Smart Grid Research and Development at Sandia National Laboratories

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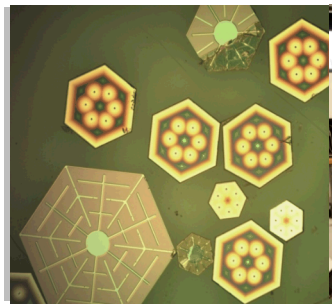
Exceptional service in the national interest

Sandia National Laboratories





U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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

http://www.newmexico.org/

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

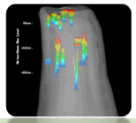
History of Sandia Energy Programs

Sandia National Laboratories

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

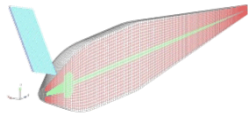
METAL HYDRIDE CENTER OF EXCELLENCE

Advent Solar

Energy Policy Act of 2005

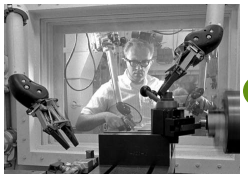
Combustion Research Facility (CRF) & Cummins partner on their newest diesel engine

Joint BioEnergy Institute



Water Power Program

1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2007 | 2009 | 2010



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

Vertical axis wind turbine

NRC cask certification studies & core melt studies

Solar Tower opens

CRF opens to researchers

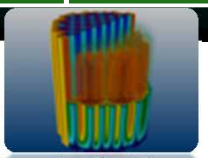
Distributed Energy Technology Laboratory (DETL) to integrate emerging energy technologies into new and existing electricity infrastructures

Power grid reliability study

SunCatcher™ partnership with Stirling Energy Systems

Sunshine to Petrol Pilot Test

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

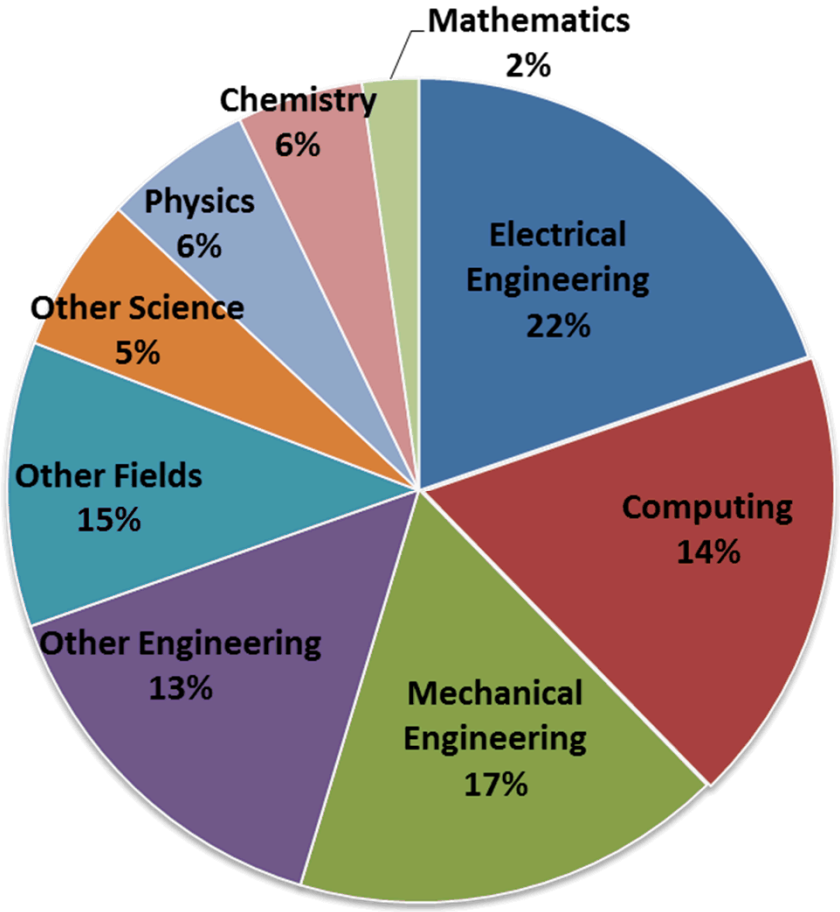
Combustion Research Computation and Visualization (CRCV) opens

