

Smart Grid Research and Development at Sandia National Laboratories

*Exceptional service
in the national interest*



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Where Is New Mexico?

- 5th largest state in the US
- Population: 2.1 million
- New Mexico is known for its beautiful landscape, rich culture, high tech industry, plentiful wind and solar resources



Outline

- Sandia National Laboratories and Energy
- Smart Grid Drivers
 - Renewable generation
 - Grid modernization
- Examples of Smart Grid Activities at Sandia
 - Optimal and Secure Virtual Power Plant
 - Grid Resilience and Security
 - Microgrids for Critical Infrastructure Resilience
 - Optimization of grid operations under high uncertainty
 - Wide-area controls using
- Q&A (time permitting)

Sandia National Laboratories

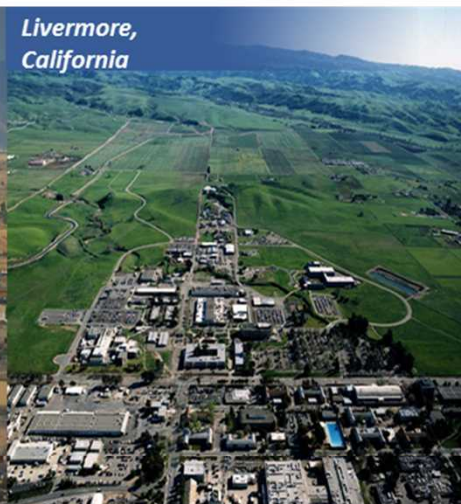
- Large, multi-program research and engineering laboratory
- Focusing on National Security, including energy
- Headquartered in Albuquerque, NM



Albuquerque, New
Mexico



Livermore,
California



Kauai, Hawaii



Pantex Plant,
Amarillo, Texas



Sandia Energy, Climate and Infrastructure Security (ECIS) Program



Energy
Security



Infrastructure
Security



Climate
Security



Enabling
Capabilities

History of Sandia Energy Programs

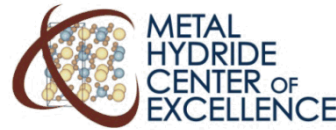
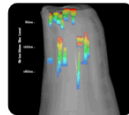


Sandia was born as a nuclear weapons engineering laboratory with deep science and engineering competencies



Energy crisis of the 1970s spawned the beginning of significant energy work

Strategic Petroleum Reserve – geological characterization of salt domes to host oil storage caverns



DOE's Tech Transfer Initiative was established by Congress in 1991



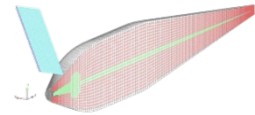
Advent Solar

Energy Policy Act of 2005

Combustion Research Facility (CRF) & Cummins partner on their newest diesel engine



Joint BioEnergy Institute



Water Power Program

1950 1960 1970 1980 1990 2000 2007 2009 2010

Vertical axis wind turbine

NRC cask certification studies & core melt studies



Solar Tower opens

CRF opens to researchers



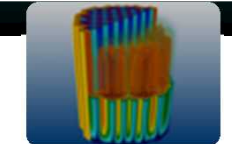
Power grid reliability study



SunCatcher™ partnership with Stirling Energy Systems

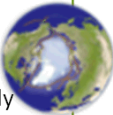


Large-scale pool fire tests of liquefied natural gas (LNG) on water



Consortium for Advanced Simulation of Light Water Reactors (CASL)

Climate study uncertainties to economies



Combustion Research Computation and Visualization (CRCV) opens

Our core NW competencies enabled us to take on additional large national security challenges



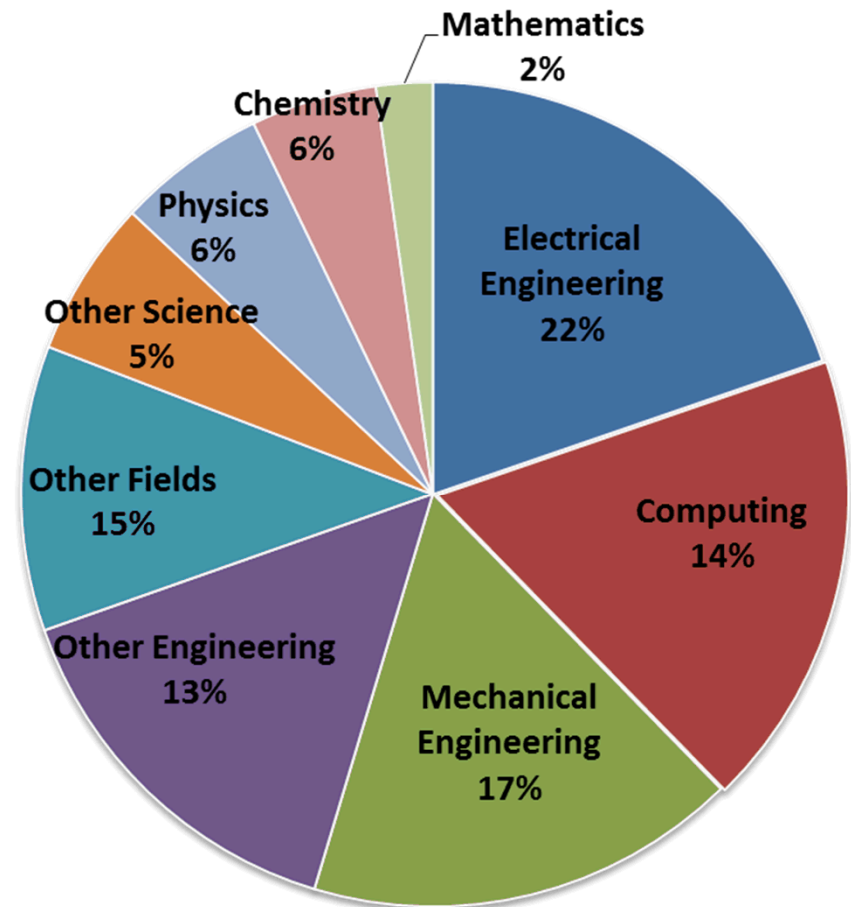
Distributed Energy Technology Laboratory (DETL) to integrate emerging energy technologies into new and existing electricity infrastructures

