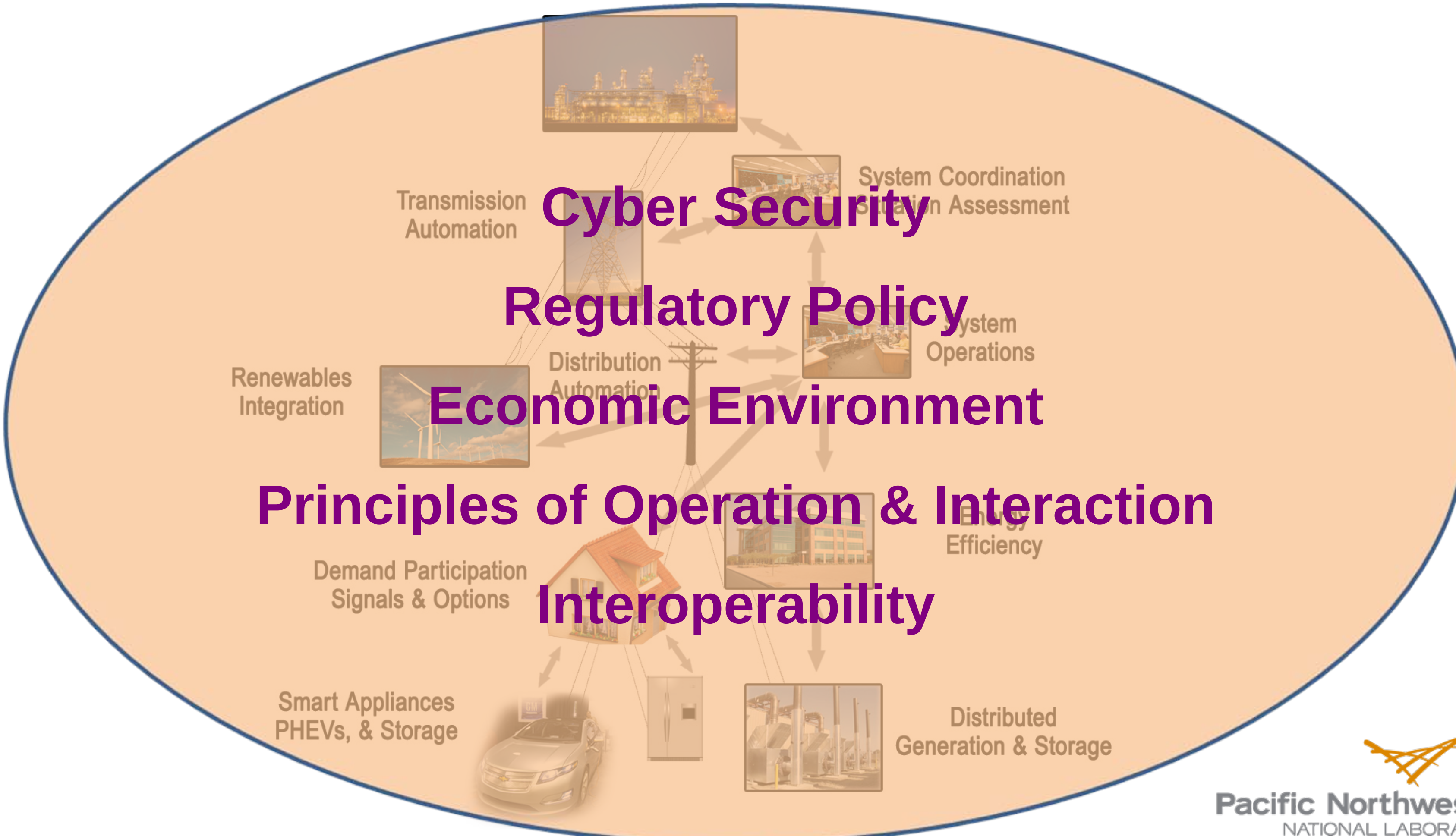
Scope of a Smart Grid

Use of digital technology to improve reliability, security, and efficiency of the electric system with applications for dynamic optimization of system operations, maintenance, and planning.



Cyber Security

Regulatory Policy

Economic Environment

Principles of Operation & Interaction

Interoperability

Smart-Grid Vision

Bring digital intelligence & real-time communications to transform grid operations

- Demand-side resources participate with distribution equipment in system operation
  - Consumers engage to mitigate peak demand and price spikes
  - More throughput with existing assets reduces need for new assets
  - Enhances reliability by reducing disturbance impacts, local resources self-organize in response to contingencies
  - Provide demand-side ancillary services – supports wind integration
- The transmission and bulk generation resources get smarter too
  - Improve the timeliness, quality, and geographic scope of the operators' situational awareness and control
  - Better coordinate generation, balancing, reliability, and emergencies
  - Utilize high-performance computing, sophisticated sensors, and advanced coordination strategies

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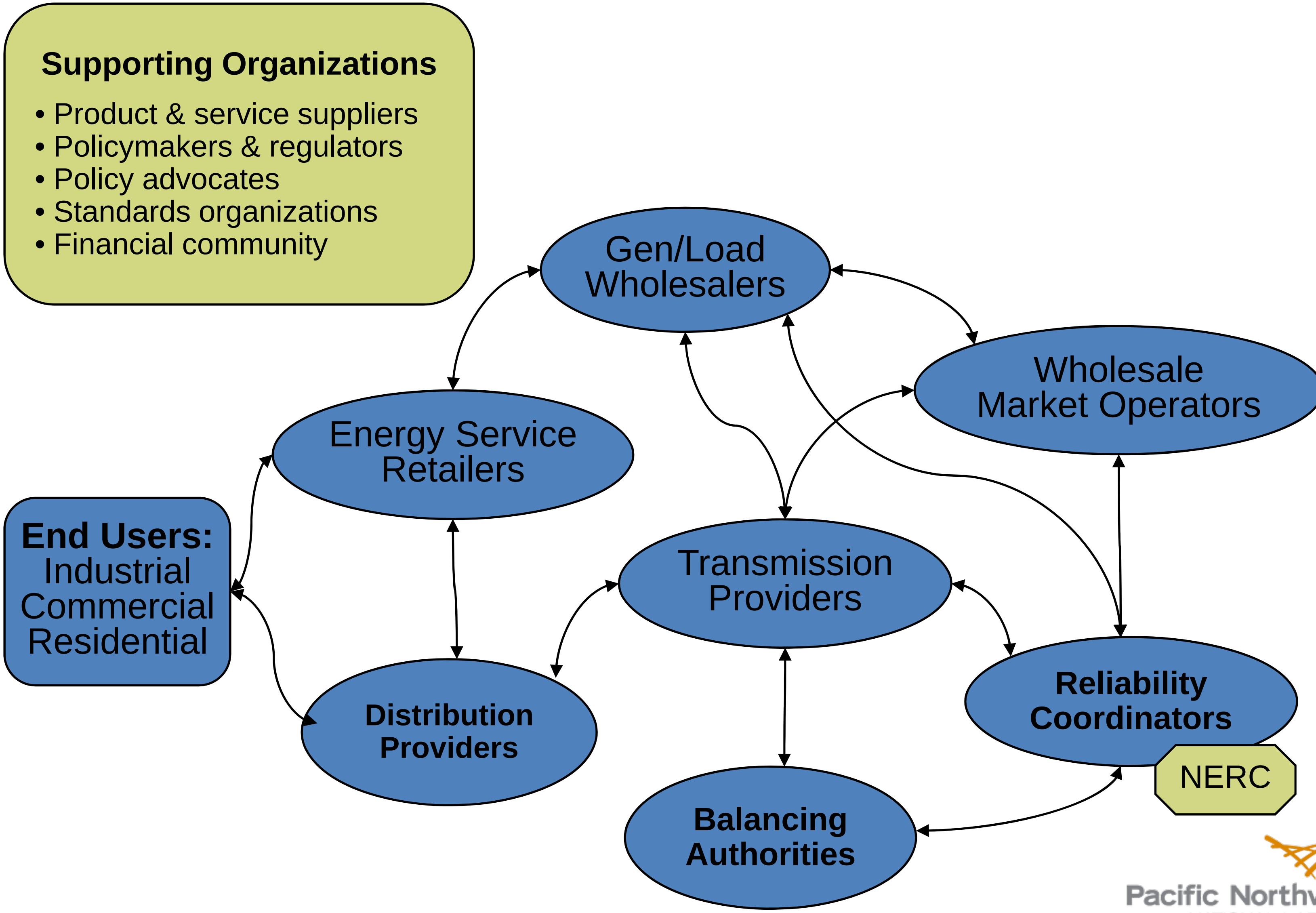
Operational Stakeholders