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



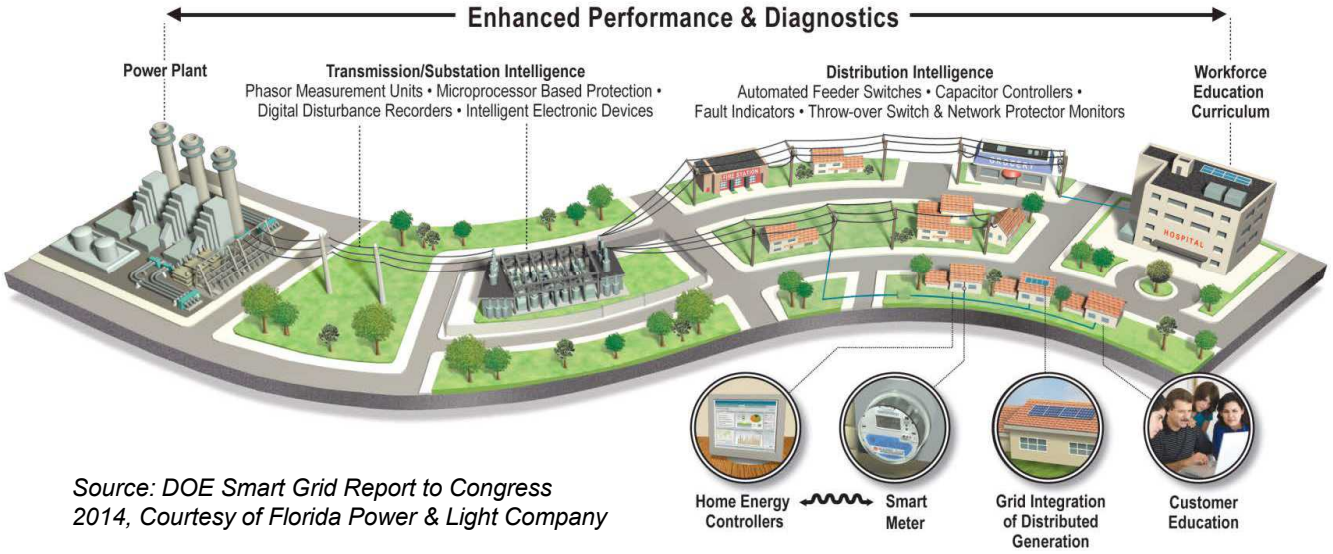
Scope of Smart Grid is Enormous!

Sandia National Laboratories

- 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



Source: DOE Smart Grid Report to Congress 2014, Courtesy of Florida Power & Light Company

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)	
China	16,088
Germany	3,237
India	1,987
United Kingdom	1,833
Canada	1,599
United States	**1,087**
Brazil	948
Poland	894
Sweden	724
Romania	695
Rest of World	7,045
TOTAL	36,137

Cumulative Capacity (end of 2013, MW)	
China	91,460
United States	**61,110**
Germany	34,468
Spain	22,637
India	20,589
United Kingdom	10,946
Italy	8,448
France	8,128
Canada	7,813
Denmark	4,747
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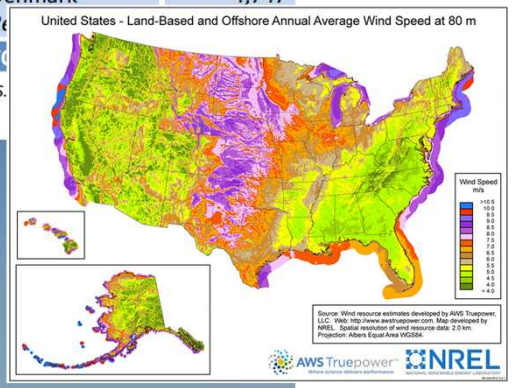
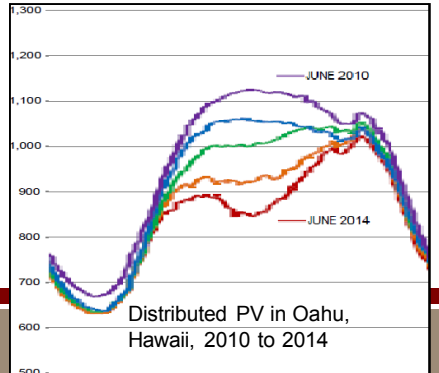
Source: Navigant; AWEA project database for U.S.