Sandia National Laboratories

- On-site workforce: ~11,700
- Regular employees: ~9,500
- Total Budget: ~\$2.5 billion

Data as of end of 2013

R&D staff (~4,800) by discipline

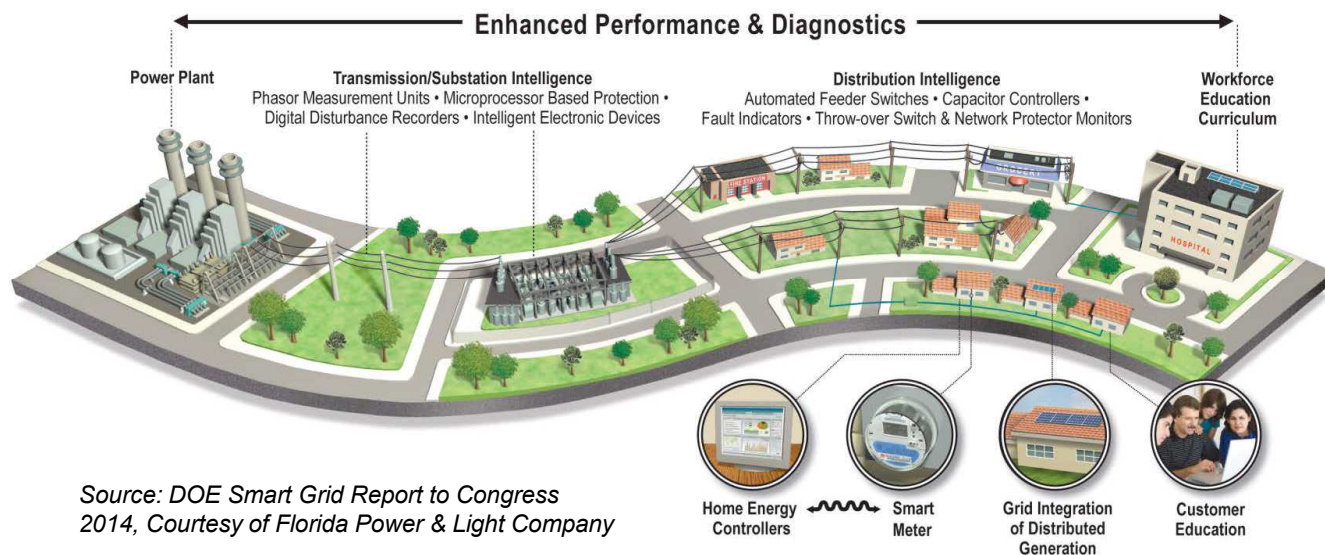


Scope of Smart Grid is Enormous!

- A wide range of domains and technologies
- Complex policy and regulatory landscape
- Multiple drivers

SMART GRID DRIVERS

- Ageing electricity infrastructure
- Distributed and variable generation
- Growing and shifting demand (EVs, digital)
- Higher efficiency, reliability, resilience
- New energy services, and greater consumer participation



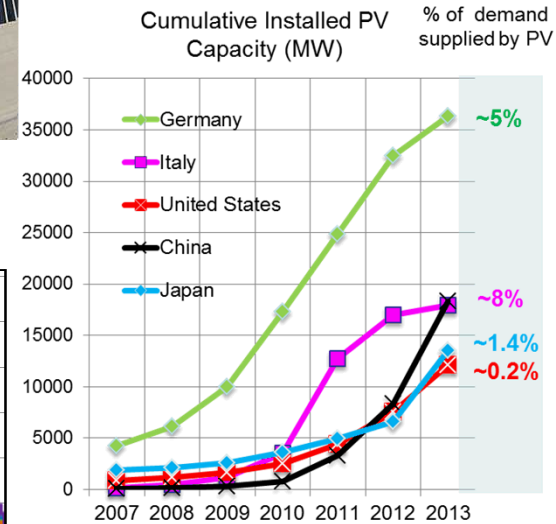
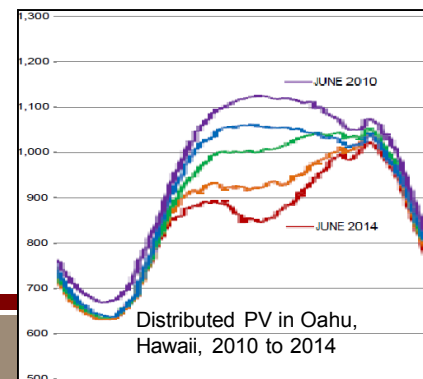
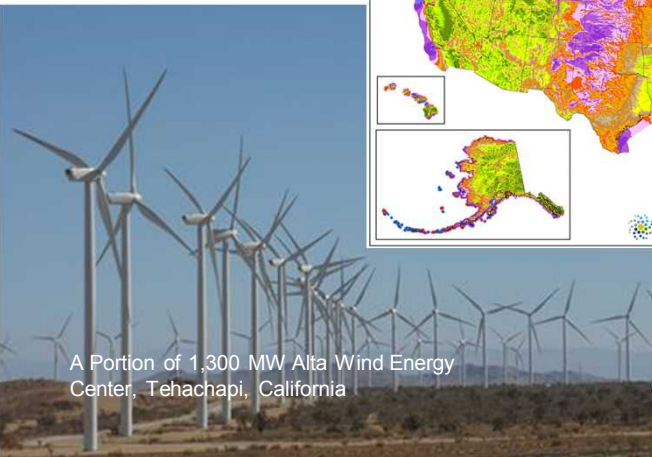
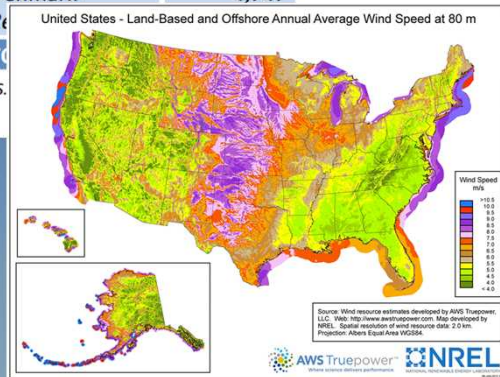
Renewable Energy Deployment

