Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Transitioning to the Grid of the Future

By Carl Imhoff
Electric Infrastructure Sector
Pacific Northwest National Lab

DISSCUSSION POINTS

TOPICS

- Challenges
- Substantial Transformation
- Building blocks to GUI Grid Modernization thought leadership
- Emerging DOE Grid Modernization initiative

SG OUTCOMES FOR INDUSTRY, UNIVERSITIES AND GOVERNMENT

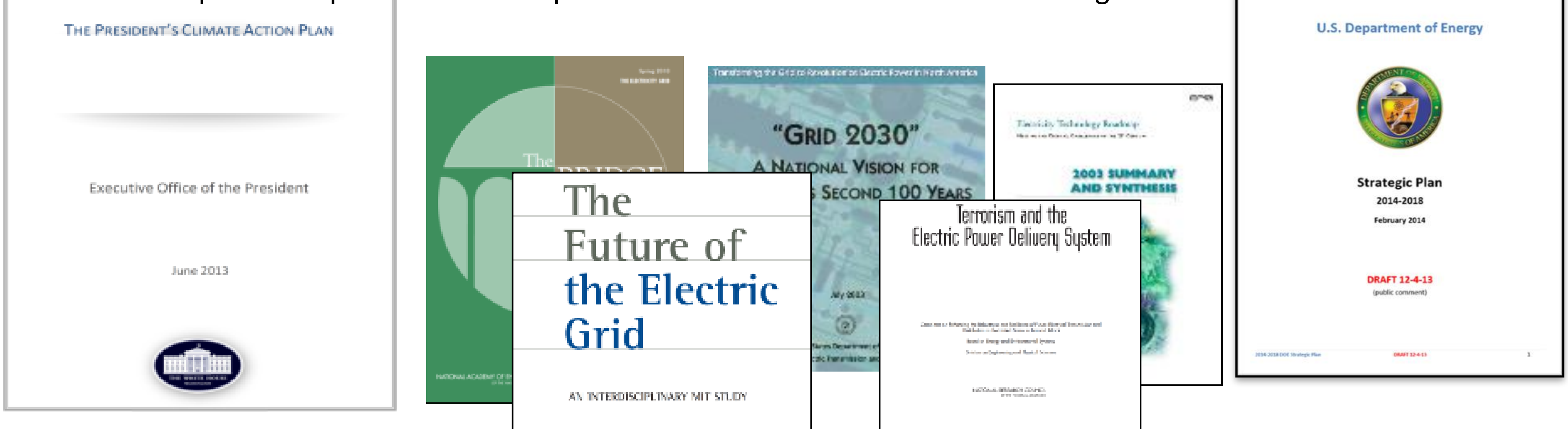
1. Collectively frame agenda on long-term SG needs and opportunities
   - Grid architecture of 2050
   - Engaging emerging digital realities at scale? To what end?
   - Enabling resilient, affordable ops today; robust across energy futures beyond 2050
2. Better link “science”
3. Federate innovation assets
4. Policy / regulatory engagement

U.S. Grid Challenge

- Increasingly vulnerable to both extreme weather and cyber/physical attacks
- Aging and inefficient
- Poorly prepared to integrate large amounts of new dynamic resources
  - Real-time measurement and control of variable generation and loads
  - Distributed vs centralized generation
  - Loss of traditional baseload generation