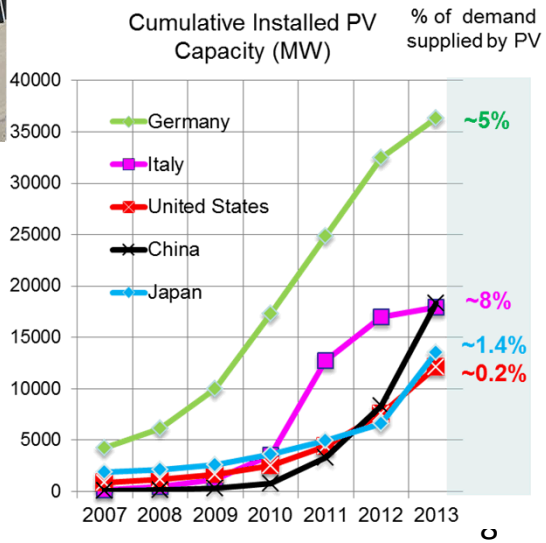



A Portion of 1,300 MW Alta Wind Energy Center, Tehachapi, California


250 MW Agua Caliente Solar Project, Gila River Valley, Arizona. Photo: Genter for Land Use Interpretation, 2014.



Distributed PV in Oahu, Hawaii, 2010 to 2014



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  - Renewable generation
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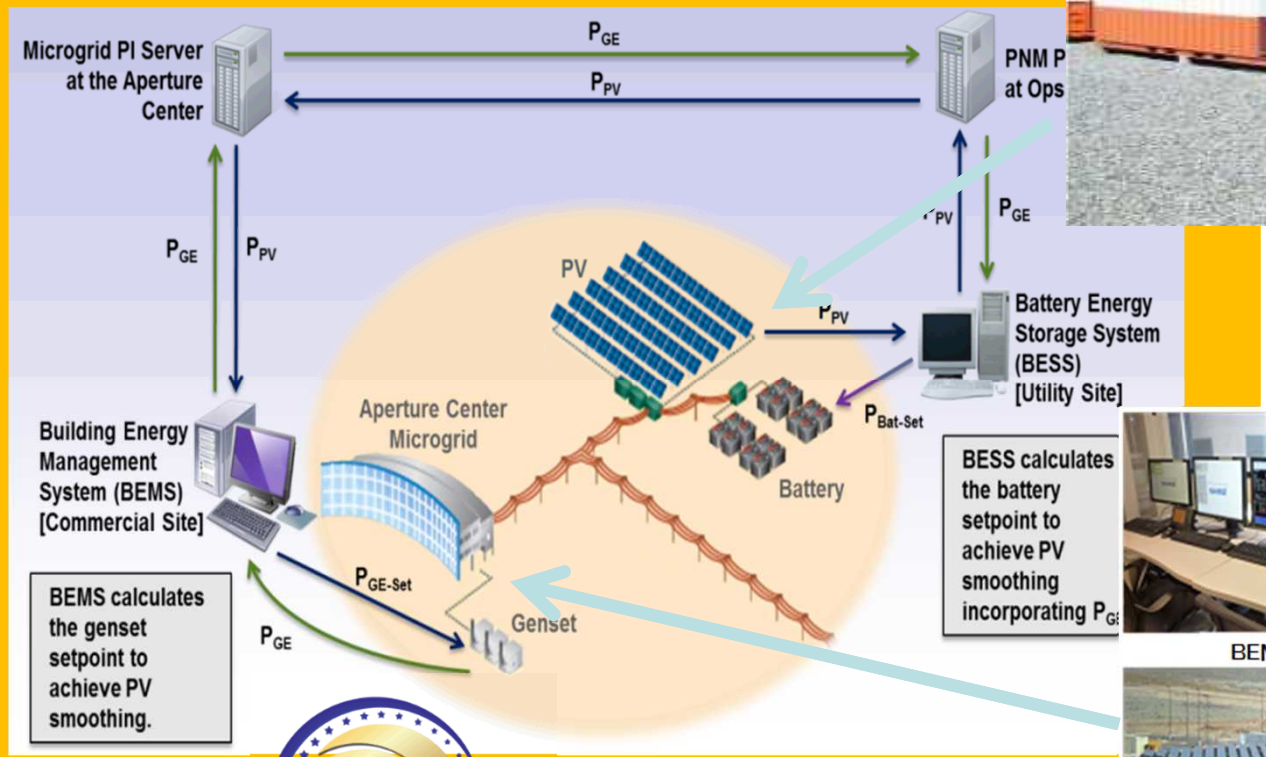
  - Virtual Power Plants 2.0
  - Optimization of grid operations under high uncertainty
  - Wide-area controls using
  - Microgrids for Critical Infrastructure Resilience
- Q&A (time permitting)