- US installed Wind and PV capacity are growing fast
 - PV: 12.1 GW, Wind at 61.1 GW (2013 figures)
- Technical potential and growth rate are very high

Annual Capacity (2013, MW)		Cumulative Capacity (end of 2013, MW)	
China	16,088	China	91,460
Germany	3,237	United States	61,110
India	1,987	Germany	34,468
United Kingdom	1,833	Spain	22,637
Canada	1,599	India	20,589
United States	1,087	United Kingdom	10,946
Brazil	948	Italy	8,448
Poland	894	France	8,128
Sweden	724	Canada	7,813
Romania	695	Denmark	4,747
Rest of World	7,045	Rest of World	1,087
TOTAL	36,137	TOTAL	361,370



Source: Navigant; AWEA project database for U.S.



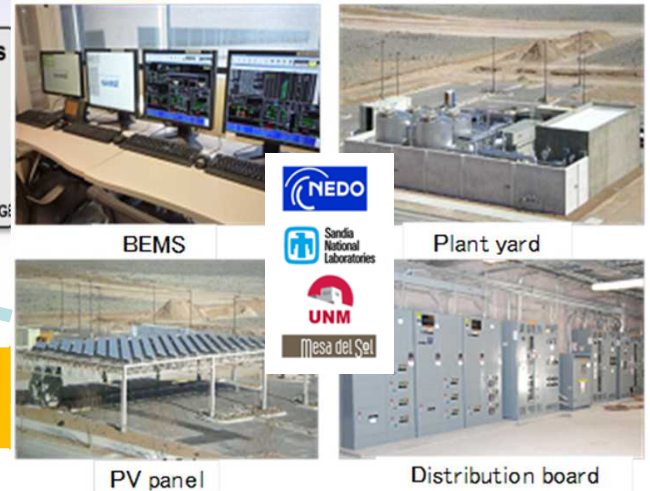
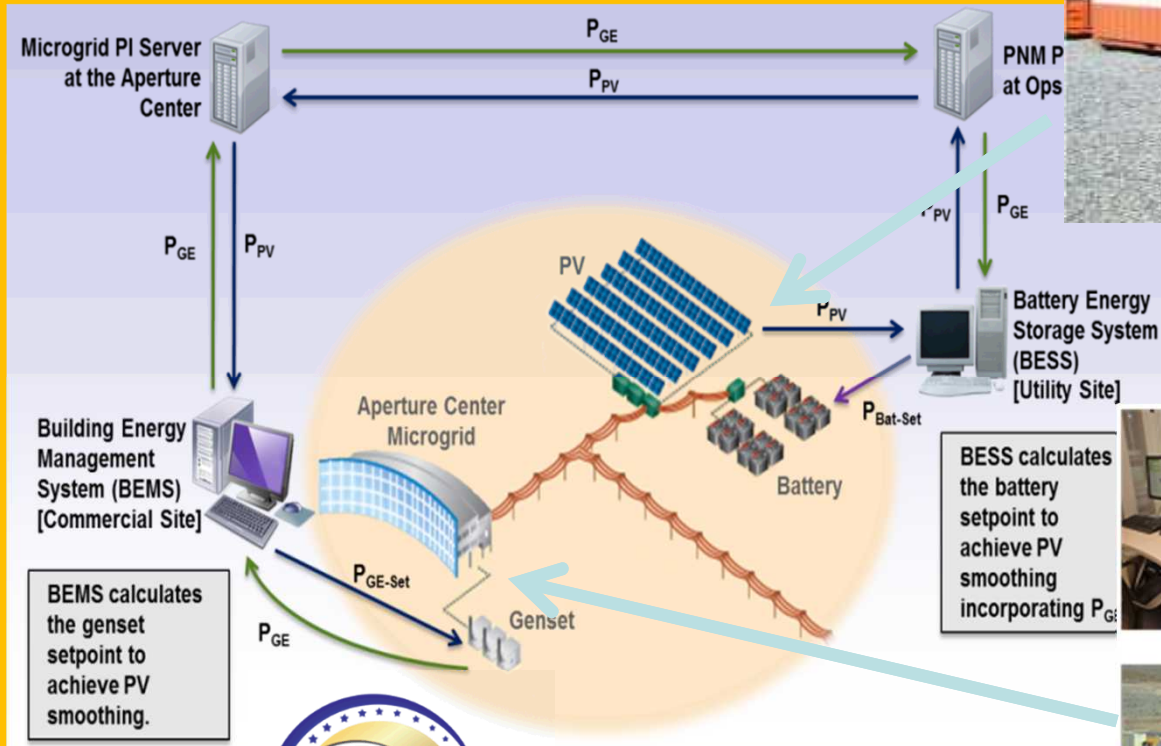
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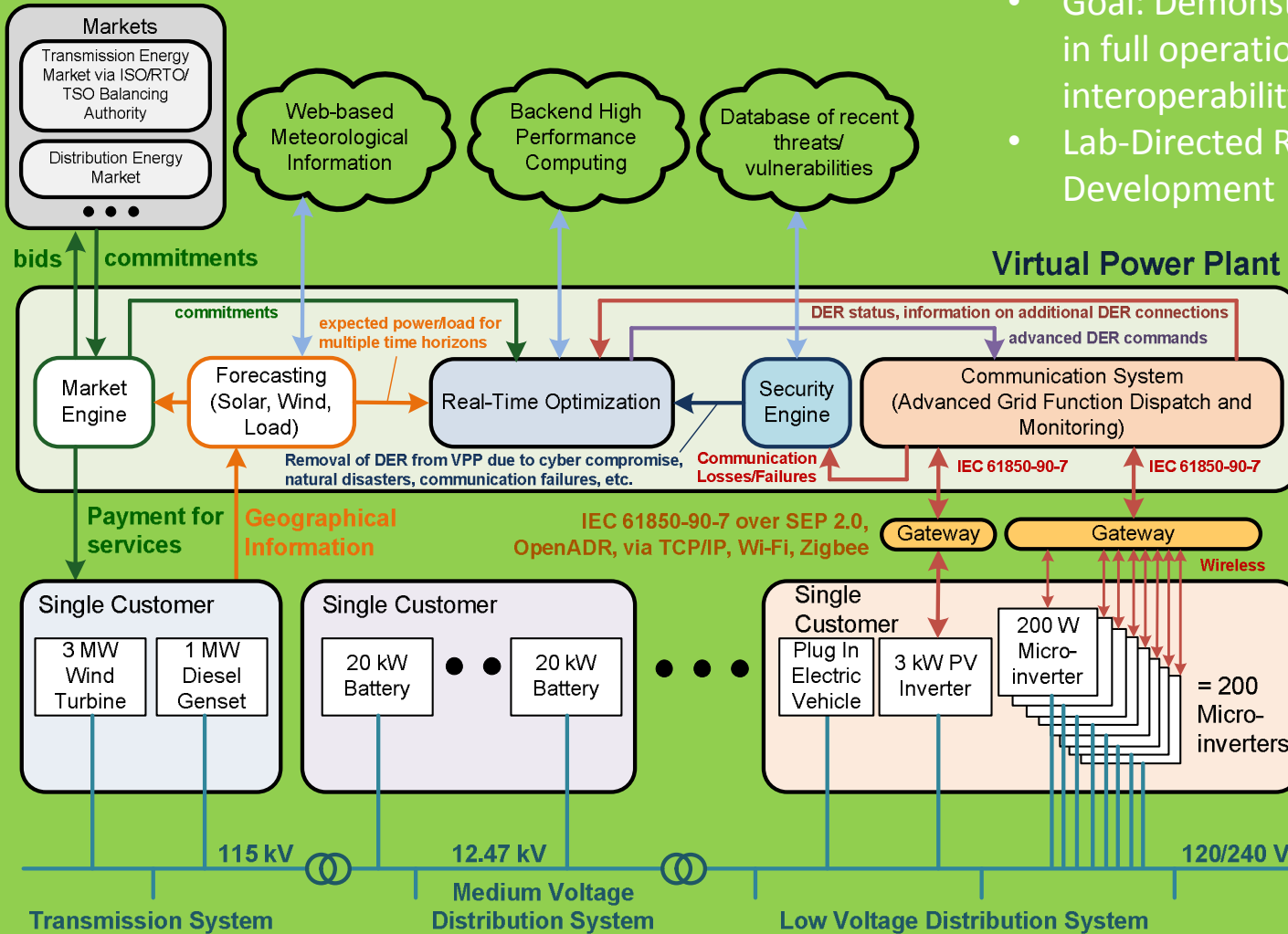
Smart Grid Demonstration in Alb., NM