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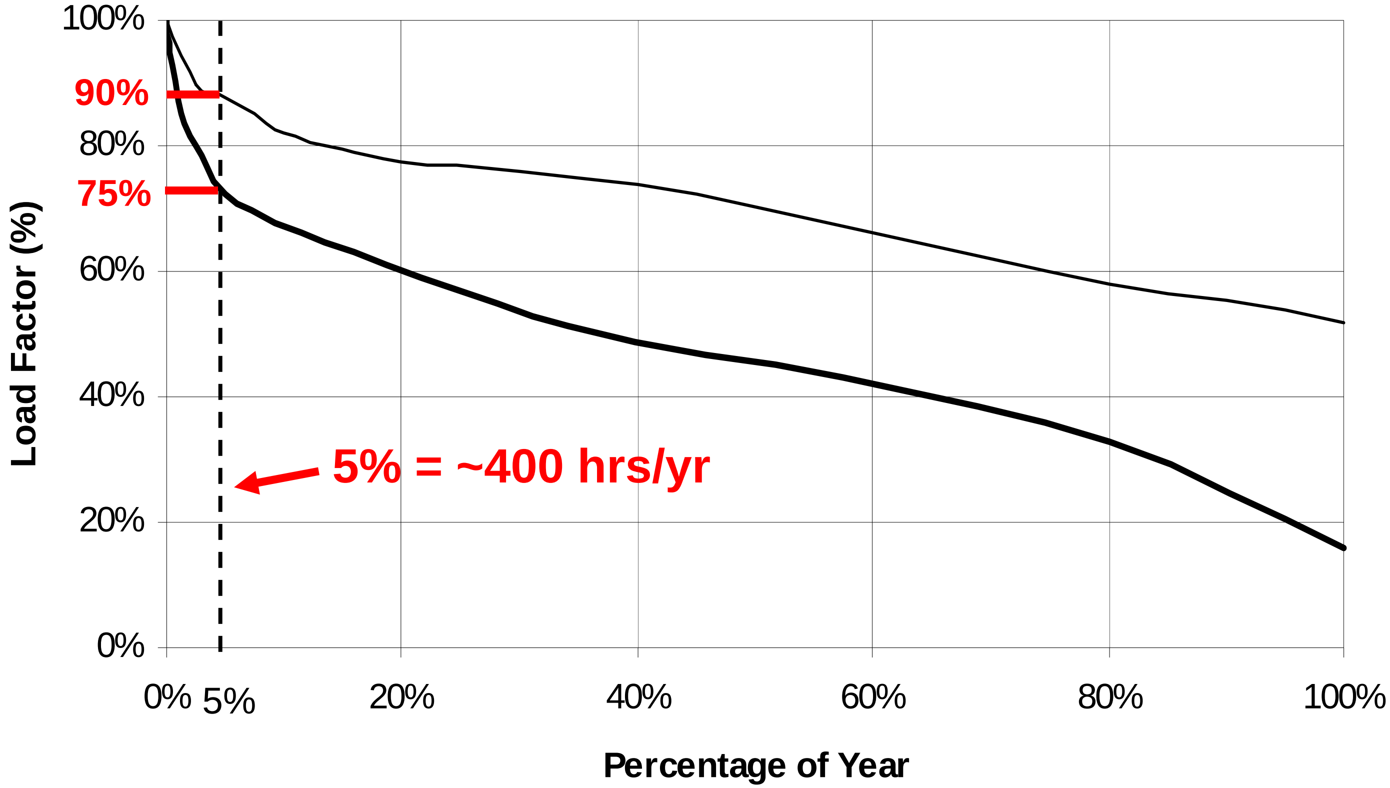
Value of Demand Response

Lower Peak Demand Reduces Infrastructure Investments

Hourly Loads as Fraction of Peak, Sorted from Highest to Lowest



25% of distribution & 10% of generation assets (transmission is similar), worth 100s of billions of US dollars, are needed less than 400 hrs/year!

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GridWise® Demonstration Projects

- Olympic Peninsula GridWise demo
  - Explored how consumers respond to real-time pricing
  - Tested smart appliances in 112 homes for one year
  - Tested commercial facility integration with backup generation
  - Real-time, two-way market with real cash incentives
- Grid Friendly™ Appliance demo
  - Tested device response to stress on grid and consumer acceptance of device in appliances
  - Installed in 150 dryers for one year