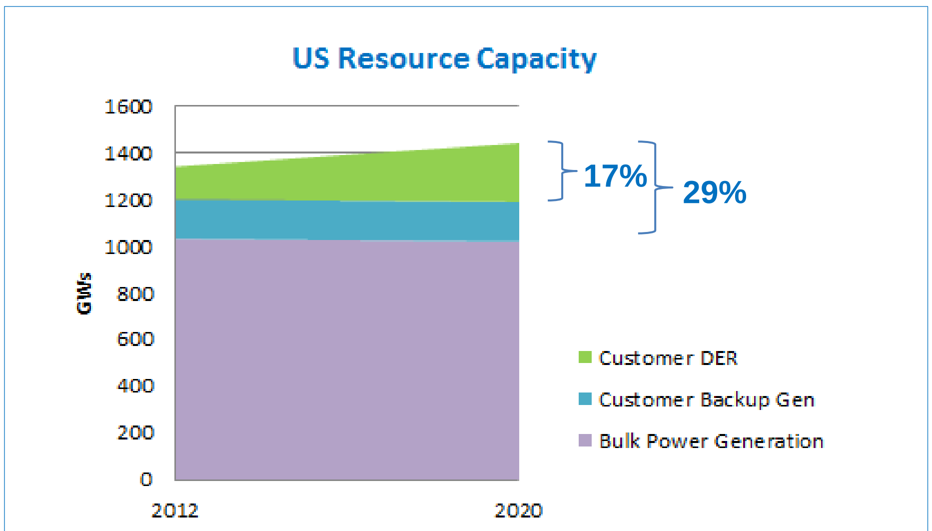
Climate Action Plan – "Expanding and modernizing the electric grid"

U.S. Department of Energy Strategic Plan 2014-2018. "DOE will develop models and next-generation grid operating systems, broaden integration of distributed resources, pursue techniques for decentralized and coordinated control of energy resources, and establish partnerships to address adoption barriers to meet Climate Action Plan goals."

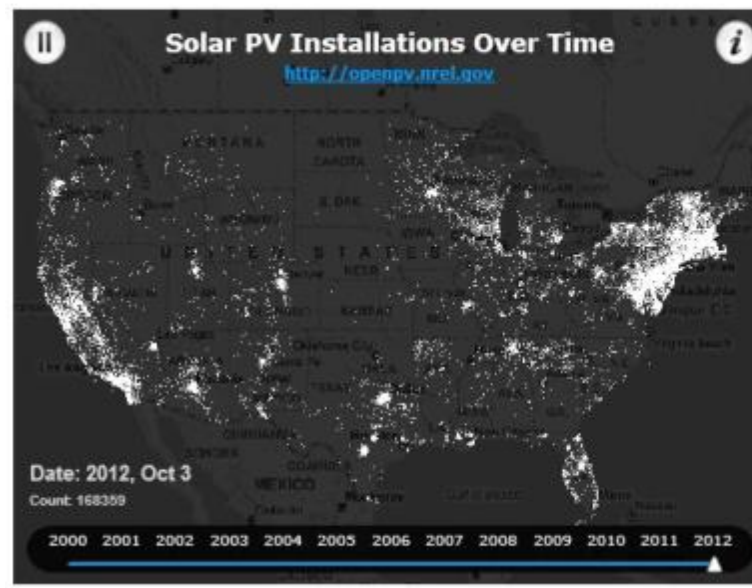


Emerging Trends - Unintended Consequences

- Inversion of the generation model – central to distributed
- Destabilization of the grid due to penetration of renewable energy
- Responsive loads and wide market participation by consumers
- Impact of storage and high voltage power electronics



