Grid Modernization at the Department of Energy

Kevin Lynn, Director of the Grid Integration Initiative
Office of Energy Efficiency and Renewable Energy

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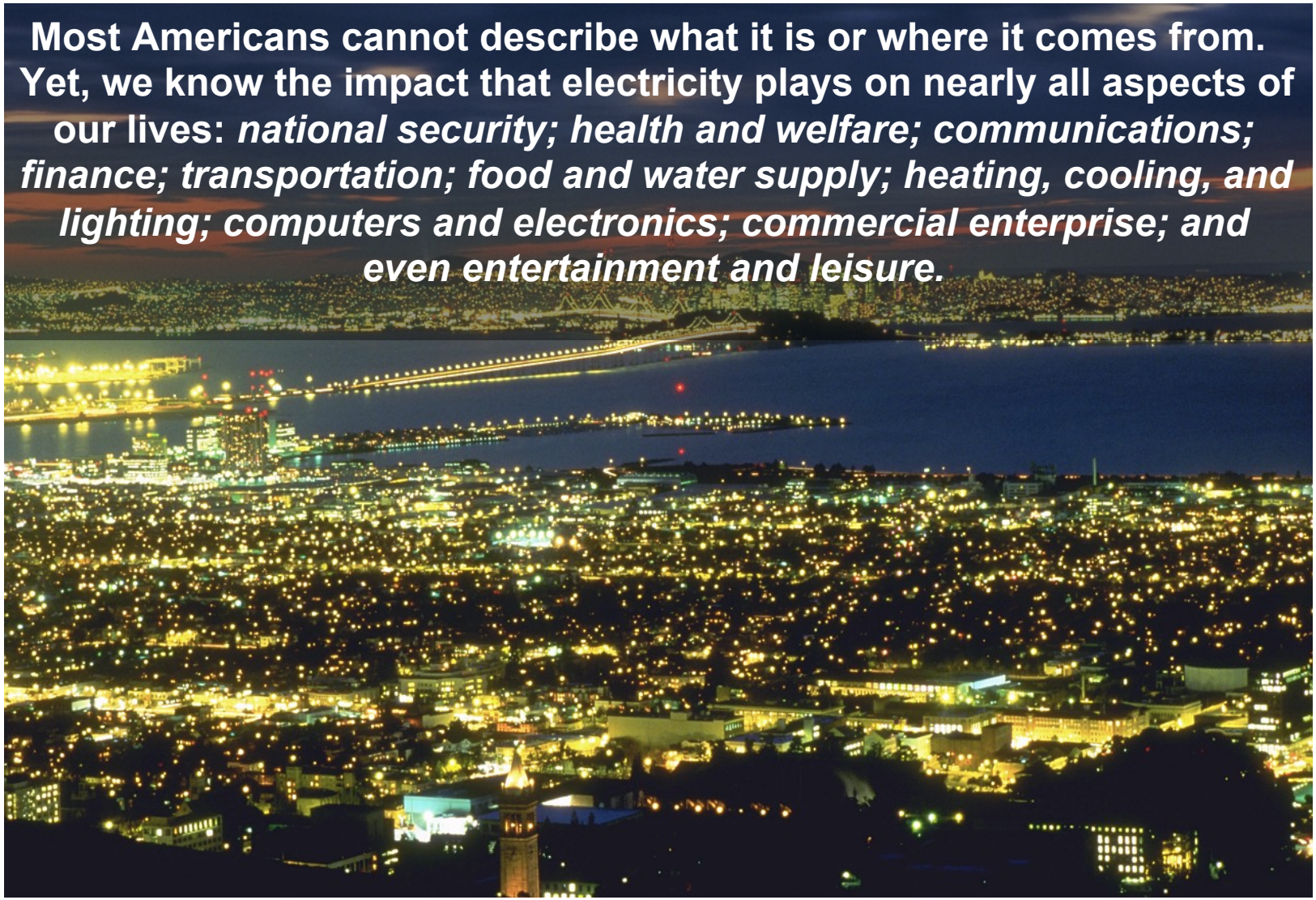
Electricity Plays a Vital Role to our Economy & National Security

Most Americans cannot describe what it is or where it comes from. Yet, we know the impact that electricity plays on nearly all aspects of our lives: *national security; health and welfare; communications; finance; transportation; food and water supply; heating, cooling, and lighting; computers and electronics; commercial enterprise; and even entertainment and leisure.*