Concept Demonstration (2013-2014)

- Customer Microgrid (Mesa del Sol project)
- Utility-operated PV/Storage (Prosperity project)



Optimal and Secure Virtual Power Plant



- Goal: Demonstrate advancements in full operational optimization, interoperability and cyber-security
- Lab-Directed Research and Development

Communications and Interoperability

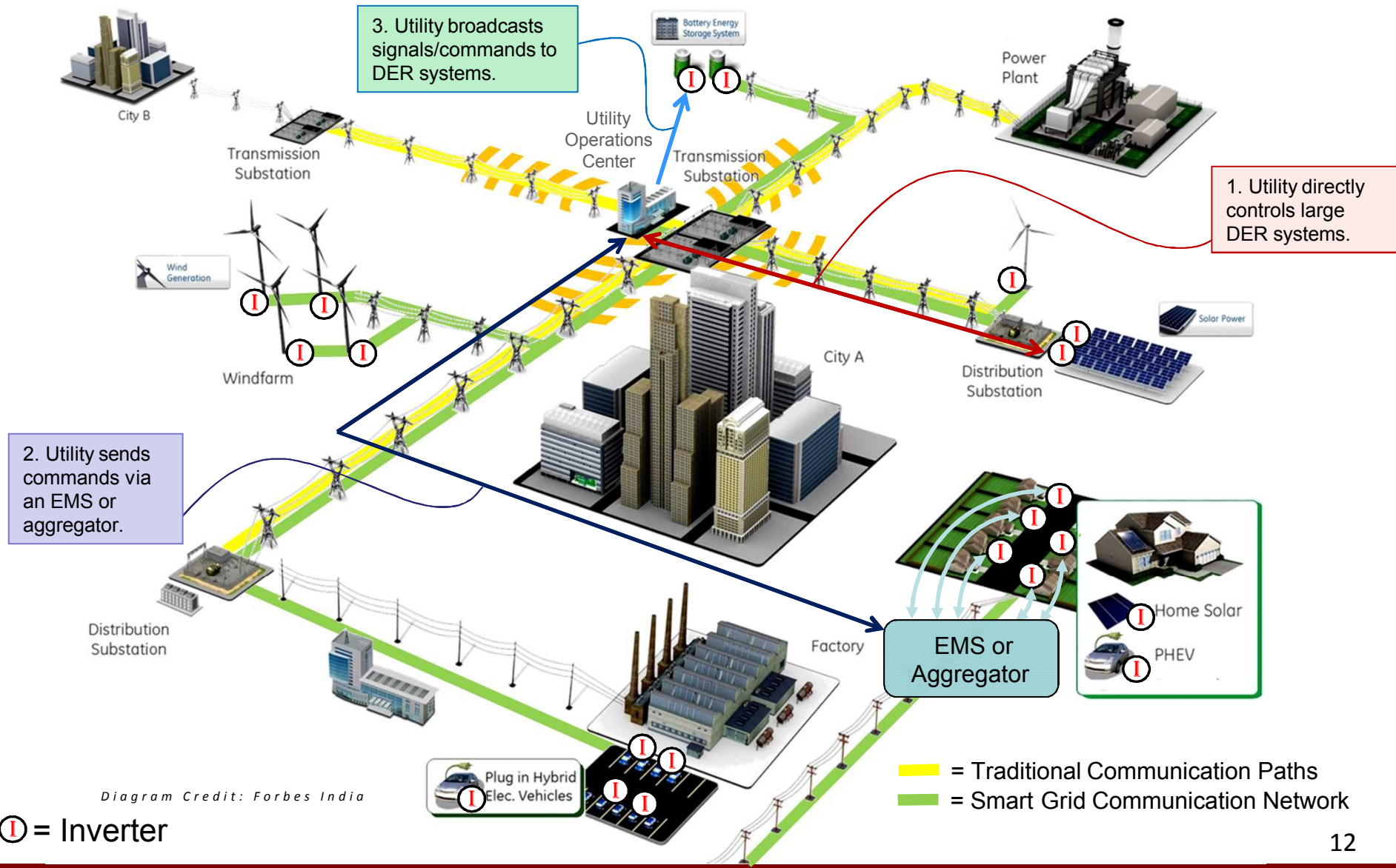
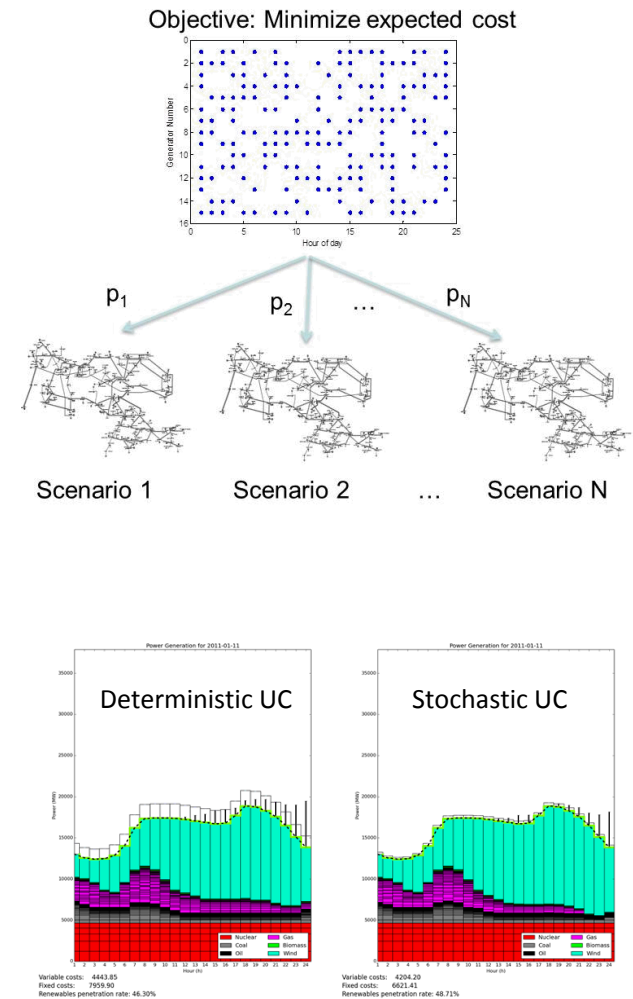
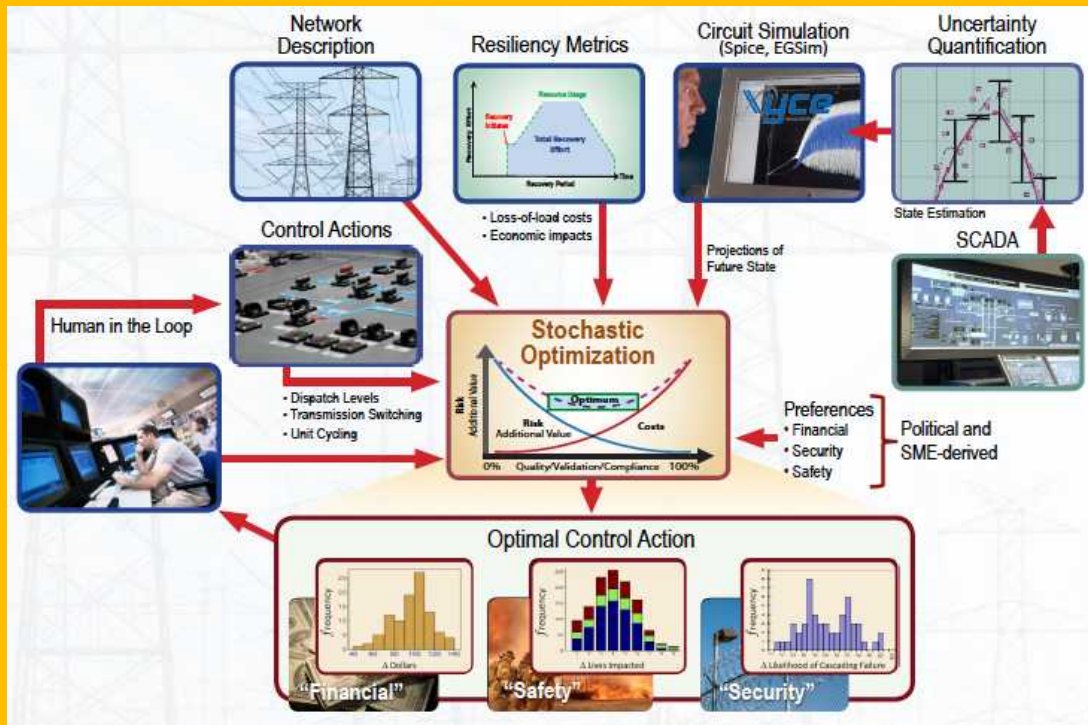