Sources: EIA, FERC, DoE, GlobalData



Transformation is Already Substantial

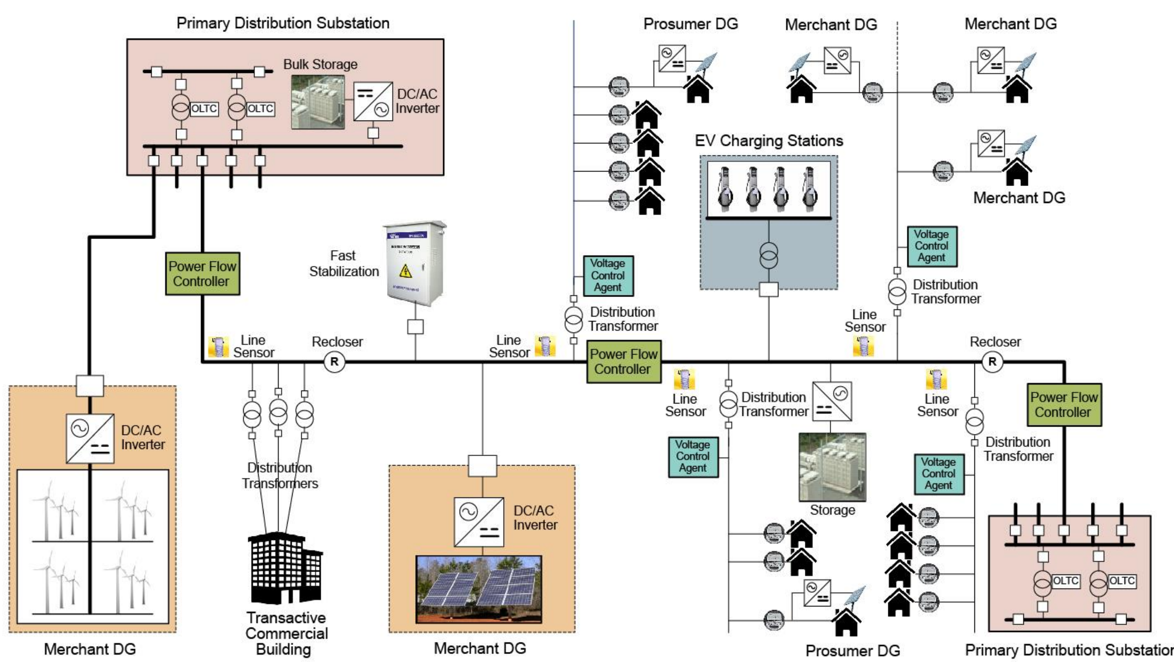
- SG is sensing, communications and control across the entire power system, from high voltage generation to customer premise
- North American phasor measurement network will exceed 1200 measurement points networked by 2014
- Digital metering expected to reach 30% market share 2013, 50% by 2015
- Mainstay operational tools (minutes) now being demonstrated at SCADA rate (seconds)
- Distribution automation demonstrating substantial improvements in efficiency and reliability
- Demand response at the GW scale in several markets in the U.S.

Challenge: How do we capture Smart Grid benefits in current grid AND position to enable new paradigms for the grid we want in 2050?

Key Trend: Rapid Evolution toward a *Broad Access Distribution Grid*

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by **Battelle** *Since 1965*

- NY Reforming the Energy Vision (REV) process
- California Beyond Smart
- Hawaii Grid Modernization
- Trend towards broad distribution system access
  - DSO in context
  - TE in context
  - B2G in context



National Challenge in Grid Architecture and Control

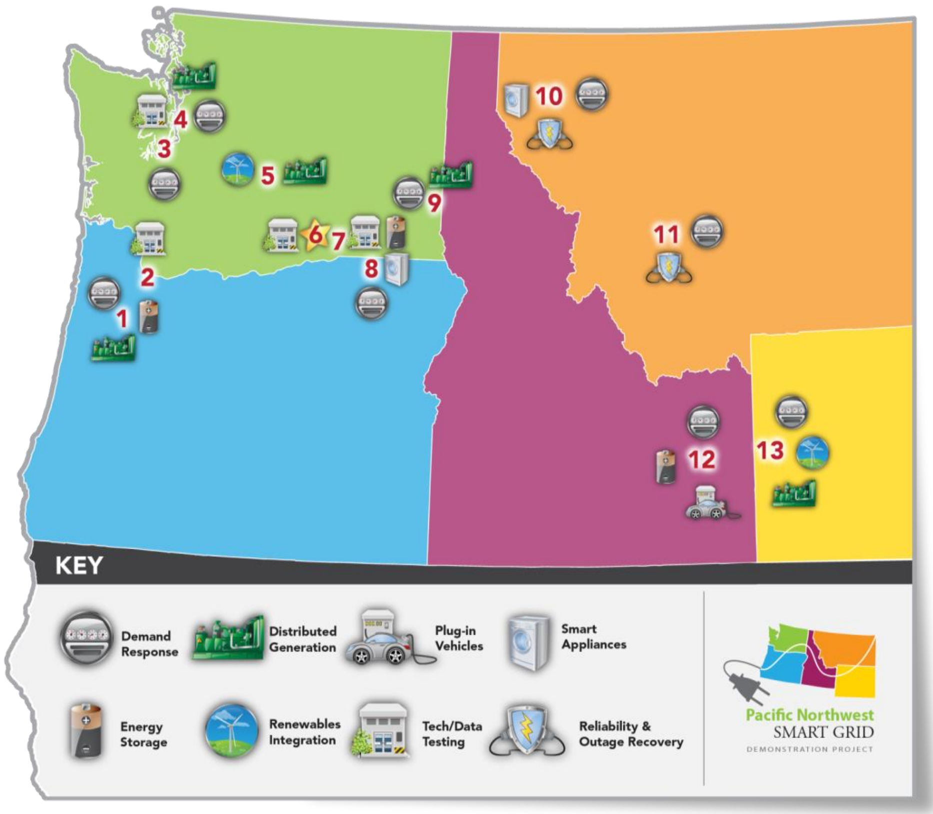
- New grid architecture and advanced control methods and tools
  - Control system vendors won't move first on this due to slim nature of their markets
  - Utilities need to "kick the tires" before they will commit
- DOE can drive the step change
  - Validated reference architecture: grid, storage, renewables, controls…
    - Best way to illustrate end-state view of complex system
    - Each stakeholder can identify and understand their interests
  - Key science/technology elements
    - Mathematics and control/coordination theory, computer science, storage, power flow control
  - Technology demonstrations (support tire-kicking)
    - Key technologies, regional demonstrations