Smart Grid Demonstration in Alb., NM

Sandia National Laboratories

Concept Demonstration (2013-2014)

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




BEMS


Plant yard


PV panel


Distribution board

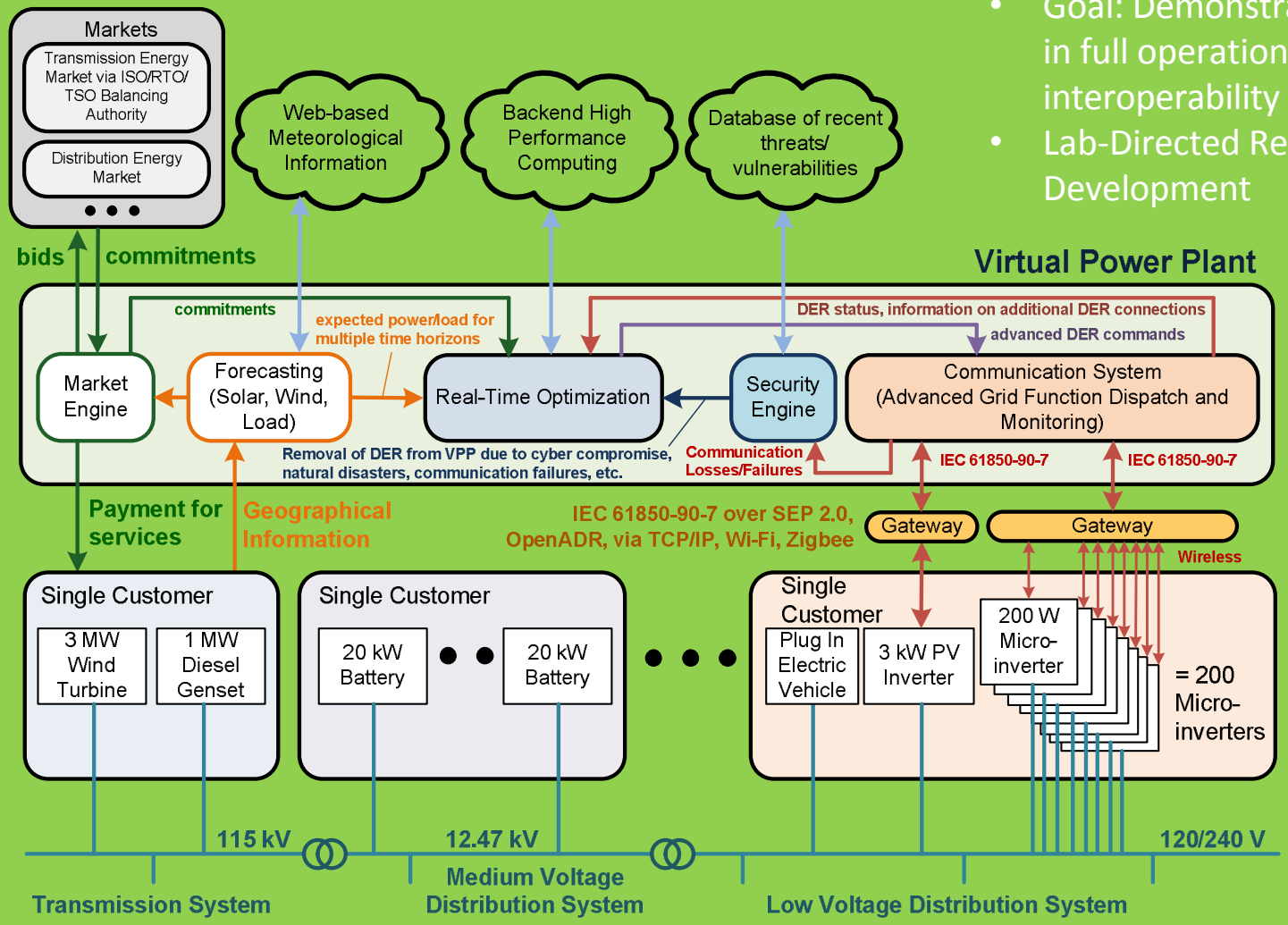
NEDO
Sandia National Laboratories
UNM
Mesa del Sol