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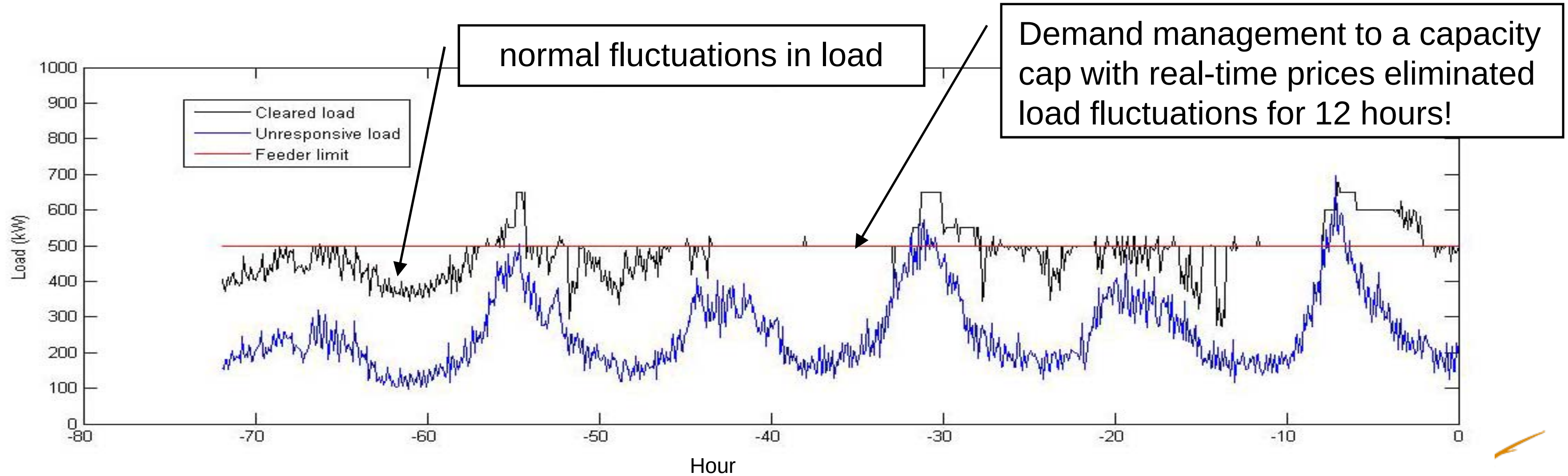
Olympic Peninsula Demo – Key Findings

- Customers will respond to (~5-min.) real-time prices:
  - Opportunity for significant savings on their electric bill
  - Technology automates their desired level of response and keeps it simple
  - They're in control of how much to respond with override capability
- Significant demand response was obtained
  - 15% reduction of peak load
  - Up to 50% load reduction for several days during shoulder periods
  - Can respond energy prices and T&D congestion
  - Potential to provide regulation and other ancillary services
  - Same signals integrate commercial loads, distributed resources

Potential for Demand to Provide Regulation Services

Regulation: fast-responding power plants move to match fluctuations in load

- Highest cost generation in markets
  - Zero energy sales, wear & tear, fuel consumption
- Fluctuations in wind farm output exacerbate need for regulation
  - Reduce cost effectiveness of wind power at high penetrations



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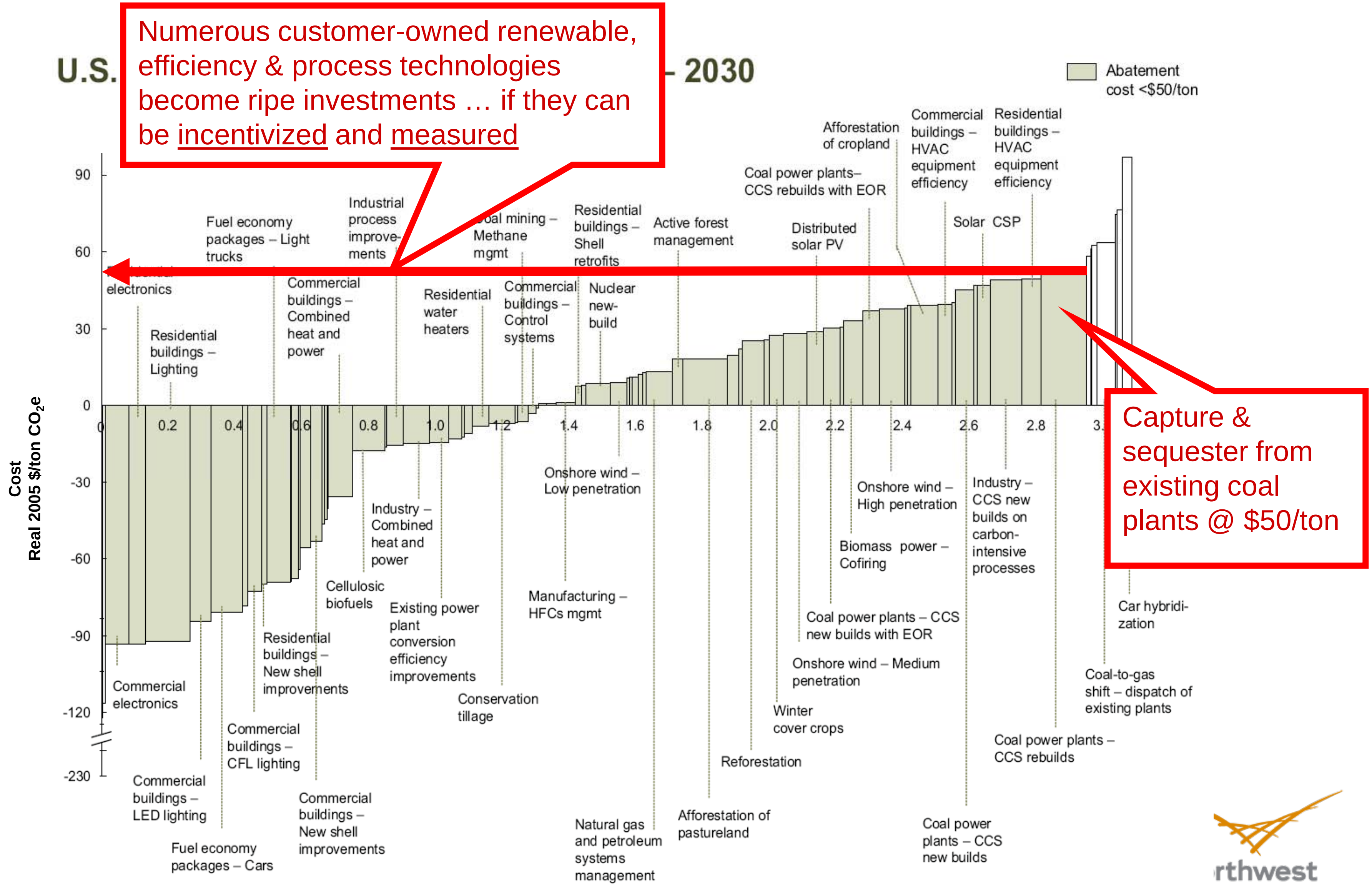
Carbon Supply Curve Suggests Massive Investment in Diverse Set of Resources