2003 Blackout, 50M people, $6B

The President's Climate Action Plan

Expanding and Modernizing the Electric Grid

- "Upgrading the country's electric grid is critical to our efforts to make electricity more reliable, save consumers money on their energy bills, and promote clean energy sources."
- Policy goals outlined in President Obama's Climate Action Plan Progress Report, June 2014
  - Enable the development of 8,100 megawatts of wind, solar, and geothermal energy, enough to power nearly 2 million homes;
  - Save consumers more than $60 billion on their energy bills through 2030
  - Improve the energy efficiency of more than 1 billion square feet of city buildings, schools, multifamily housing complexes, and business across the country, an area the size of 17,000 football fields

Grid Modernization Vision and Motivation

The future grid provides a critical platform for US prosperity and energy innovation in a global clean energy economy. It must deliver reliable, affordable, and clean electricity to consumers where they want it, when they want it, how they want it.

Achieve Public Policy Objectives

- 80% clean electricity by 2035
- State RPS and EEPS mandates
- Access to reliable, affordable electricity
- Climate adaptation and resilience

Sustain Economic Growth and Innovation

- New energy products and services
- Efficient markets
- Reduce barriers for new technologies
- Clean energy jobs
- Competitive Domestic Industries

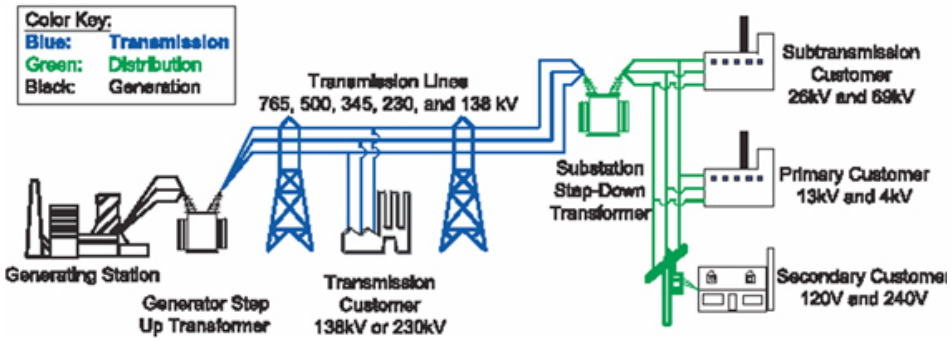
Mitigate Risks and Secure the Nation

- Extreme weather
- Cyber threats
- Physical attacks
- Natural disasters
- Fuel and supply diversity
- Aging infrastructure
- Utility credit ratings

From Monolithic to Modular and Agile

- Centralized generation
- Decisions driven by cost
- Catastrophic events
- Limited energy choices
- Vulnerable to new threats

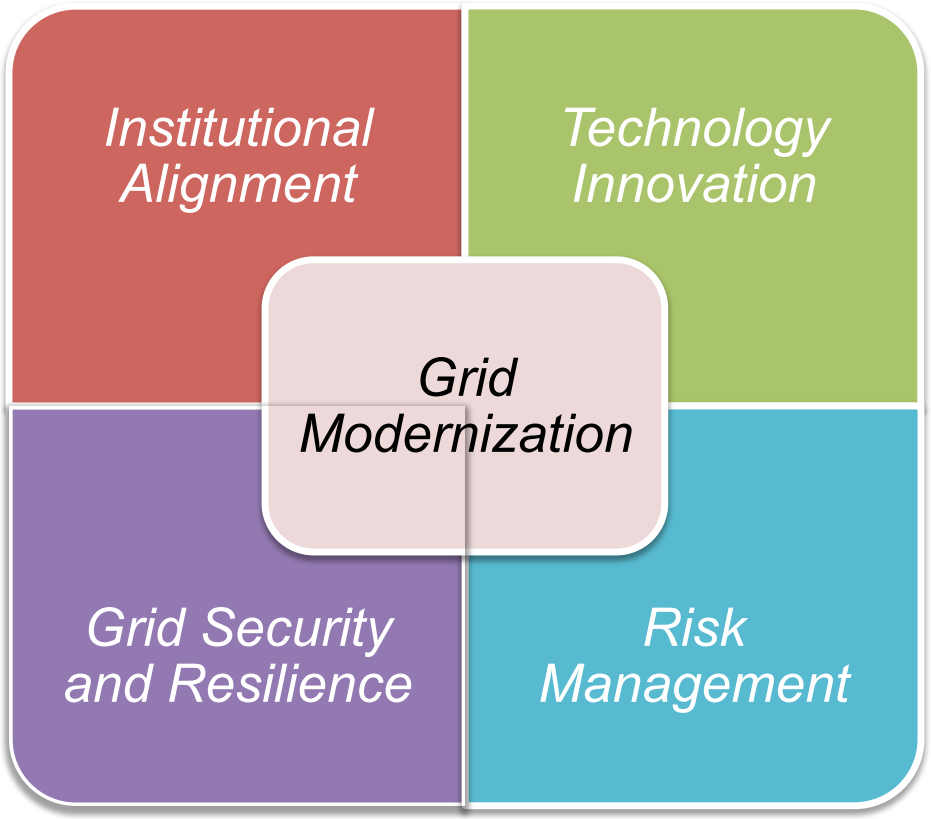
- Centralized and distributed generation
- Decisions driven by cost and environmental sustainability
- Contained events
- Personalized energy options
- Inherently secure to all threats