Pacific NW Smart Grid Demo Expanded Transactive Systems in Scope and Scale

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

Region-scale, BPA and 11 utilities

- $80M smart grid equipment & systems
- 90 different technologies, 30 transactive
- Transactive system coordinates as both local and regional resources
- Demonstrated response to regional wind energy imbalances



Advancing transactive technology

- Formalized protocol, interoperability testing for the transactive signals
- Incorporated forward-looking cost & quantity
- New algorithms for a very broad range of smart grid assets, e.g.
  - Battery storage
  - Managing wholesale monthly non-coincident peak load charges
  - Integrated legacy approaches (e.g., direct load control)

Momentum Building around Transactive Energy

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

U.S. DOE is increasingly engaged

- Office of Electricity
  - Supported demos, developing ancillary service algorithms for loads
  - New program to develop & test transactive designs, theory, valuation methods
- Buildings Technology Office
  - Extending TE beyond grid focus to include energy efficiency, building/campus controls, other consumer- & societally-motivated transactions*

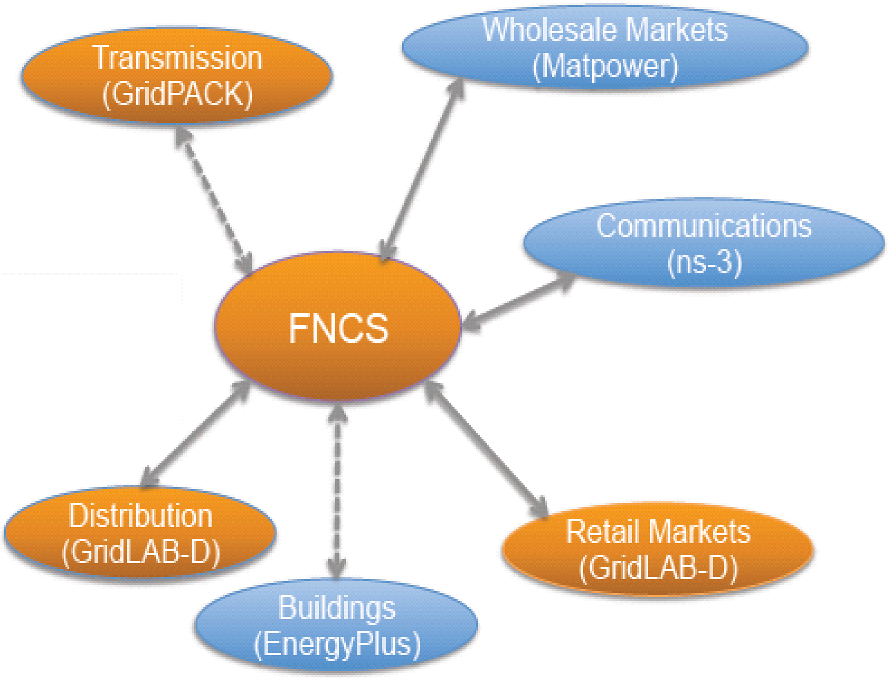
    * http://www.regulations.gov/#!documentDetail;D=EERE-2014-BT-NOA-0016-0041
  - Characterization connected equipment & systems capable of transactions