ISGAN Award of Excellence 2014

Optimal and Secure Virtual Power Plant

Sandia National Laboratories

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



Communications and Interoperability

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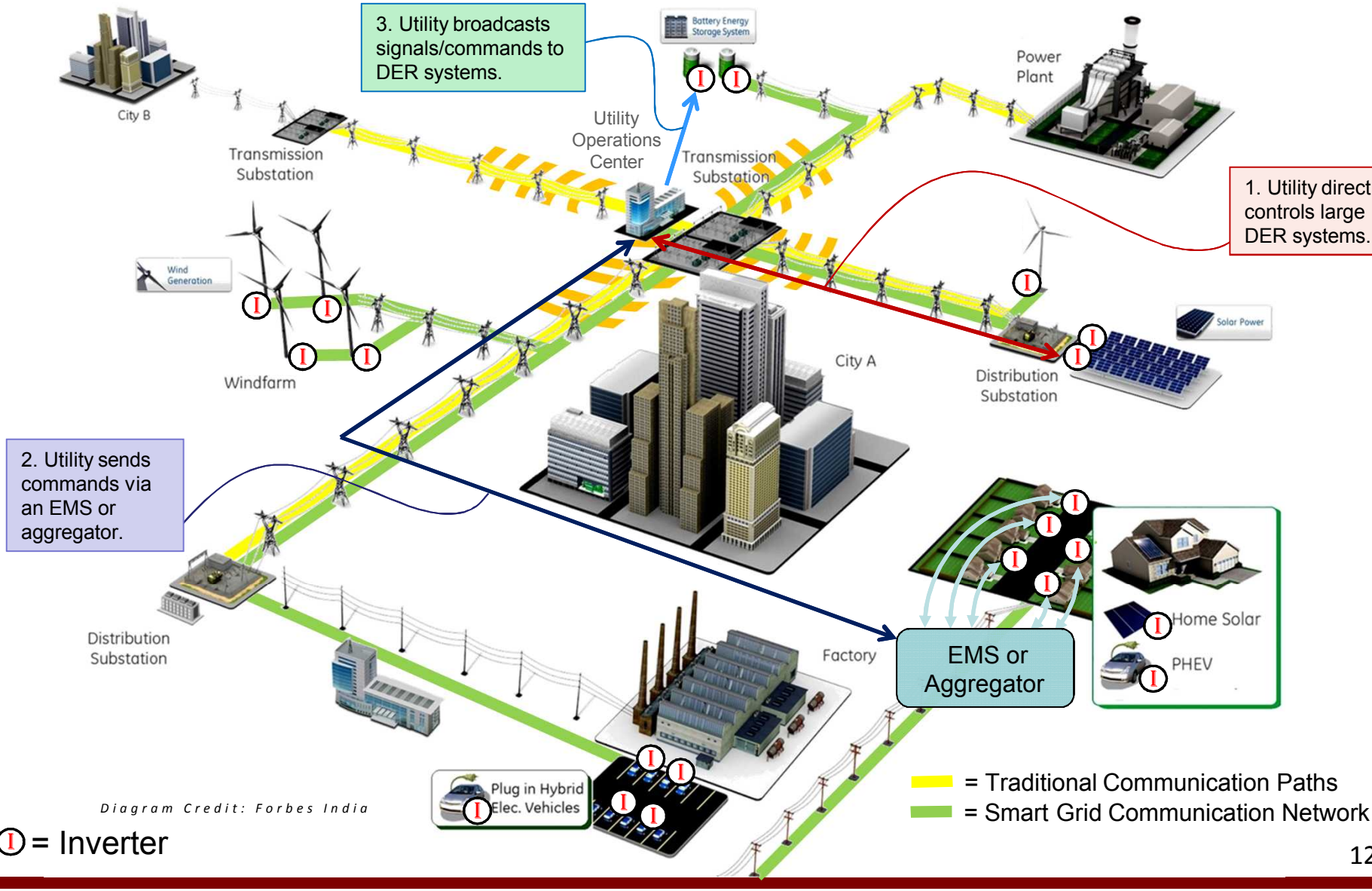
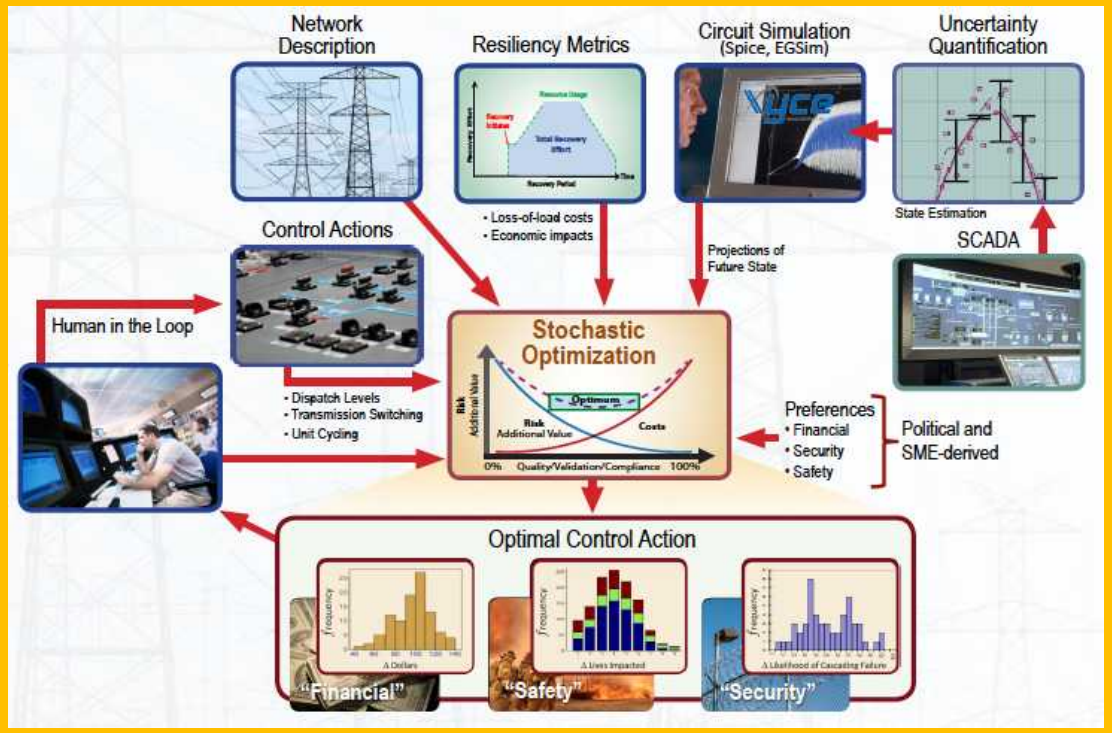