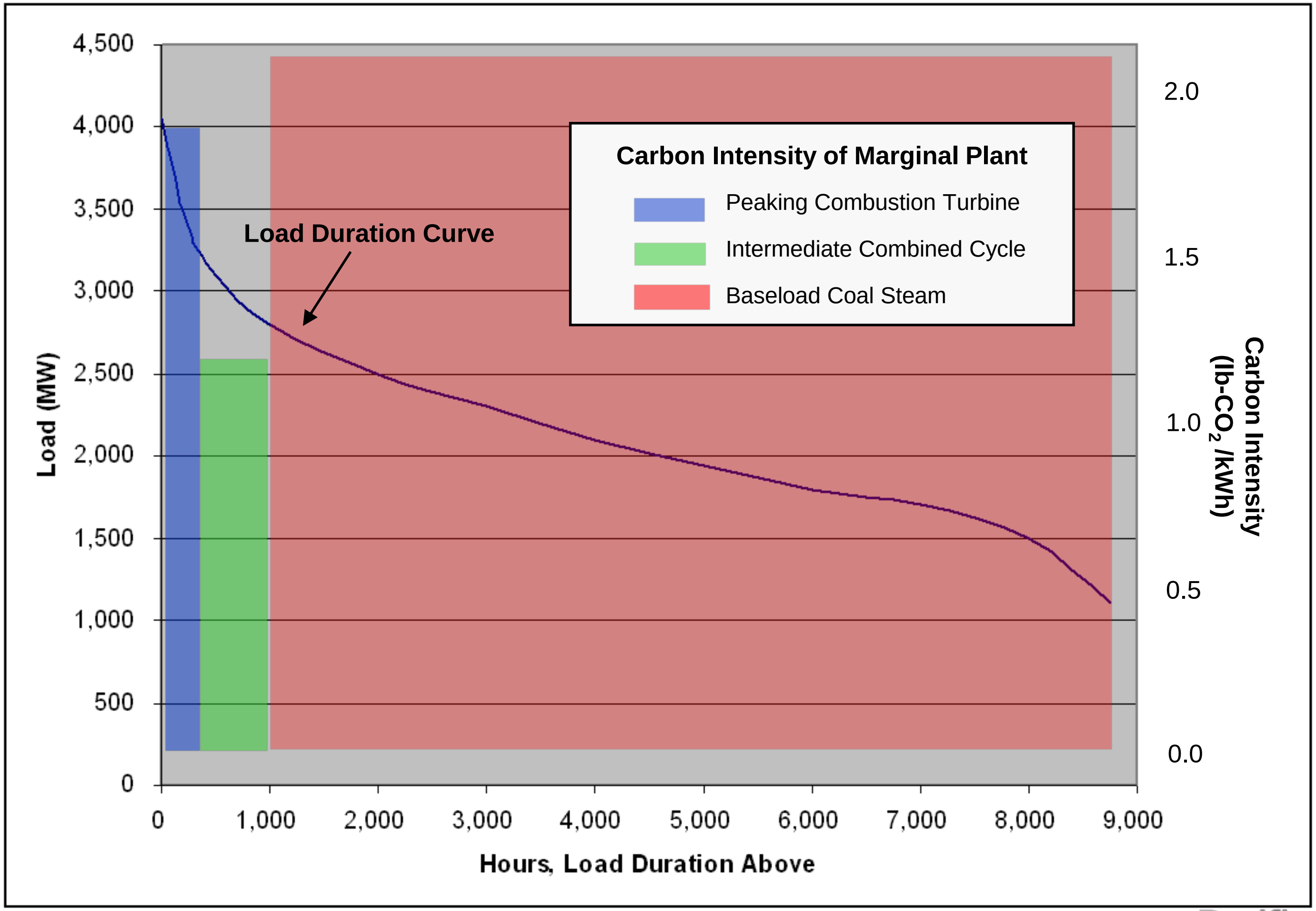


Source: McKinsey analysis

Load Shifting from Peak to Intermediate Plants

Demand Response Saves Carbon – Even Without Saving kWh

Load Duration Curve and Carbon Dispatch of a Typical Coal-Based Utility



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Smart Grid Delivers & Enables Carbon Savings

Sample Mechanisms

A *smart grid* can <u>deliver</u> carbon savings

- End-use efficiency from demand response controls
- Carbon savings from peak load shifting
- Lower wind/solar power integration cost by regulating fluctuations
- Optimize delivery system operation
- Cost effective and cleaner energy for electric vehicles

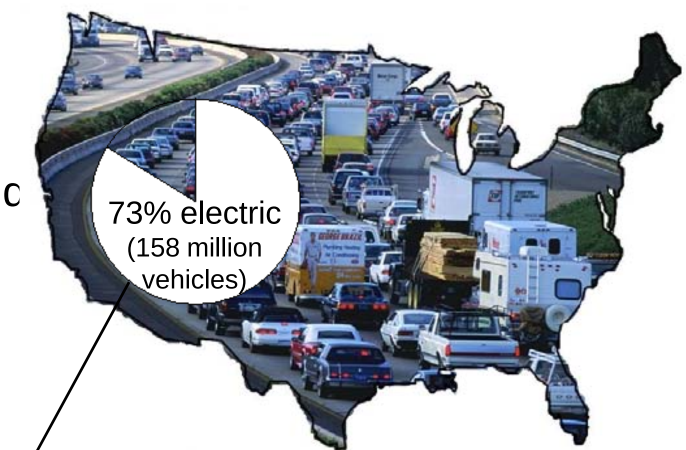
A *smart grid* can <u>enable</u> more, lower cost carbon savings

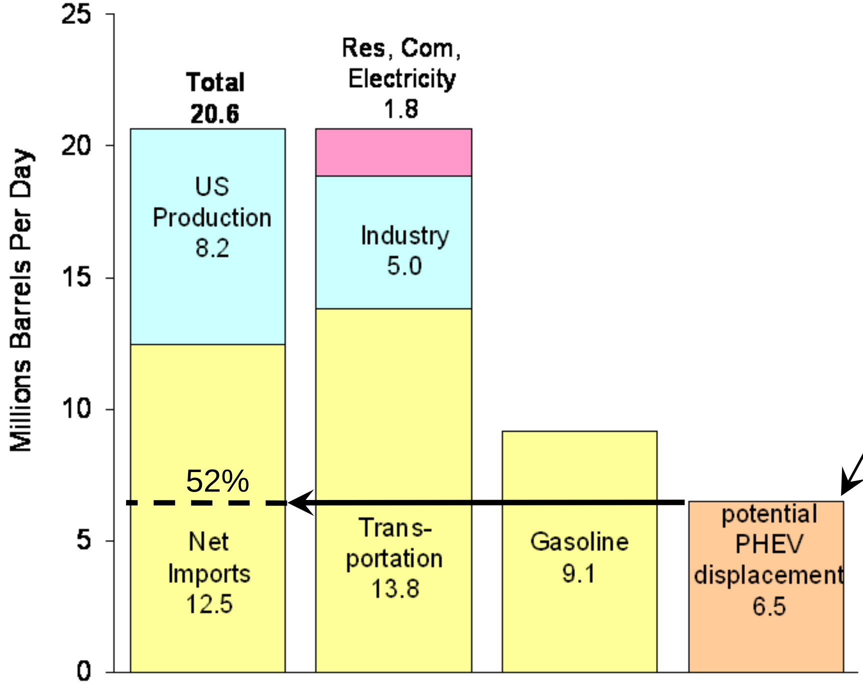
- Support efficiency programs by using network to measure and verify
- Support carbon reduction from generation displaced by efficiency and renewables
  - o Verification enhances value and exchange of carbon offsets