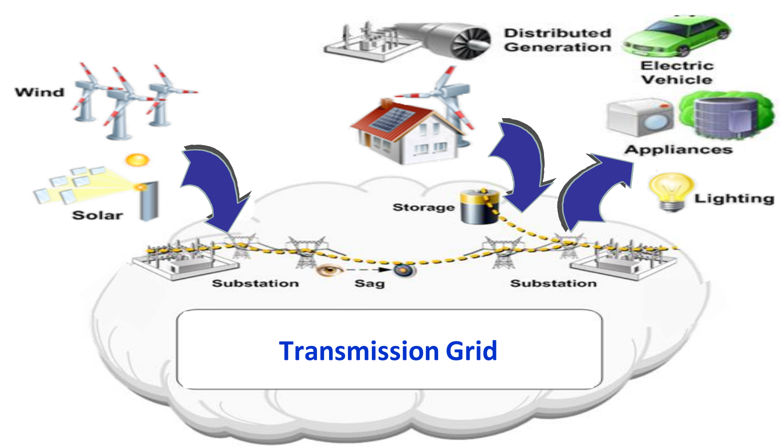
Others around the U.S. and internationally are contributing

- TeMIX design based on forward contracts for energy & transport
- University research activities: MIT, CalTech, Iowa State, U. Victoria, U. Michigan, Virginia Tech, many others
- Power Matcher (Netherlands), Australia
- GridWise Architecture Council convening TE community, building consensus around foundational principles, architecture, & roadmap
- Smart Grid Northwest exploring options to build regional engagement with vendors and others