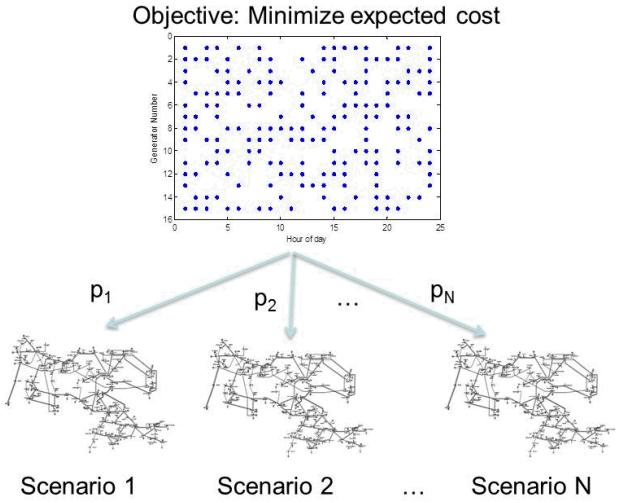
Diagram Credit: Forbes India

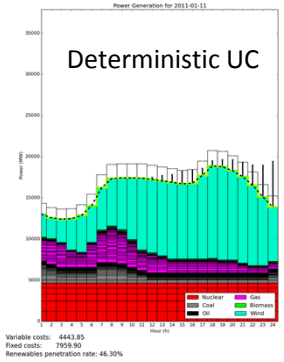
Ⓘ = Inverter

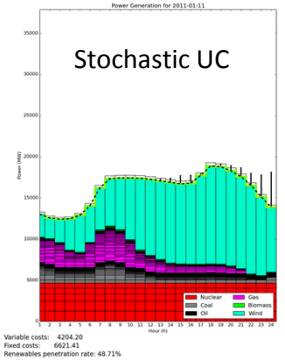
Grid Resilience Metrics & Optimal Control

- 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

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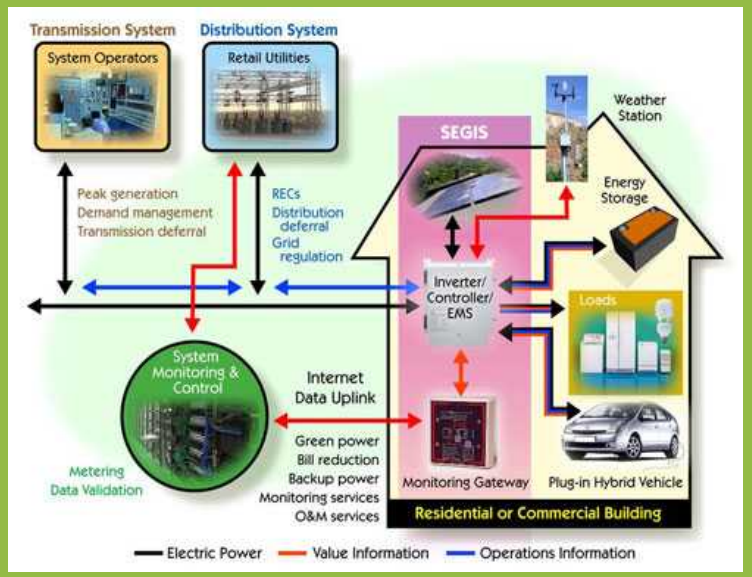
Technology Development