Potential Impacts of High Penetration of Plug-in Hybrid Vehicles (PHEVs) on the U.S. Power Grid*

*PNNL study for DOE Office of Electricity

The idle capacity of today's U.S. grid **could supply 70%** of the energy needs of <u>today's</u> cars, SUVs, pickup trucks, and **without adding generation or transmission** **<u>if vehicles are managed to charge off peak</u>**





- Potential to displace 52% of net oil imports (6.7 MMbpd)
- More sales + same infrastructure = downward pressure on rates
- Reduces CO_2 emissions by 27%
- Emissions move from tailpipes to smokestacks (and base load plants) … cheaper to clean up
- 40%-90% reduction in vehicle urban air quality emissions
- Introduces vast electricity storage potential for the grid

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Measuring Smart-Grid Deployment: 20 Metrics

- Area Coordination
  - Dynamic pricing
  - Real-time data sharing
  - Distributed resource interconnection policy
  - Policy/regulatory progress
- Distributed Energy Resources
  - Load participation
  - Microgrids
  - Distributed generation
  - Plug-in electric vehicles
  - Grid-responsive load
- Delivery (T&D) Infrastructure
  - T&D system reliability
  - T&D automation
  - Advanced meters
  - Advanced system measurement
  - Capacity factors
  - Generation, T&D efficiencies
  - Dynamic line ratings
- Information Networks & Finance
  - Cyber security
  - Open architecture/standards
  - Venture capital investment

Indicators of smart grid deployment progress – not comprehensive measures

Smart-Grid Trends in USA

Trend	Metric Areas
High	Distributed generation, T&D automation, advanced meters, venture capital
Moderate	Dynamic pricing, real-time data sharing, distributed resource interconnection policy, policy/regulatory progress, advanced system measurement
Low	Load participation, microgrids, plug-in electric vehicles, grid-responsive load, gen-T&D efficiencies, dynamic line ratings
Nascent	Cyber security, open architecture/standards
Flat or slight decline	Capacity factors, power quality

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Smart Grid Challenges

- Value proposition immature
  - Cost: some estimate electric system upgrade needs $1.5 trillion by 2030*
  - Cost/benefit for delivered capabilities
  - Valuation of unleashed potential
- Business environment & regulatory landscape
  - Complex regulatory environment: local, state, federal
    - e.g., how to encourage dynamic pricing
  - Risk/reward in competitive v cost-recovery environments
- Interoperability
  - Avoid lock-in, non-competitive situation, stranded assets
  - Standards are not enough
  - Balance alignment with flexibility for innovation, evolution
- Reliability, robustness, resilience
  - Cyber-security
  - System stability and unintended consequences

* Chupka et al, “Transforming America’s Power Industry: the Investment Callenge 2010-2030”, Nov 2008.
http://www.eei.org/ourissues/finance/Documents/Transforming_Americas_Power_Industry.pdf

Smart-Grid Deployment Is a Journey

- Smart-grid vision aligns stakeholders toward a direction
- Action plans need to prioritize incremental steps that provide acceptable return on investments
- Action plans will have regional and organizational differences
  - Starting points
  - Value propositions and preferences/priorities
  - Government and economic/market frameworks
  - Stakeholder composition (service providers, customer composition, reliability coordinators…
- Long term plans need flexibility to change

One size does not fit all

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Part II:

DOE's Smart-Grid Program

ARRA of 2009

- New administration's interest in smart grid to support nation's energy future
  - Energy Secretary Chu & Commerce Secretary Locke involvement
- $4.3 billion in grants for smart grid projects
- $615 million in smart grid demonstrations
- Appropriates $10M to NIST for interoperability framework

ARRA = American Recovery & Reinvestment Act

Smart Grid Investment Grant Program

Overview

Competitive, merit-based solicitation; more than 1000 applications expected
Covers electric transmission, distribution, and customer-side applications
Deployment of Phasor Measurement Units (PMU) a specific program goal

Funding

- $4.3 billion for the program
- Expected project awards range from $100,000 to $5,000,000 for PMU projects; $500,000 to $20,000,000 for others
- Funding provided for up to 50% of qualified investments requested by grant applicants

Anticipated Schedule

Activity	Date
Notice of Intent (NOI)	April 16, 2009
Funding Opportunity Announcement (FOA)	After 30 day comment period for NOI (June, 2009)
FOA – Round 2, if necessary	December, 2009
FOA – Round 3, if necessary	April, 2010
All Funds Obligated	September 2010

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Smart Grid Demonstration Program

Overview

- Competitive, merit-based solicitation; several hundred proposal expected
- Covers transmission, distribution, & end-use projects at a scale for replication across the country
- Scope includes (1) regional smart grid, (2) energy storage, (3) synchrophasor demonstrations

Funding

- $615 million for the program
- Applicant's cost share must be at least 50% of the total allowable costs
- Expect to fund: 8-12 regional demonstrations, 12-19 energy storage projects, and 4-5 synchrophasor projects

Anticipated Schedule

Activity	Date
Draft Funding Opportunity Announcement (FOA)	April 16, 2009
Funding Opportunity Announcement	After 20 day comment period June, 2009
Project Awards	December, 2009

5 Technologies to Look for in Smart Grid Projects

- **Integrated communications**, connects components to open architecture for information and control, allowing grid components to both 'talk' and 'listen'

- **Sensing and measurement technologies**, supports faster and more accurate response such as remote monitoring, dynamic pricing and demand-side participation
- **Advanced components**, applies the latest research in superconductivity, storage, power electronics, and diagnostics
- **Advanced control methods**, monitors essential components, enabling rapid diagnosis and precise solutions appropriate to any event
- **Improved human interfaces and decision support**, amplifies decision-making, transforming grid operations & management with clarity of perspective when examining complex systems & situations

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Part III:

Interoperability and the GridWise Architecture Council

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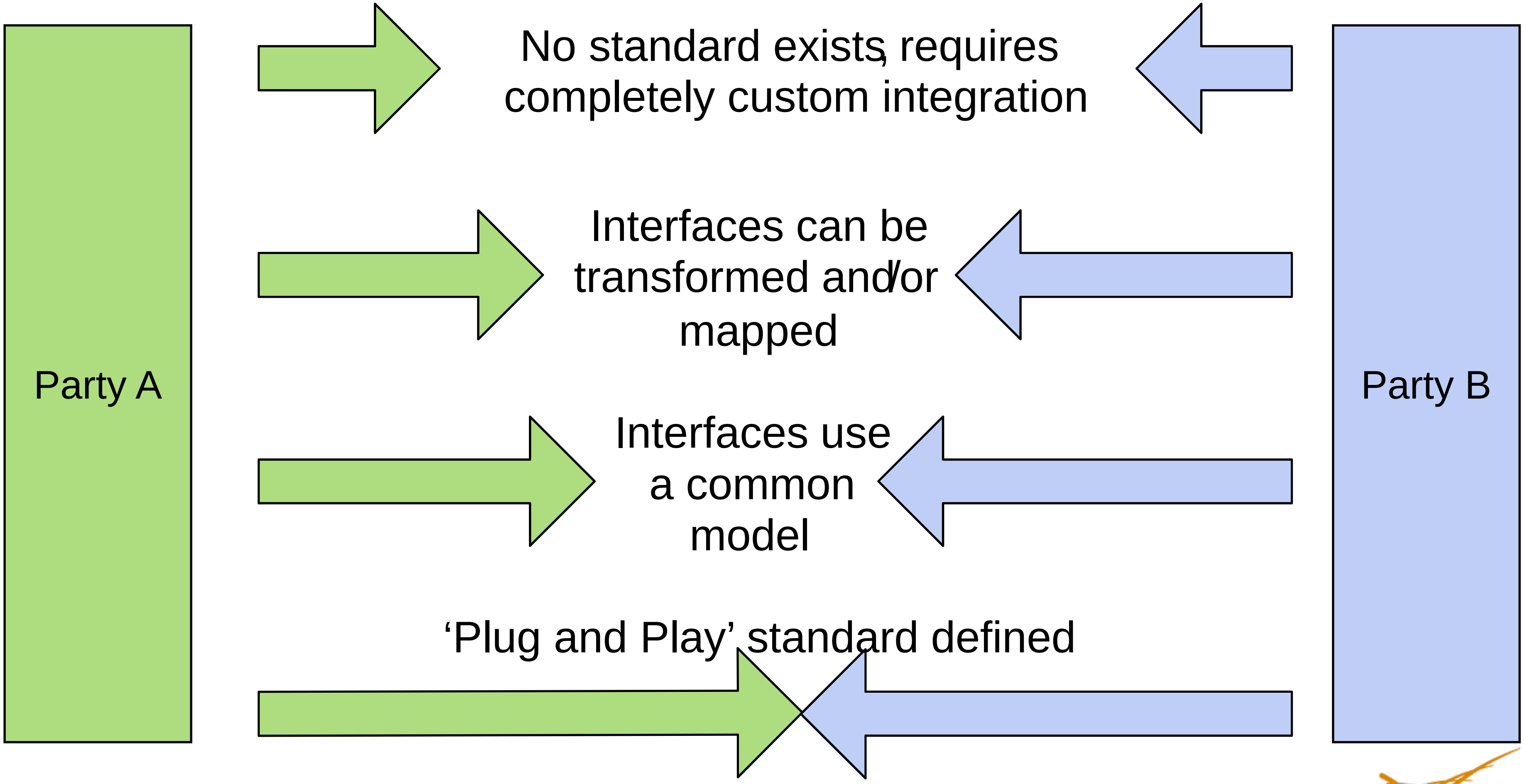
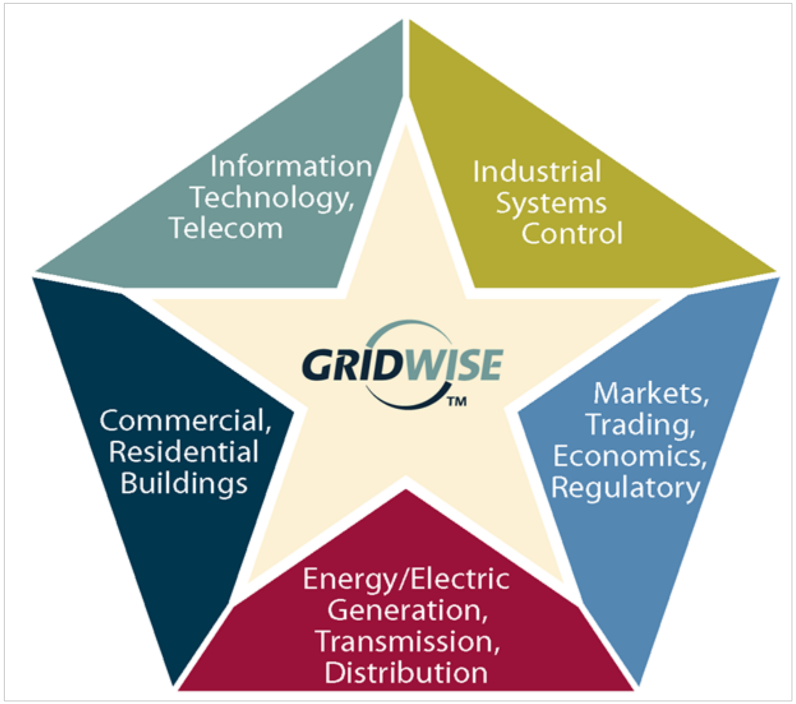
Reduce Distance to Integrate



Credit: Scott Neumann, UISol position paper

GridWise Architecture Council

The future is in the linkage of sectors across the electricity chain



The Electricity Community

www.gridwiseac.org

- Who
  - Respected experts
  - Volunteers
  - Cross-sector organizations
- What
  - Principles of interaction
  - Interoperability