Business as Usual Will Not Achieve Efficient, Timely Modernization

- **Innovation is Inhibited**
  - Generation/end-use advances outpacing grid technologies
  - Rate-based regulation stifles innovation (low risk tolerance)
  - Electricity markets do not sufficiently capture externalities
  - Advances need to be compatible with legacy systems
- **Risk and Uncertainty are More Prevalent**
  - Outages are not tolerated by consumers and regulators
  - Difficulty choosing among long-lived investment options
  - Utilities and regulators face a sour investment climate
- **The Industry is Fragmented**
  - No single entity owns the grid
  - Maze of federal, state, and local jurisdictions and policies
  - Variety of market and regulatory structures

GTT Grid Modernization Proposal



- ***Institutional Alignment:*** Focus on key policy questions related to regulatory practices, market designs, and business models.
- ***Technology Innovation:*** Increase the emphasis on coordination and create tools and technologies that measure, analyze, predict, and control the grid of the future.
- ***Grid Security and Resilience:*** Research cyber security solutions for the electric sector and provide situational awareness and incident support during energy related emergencies.
- ***Risk Management through Multi-scale Demonstrations:*** Collaborate with regulators, utilities and other stakeholder groups to test and demonstrate combinations of promising new technologies and new institutional approaches.

GTT Five-Year Goals

Technology Innovation

Institutional Alignment	•Evaluate impacts of regulatory options, implications of various grid ownership and operational models, and policy implications of emerging technologies. Provide tools to state, regional and federal policymakers
Design and Planning Tools	•Develop planning tools that integrate transmission and distribution and system dynamics and can use high performance computing platforms - deliver 50x speed-up
System Control and Power Flow	•Increase ability to coordinate and control up to millions of devices and integrate with energy management systems – coordinate millions of devices; enable one-minute contingency analysis at the interconnect scale
Sensing and Measurements	•Develop sensors, analytics, and visualizations that enable 100% observability of generation, loads and system dynamics across the electric system – develop low cost sensors at all scales, handle 1000x data volumes, visualization tools, dynamic accuracy
Devices and Integrated Testing	•Develop advanced grid control and integration devices and validate integrated systems that can optimize operations at high variable RE penetrations and provide high reliable service – validate 50-100% DG penetration scenarios on feeders
Security and Emergency Response	•Develop advanced security (cyber and physical) solutions and real-time incident response capabilities – capable of identifying cyber events in real-time and analyzing within 12 hours.
Risk Mitigation through Multi-scale Demonstrations	•Develop 3-5 megawatt-scale demonstrations that show transfer of the technologies developed through R&D activities into the field

Institutional Alignment

Expected Outcomes

- Deliver alternate utility business model & market designs to deliver desired grid
- Develop advanced energy policy analytic tool sets that reflect emerging grid complexities
- Accelerated state & federal policy innovation due to enhanced State and Regional technical assistance

Federal Role

- Develop common analytic platforms that serve federal and state policy evaluation
- Technical assistance in understand regulatory and market changes at the national and regional levels

Example Activities

- Focus on dialogues and analysis related to valuing the impacts of distributed energy resources
- Clarify and analyze technology and policy relationships and choices to decision makers