Diagram Credit: Forbes India

Grid Resilience Metrics & Optimal Control

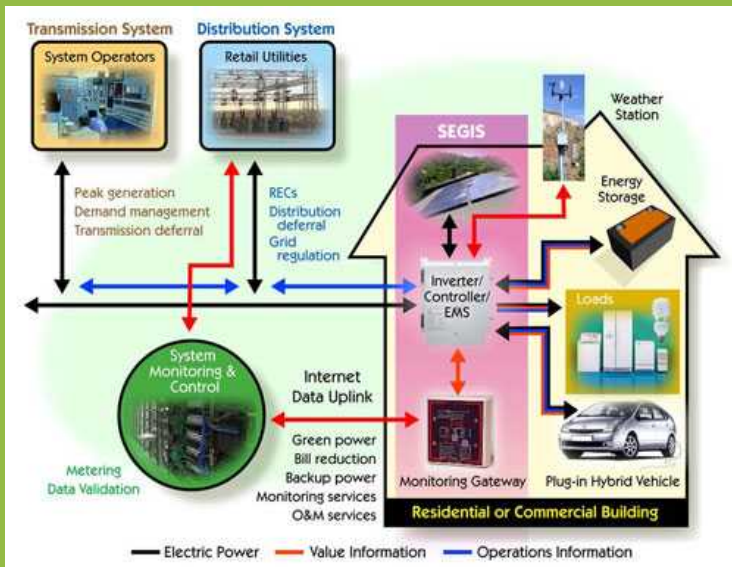
- Full-scale mixed integer stochastic optimization
- Algorithms for full-scale implementation in a production environment
- Applications to planning and operations under high uncertainty (e.g., variable generation, policy goals, etc.)



Smart Grid Technology Development

Technology Development

- Solar Energy Grid integration System (SEGIS)
- Public-Private partnership

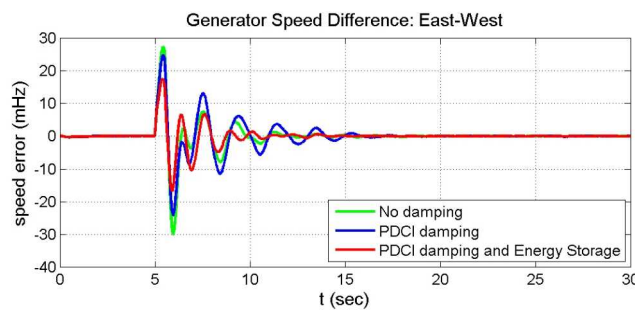
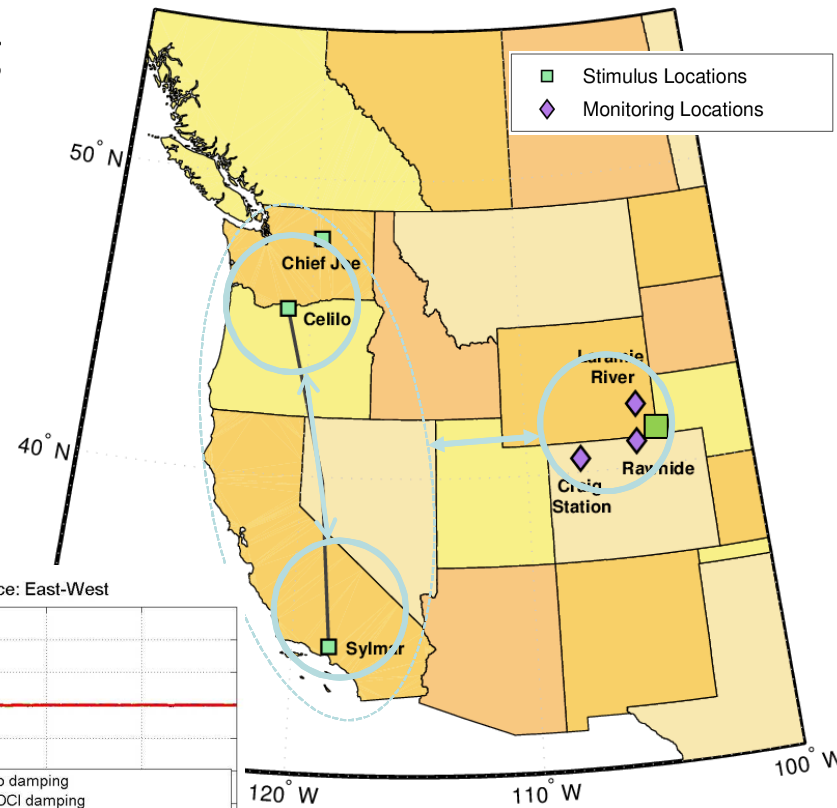
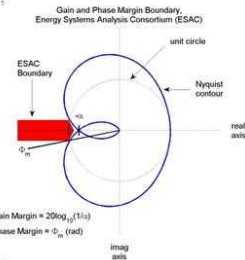
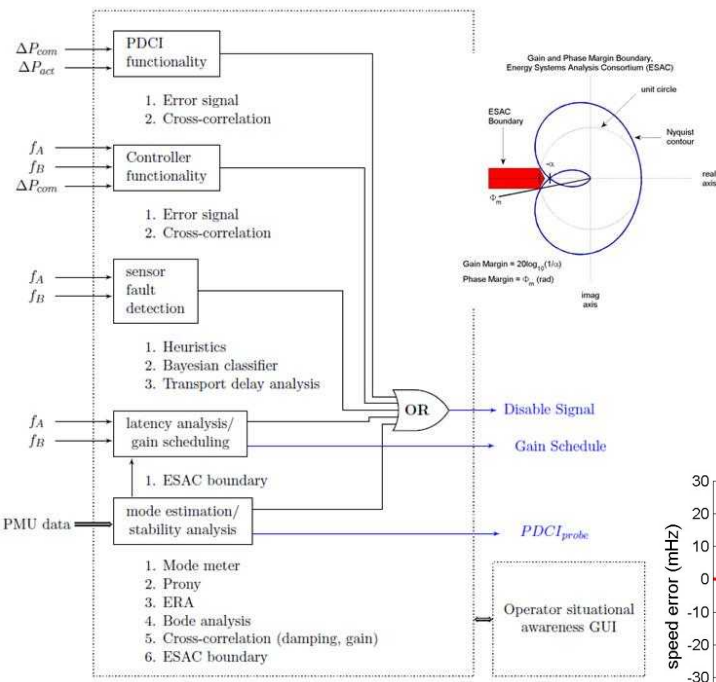