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

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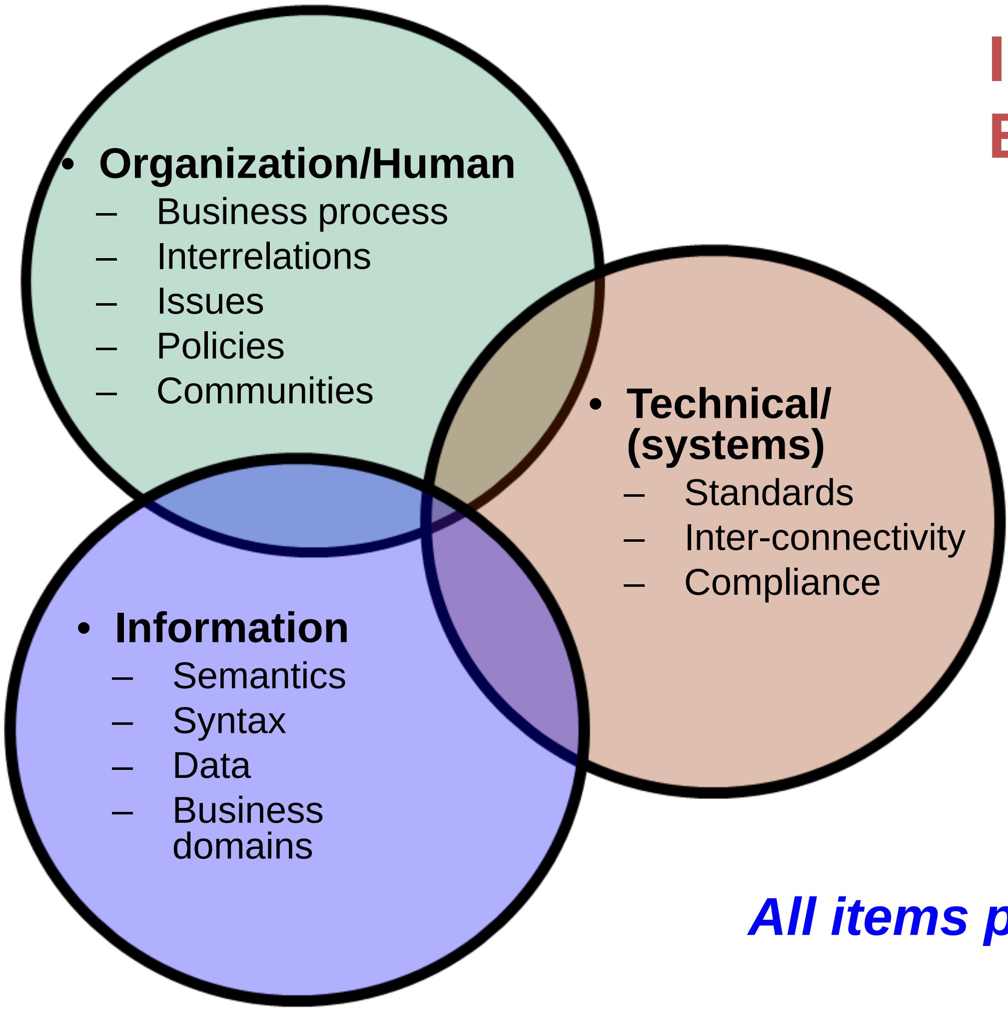
GWAC Mission - Interoperability



Interoperable Systems- Expected Impact:

- **Reduced integration cost**
- **Reduced cost to operate**
- **Reduced capital IT cost**
- **Reduced installation cost**
- **Reduced upgrade cost**
- **Better security management**
- **More choice in products**
- **More price points & features**

All items provide compounding benefits

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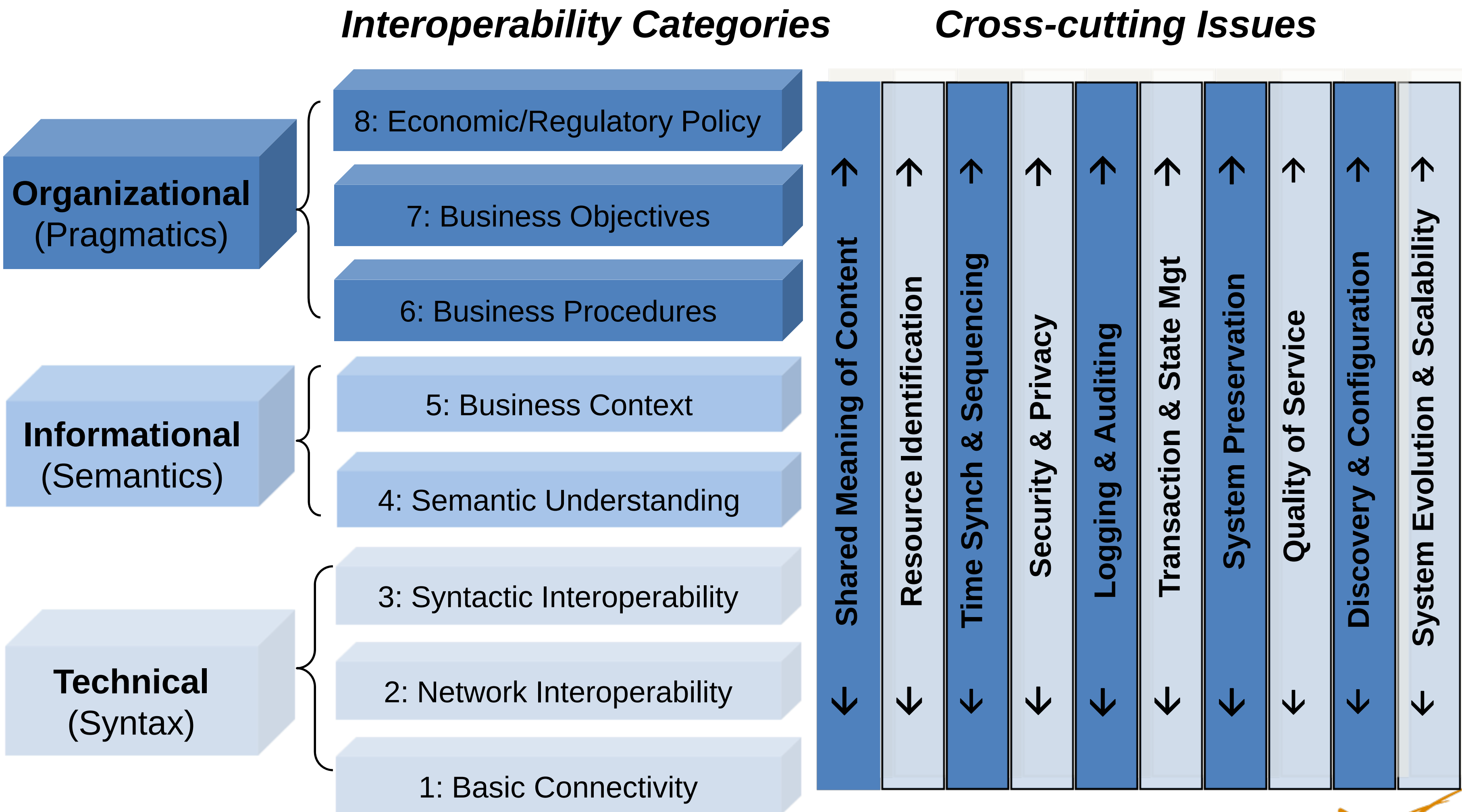
Context-setting Framework