Design and Planning Tools

Expected Outcomes

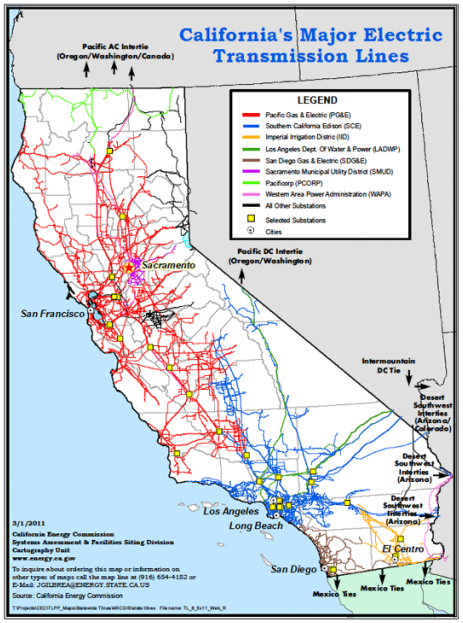
- Deliver open software platform for adding advanced computation approaches to grid planning & design tools (50x speedup)
- Add capacity to model uncertainty in grid planning for new renewable generation
- Incorporate system dynamics into planning tools to enhance resilience in face of increased system variability
- Determining cross-system effects (e.g., high penetration of DER on transmission, cyber defense)

Federal Role

- Leverage Lab system computational expertise to develop open platform for vendor engagement & leverage
- Leverage Lab system fundamental mathematics assets to incorporate uncertainty and system dynamics into grid tool sets

Example Activities

- Continue improvement of geomagnetically induced current (GIC) monitoring, modeling, and prediction
- Evaluate future scenario tools for value, benefits and uncertainty
- Determine how system flexibility can increase the hosting capacity of clean energy technologies in regions in the country and determine the lowest cost strategies for enhancing that capacity on a regional basis



Decreasing PUC RPS assessments from days to hours

System Control and Power Flow

Expected Outcomes

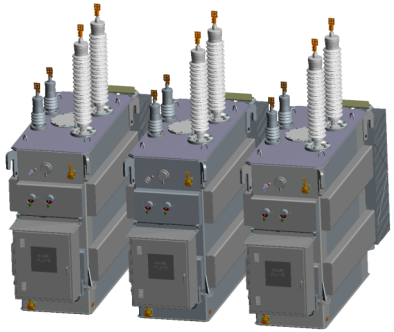
- Deliver an architecture and next-gen control framework for a clean, resilient and secure grid of 2030 & beyond
- Develop operations software platform for predictive operations & real-time adaptive control (e.g. variable generation)
- Develop new class of power flow control devices & approaches to significantly enhance the capacity and flexibility of the future power system

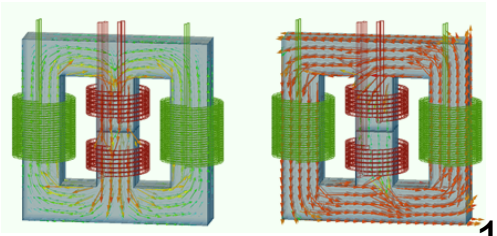
Federal Role

- Utilize DOE's convening authority to provide leadership in providing a public/private vision of advanced grid architecture
- Advance fundamental knowledge for new control paradigms for emerging grid to support industry transformation
- Utilizing expertise developed at the national laboratories, deliver computational science, materials science & mathematics to transform integrated faster-than-real-time software platforms and power electronics power controllers.

Example Activities

- Incorporate probabilistic forecasts into the future generation energy management to help system operators to make better decisions with high penetrations of variable generation.
- Transition GENI and OE work on control solutions and advanced modeling to a integrated, cohesive implementation





Sensing and Measurement

Expected Outcomes

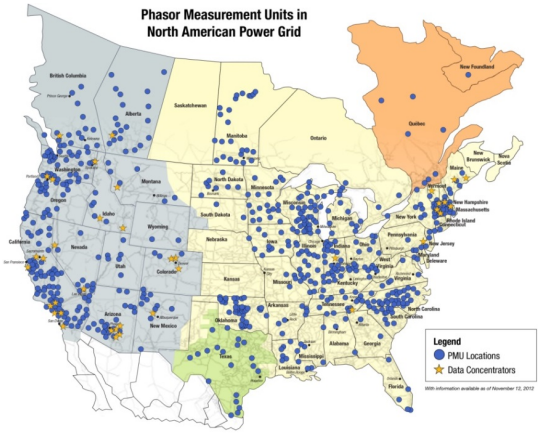
- Deliver continental data analytics framework for 100% visibility of entire T&D system
- Deliver ultra low cost sensors to engage demand at scale for grid resilience and efficiency
- Develop T&D sensors that are accurate through disturbances to transform system resilience