Construct of smart energy system simulation using FNCS

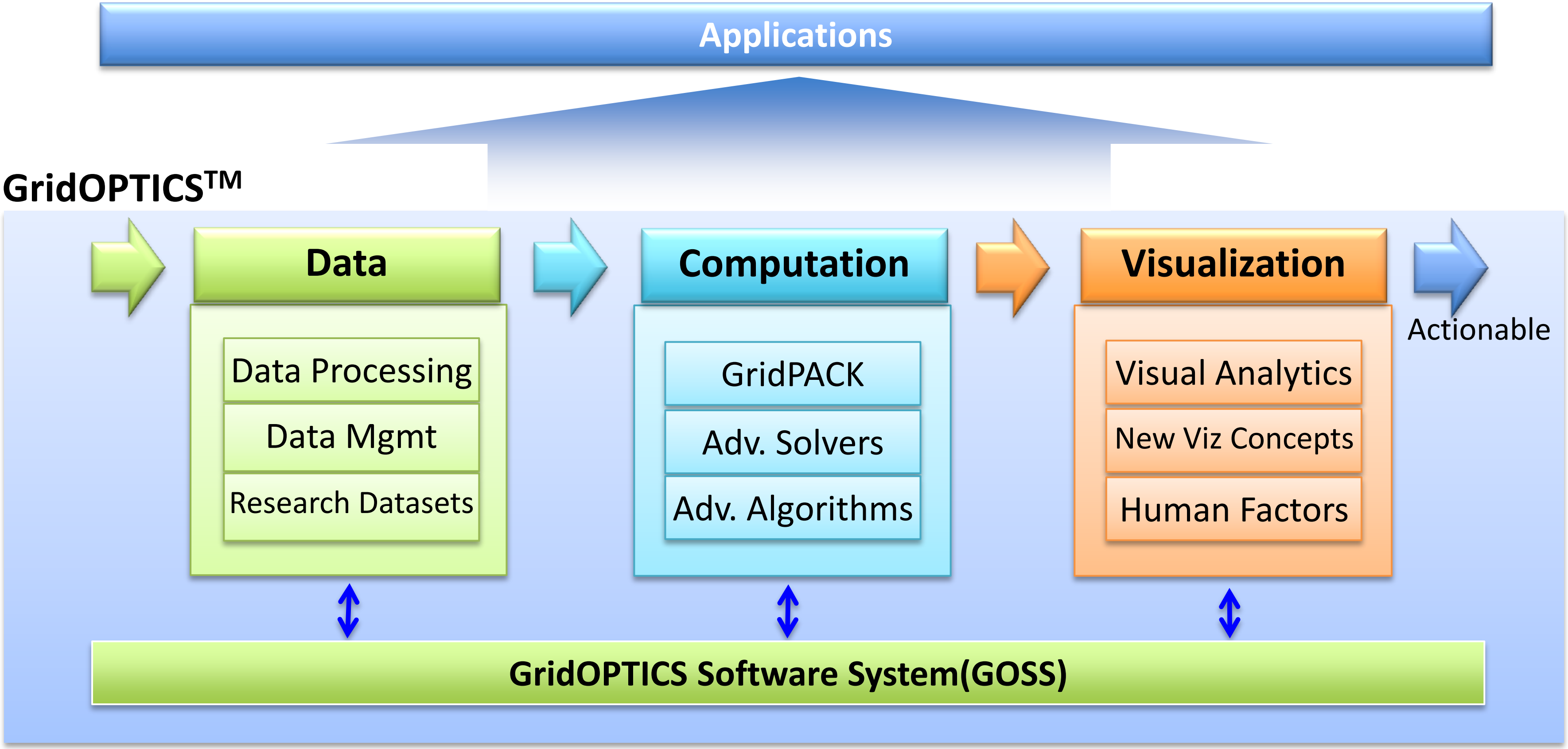
- Co-simulation allows for expansion of capabilities with minimal investment
  - Allows for re-use of existing software AND models
  - Enables multi-scale modeling and simulation
- FNCS is a framework for integrating simulators across multiple domains
  - Coordinate interaction of ns-3 with GridLAB-D and MATPOWER
  - Developed for HPC applications across multiple platforms

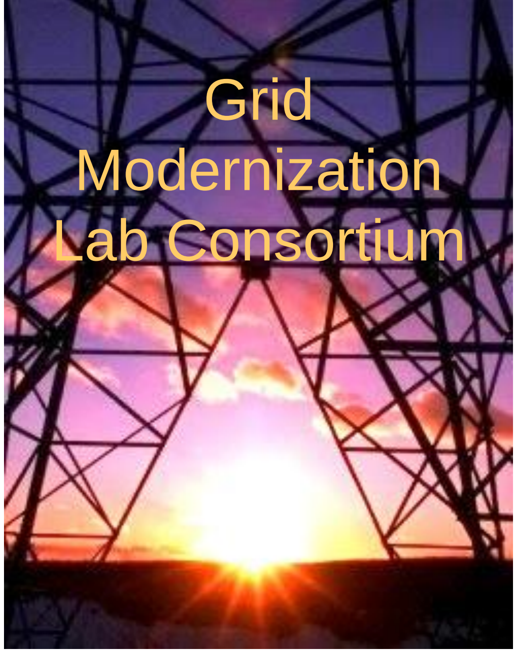




Next generation tool development require an architecture to link the pieces

- GridOPTICS™: Open Source; Open Format; Open Forum
  - Enhance interoperability of software tools
  - Overcome barriers for accelerated development of advanced technologies and tools for the future power grid.