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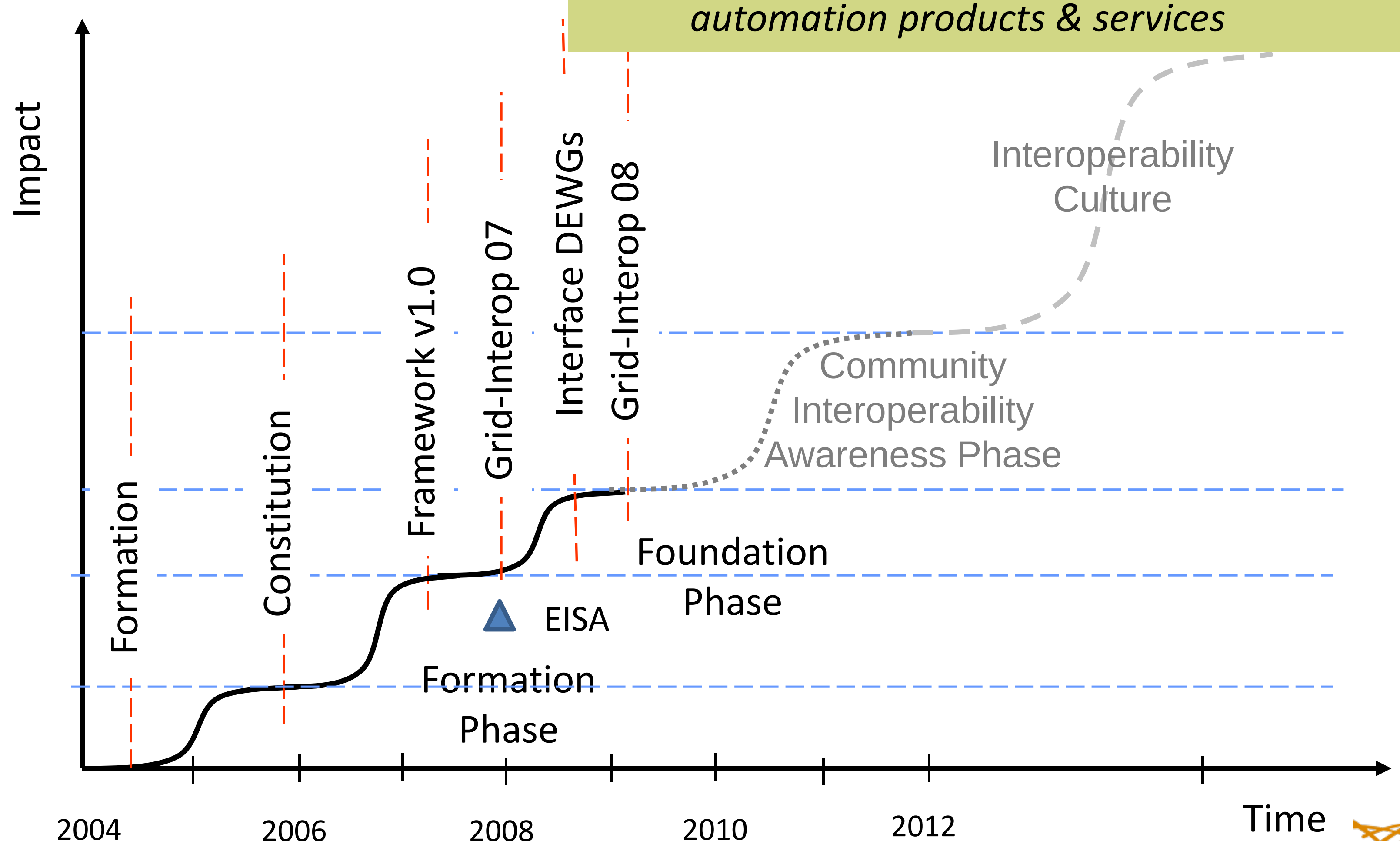
GWAC Accomplishments

Goal: Develop a culture for implementation-ready automation products & services



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NIST/GWAC Collaboration

- GWAC developed collaborative relationship with NIST
  - Understand interoperability concepts, stakeholders, & status
  - Support NIST introduction to smart grid community
  - Integrate NIST in GWAC activities
- Engage interoperability community
  - Propose teams to work on focused issues (from Grid-Interop 07)
  - NIST forms initial working groups with GWAC co-chairs
    - Industrial to Grid
    - Building to Grid
    - Home to Grid
    - Transmission & Distribution
    - Business & Policy
    - Cyber Security

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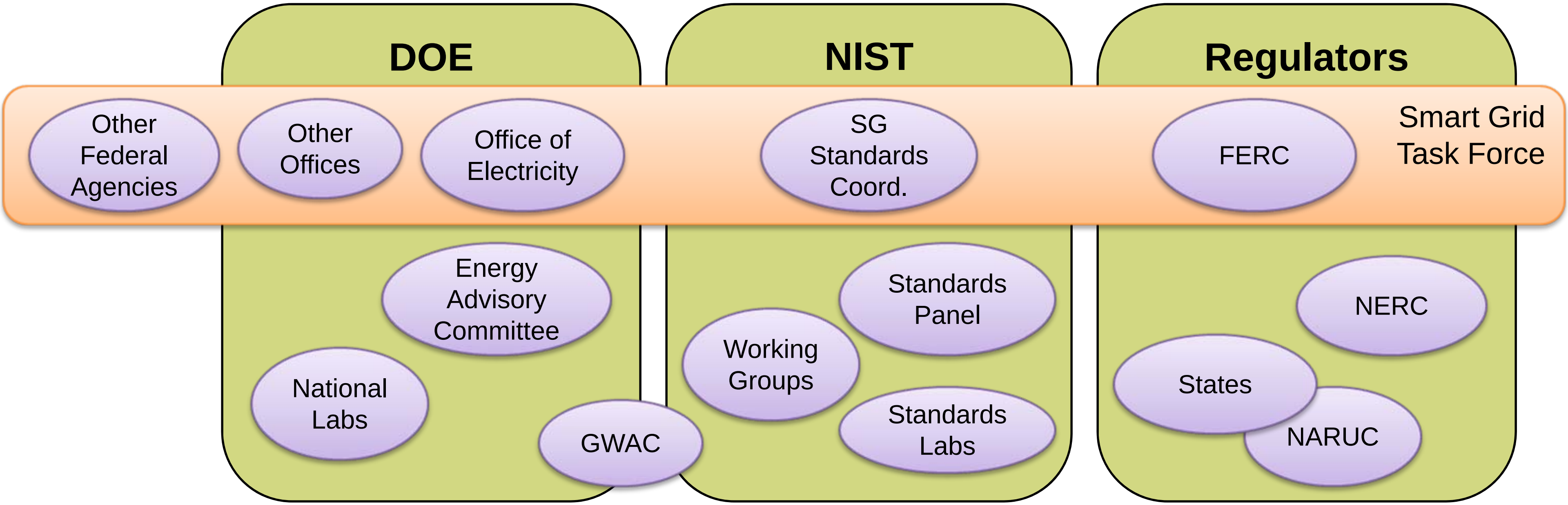
Interop Coordination Landscape*



R&D Organizations

NGOs: EPRI, IBM, Battelle, Lockheed, NRECA, …
State: CEC PIER, NYSERDA
Federal: NIST, National Labs
Academia: PSERC, NETRAC, NSF…

Standards Development Organizations

IEC, IEEE, ASHRAE, NEMA OASIS, SAE, ISA, OMG, IETF, OPC, NAESB, …

Trade Organizations

NEMA, EEI, APPA, NRECA, NMA, ELCON …

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* Service, supplier, operator companies not included. Caveat emptor: incomplete and simplified

Thank you

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