Smart Grid Ready PV Power Electronics



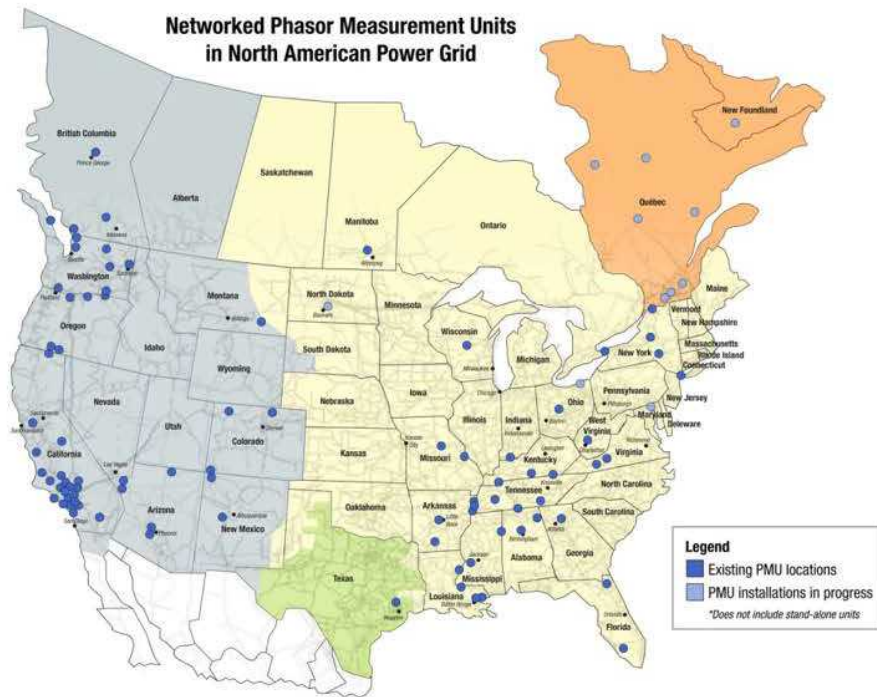
Wide Area Controls for System Stability

- Uses PMUs and energy storage to improve damping of US Western Interconnection East-West oscillatory mode
- Sandia developed supervisory control and hardware prototype for on-line testing

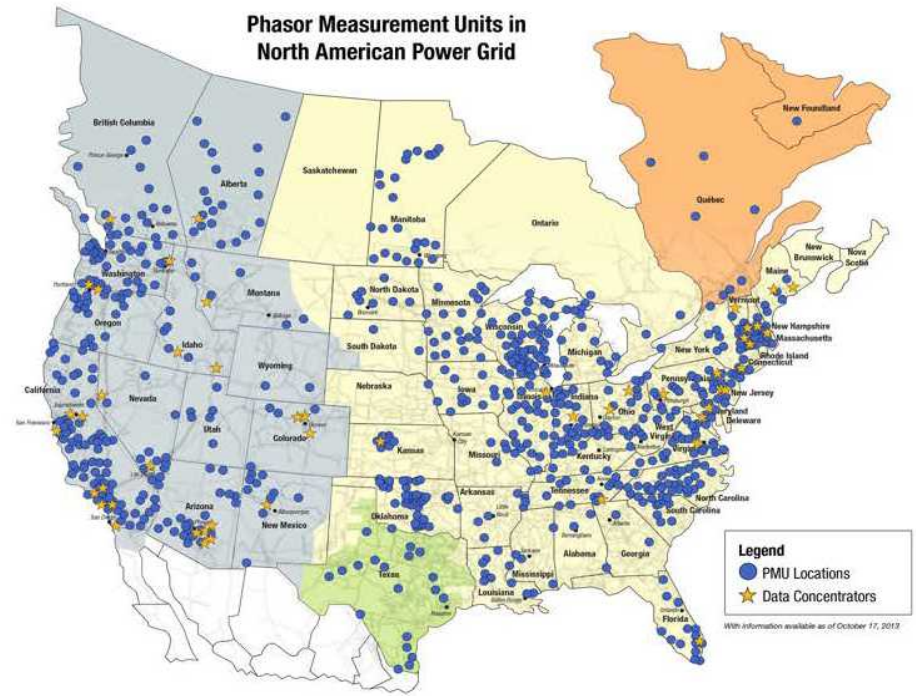


PMU Deployment in the US

PMUs (2009)