Federal Role

- Transfer national lab scientific & national security data analytics to transform grid systems
- Leverage lab cyber expertise to design resilient SCADA and communication systems for emerging grid

Example Activities

- Develop low-cost power, vehicle, and building sensors to provide visibility and understanding to grid operators
- Develop PMU-based algorithms that allow operators to identify and react to incipient equipment malfunction, physical attacks, and geomagnetic disturbance events on the grid, thus improving system reliability and providing direct value to transmission system owners and operators



Interoperability testing of advanced phasor measurement units from multiple vendors

Devices and Integrated System Testing

Expected Outcomes

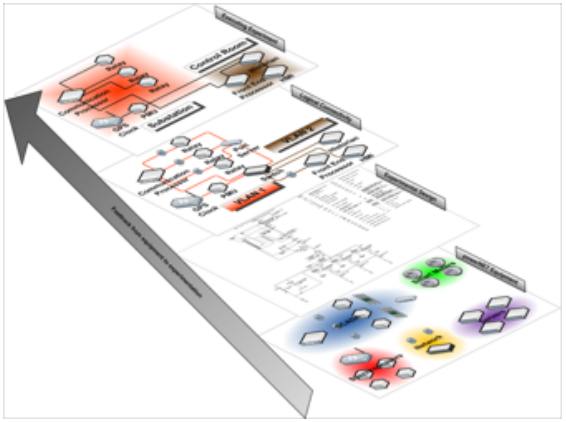
- Deliver test procedures for distributed energy resources (DER) to provide grid services
- Validate 100% renewable systems at local scale and 50% renewable at community level
- Validate power electronic control of high penetration DER to meet reliability standards

Federal Role

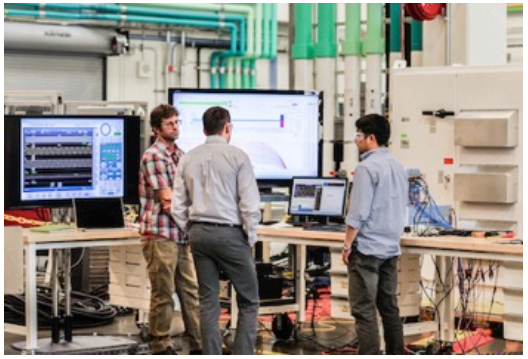
- Common approach across labs and industry testbeds for effective validation of emerging technologies
- Develop common interoperability and interconnection standards and test procedures for industry / vendor community

Example Activities

- Design, simulate and demonstrate how electric vehicles, solar technologies, and buildings technologies to work together holistically using open-source interoperability standards to increase the hosting capacity of the grid and demonstrate operational savings while being financially compensated for those services



Framework for federated testing of systems at multiple test facilities



Security and Emergency Response

Expected Outcomes

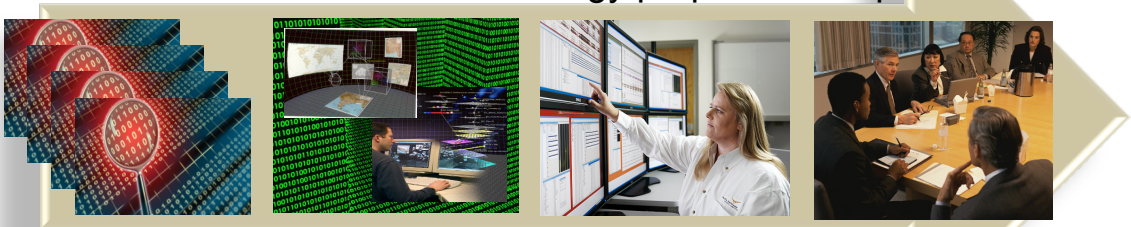
- Deliver continental gas & electric utility cyber entity delivering situational awareness (200+ utilities)
- Deliver national compliance with Cybersecurity maturity model and risk assessment by 2020