U.S. DEPARTMENT OF ENERGY

Grid Modernization Laboratory Consortium

Bill Parks
Kevin Lynn
Jud Virden
Carl Imhoff
Bryan Hannegan

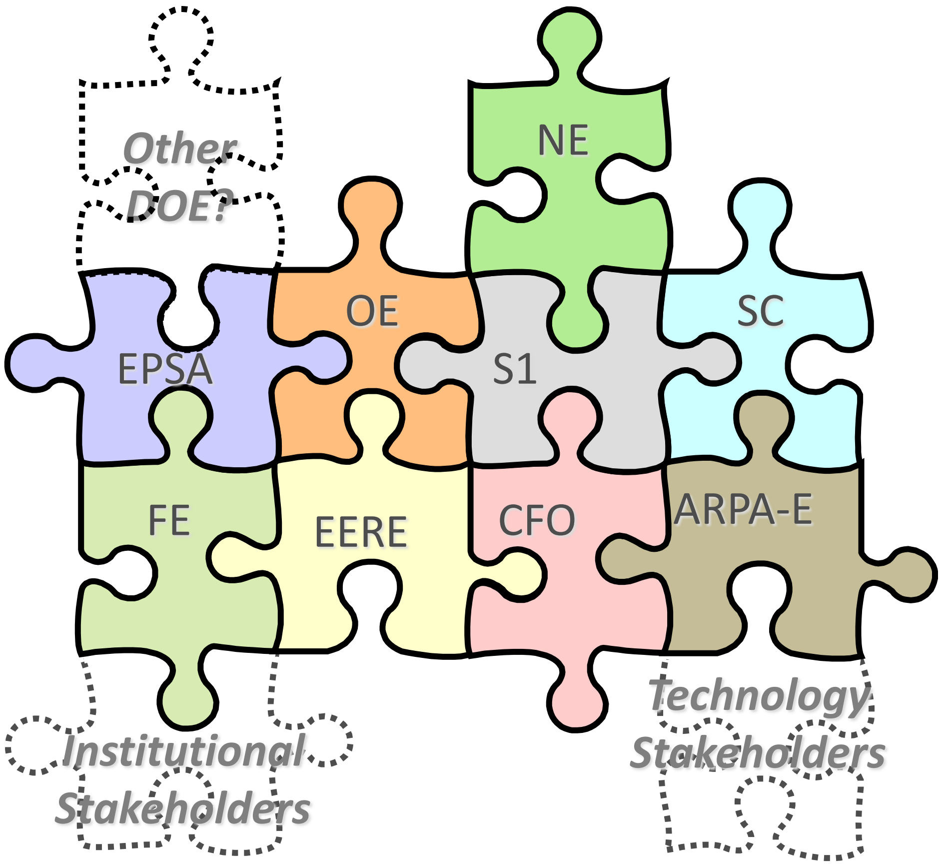
Nov. 6, 2014

Argonne National Laboratory · Ames Laboratory · Berkeley Lab · Brookhaven National Laboratory · INL Idaho National Laboratory · Lawrence Livermore National Laboratory · Los Alamos National Laboratory · NETL · NREL National Renewable Energy Laboratory · Oak Ridge National Laboratory · Pacific Northwest National Laboratory · PPPL Princeton Plasma Physics Laboratory · SLAC National Accelerator Laboratory · Sandia National Laboratories · SRNL

Grid Modernization Initiative

An aggressive and urgent five-year grid modernization strategy for the Department of Energy that includes

- Alignment of the existing base activities among the Offices
- An integrated Multi-Year Program Plan (MYPP)
- New activities to fill major gaps in existing base
- Development of a laboratory consortium with core scientific abilities and regional outreach



Discussion Points

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

FUTURE GRID OUTCOMES FOR INDUSTRY, UNIVERSITIES AND GOVERNMENT

1. Collectively frame agenda on long-term SG needs and opportunities
   - Grid architecture of 2050
   - Engaging emerging digital realities at scale? To what end?
   - Enabling resilient, affordable ops today; robust across energy futures beyond 2050
2. Better link "science to solutions"
3. Federate innovation assets
4. Policy / regulatory engagement

DISCOVERY *in Action*

energyenvironment.pnnl.gov