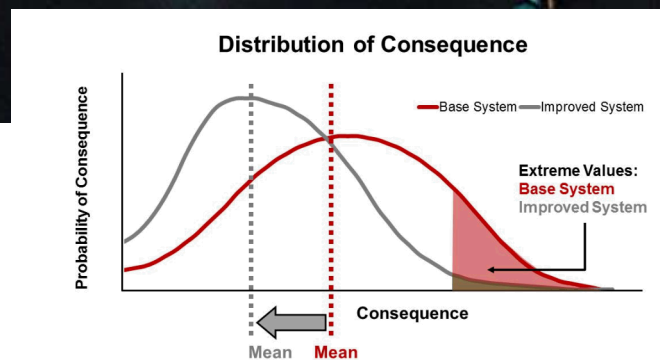
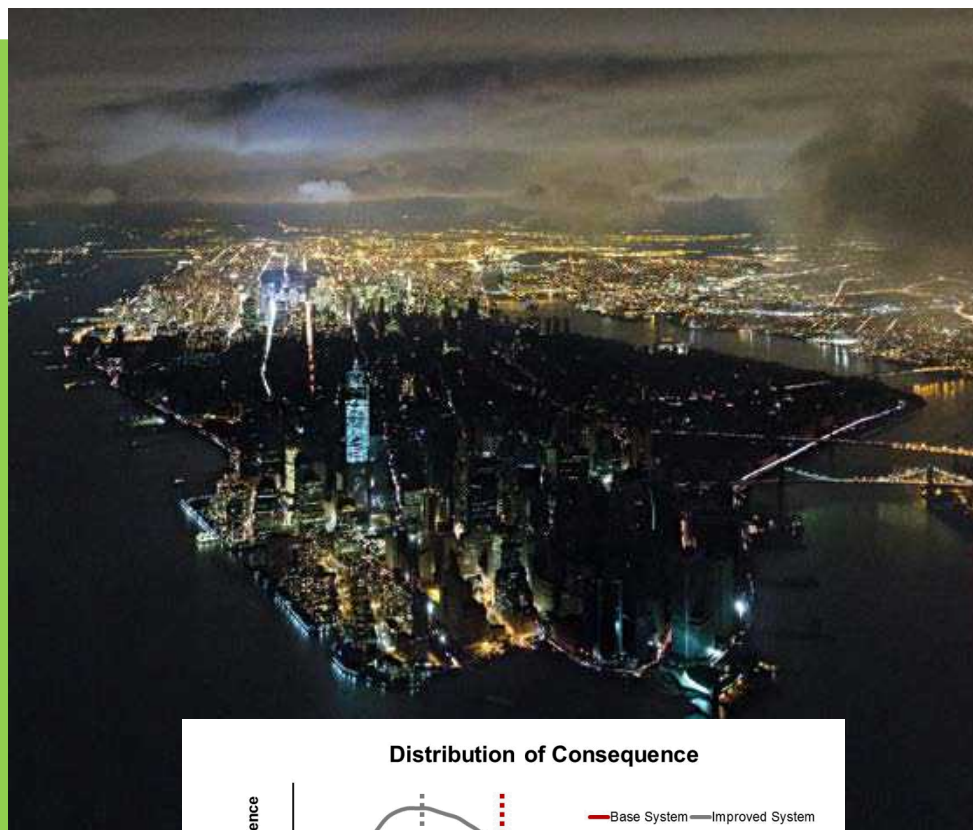
PMUs (2014)



Microgrids and Energy Resilience R&D

- Military and Civilian microgrid applications
- Conceptual design and full-scale demonstrations based on “Energy Surety” Concept

Performance Characteristic	Definition
Safety	Safe supplies of energy to end user
Security	Protection of energy supply infrastructure
Reliability	Can provide energy when and where needed
Sustainability	Can be maintained for long durations with minimal impact on resources
Cost Effective	Provided at affordable cost
Resiliency	Ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions



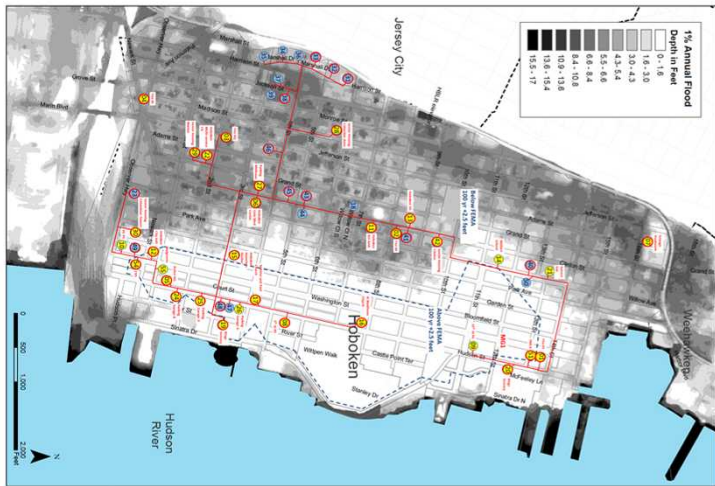
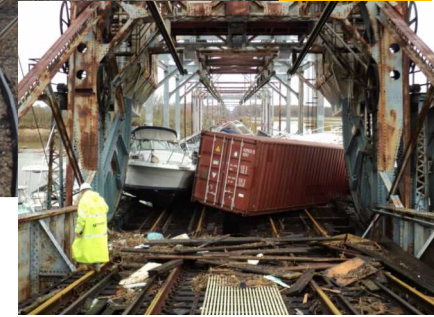
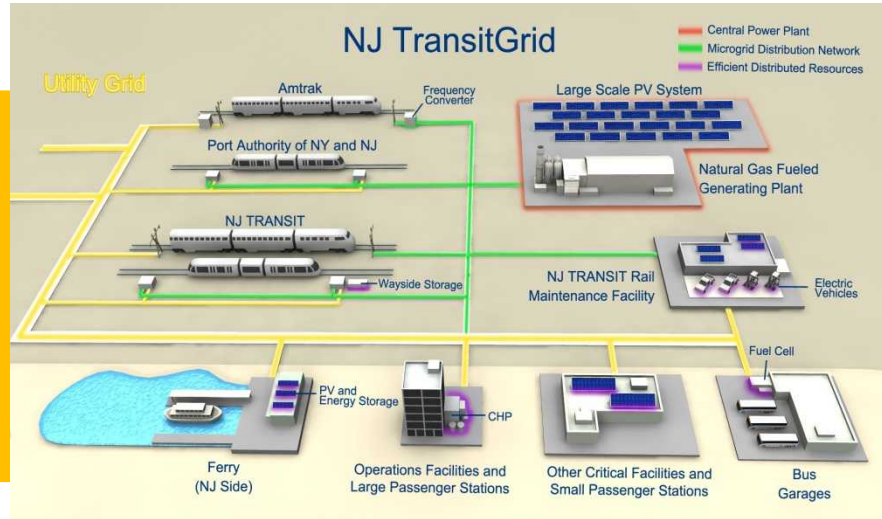
Microgrids and Energy Resilience R&D

- Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS)



Microgrids and Energy Resilience R&D

NJ TransitGrid
Transportation
Microgrid



City of Hoboken, NJ
Energy Resilience
Microgrid

Thank You

Abraham Ellis

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