Federal Role

- Lab/DOE provide information sharing from classified to non-classified utility operations
- Enable secure utility situational awareness leveraging national lab analytics capacity and national security capabilities

Example Activities

- Train 100% of Regional Coordinators and 85% of Voluntary Responders on regional energy infrastructure; test training by participating in National Level Exercise 2016 and selected Regional Exercises.
- Coordinate incorporated imbedded cybersecurity functionality in the system
- Continue implementation of National Preparedness and Critical Infrastructure Security and Resilience mandates and the coordination of other national energy preparedness policies



Data Collection

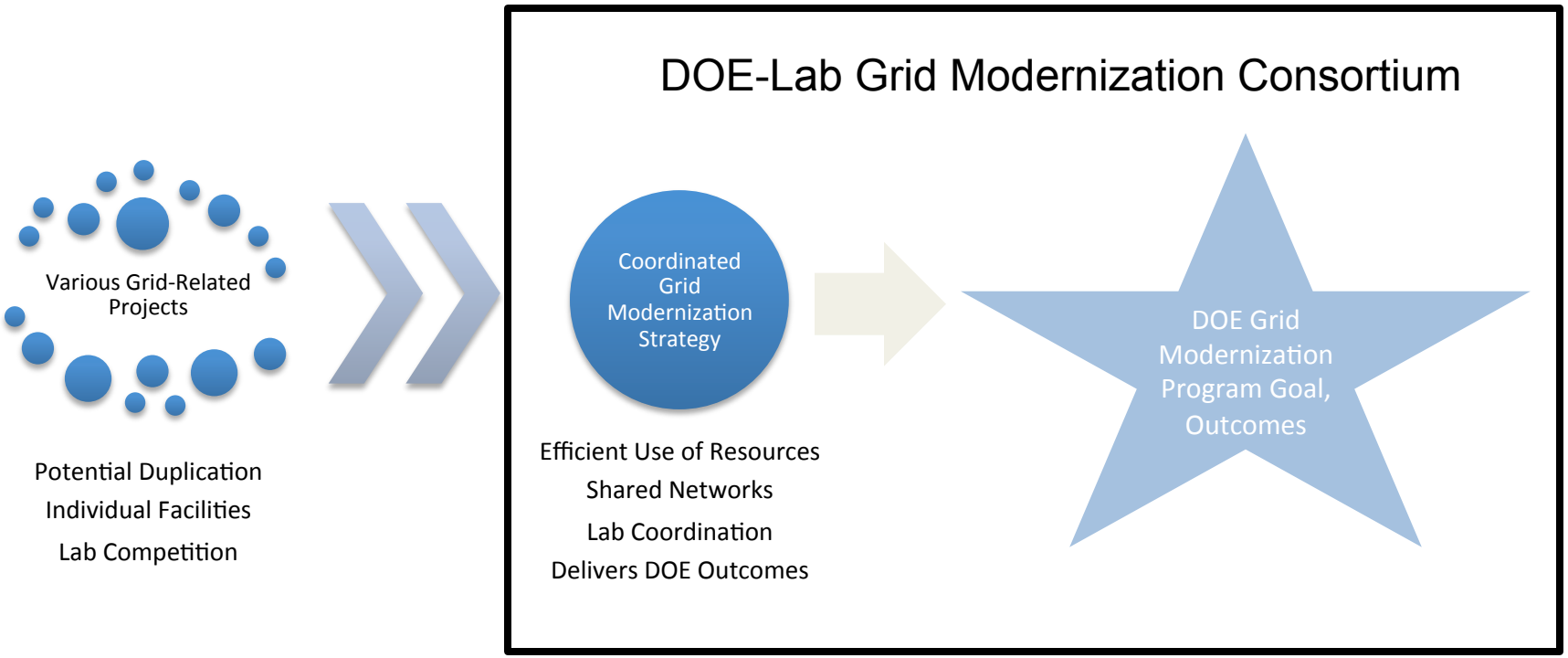
Large Scale Data Store and Analytics

Common Operating Picture

Informed Decision Making

Lab Grid Consortium Vision

Move from a collection of DOE and Lab projects to a DOE-Lab Consortium Model that integrates and coordinates Laboratory expertise and facilities to best advance DOE Grid Modernization goals



DESIRED GENERIC MODEL

GRID MODERNIZATION PLANNING & FUNDING