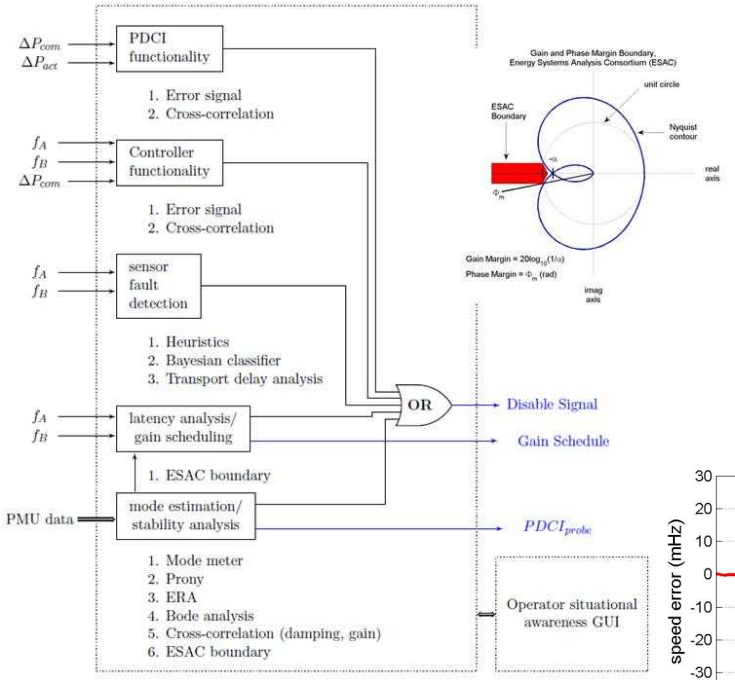
- Solar Energy Grid integration System (SEGIS)
- Public-Private partnership

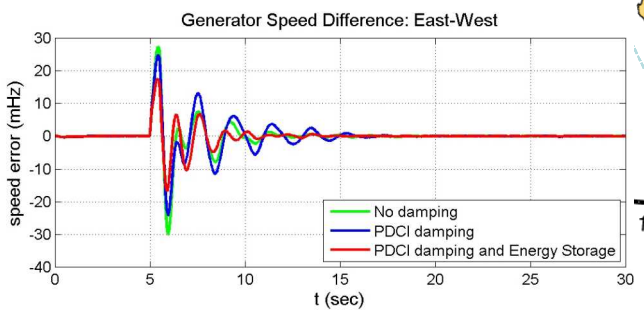


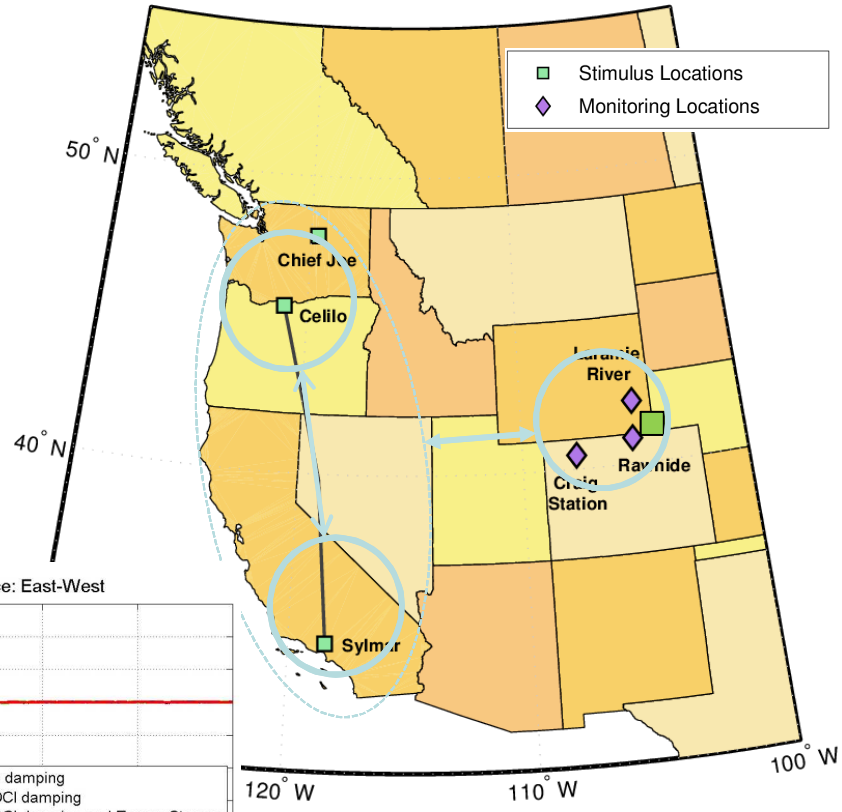
Smart Grid Ready PV Power Electronics

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

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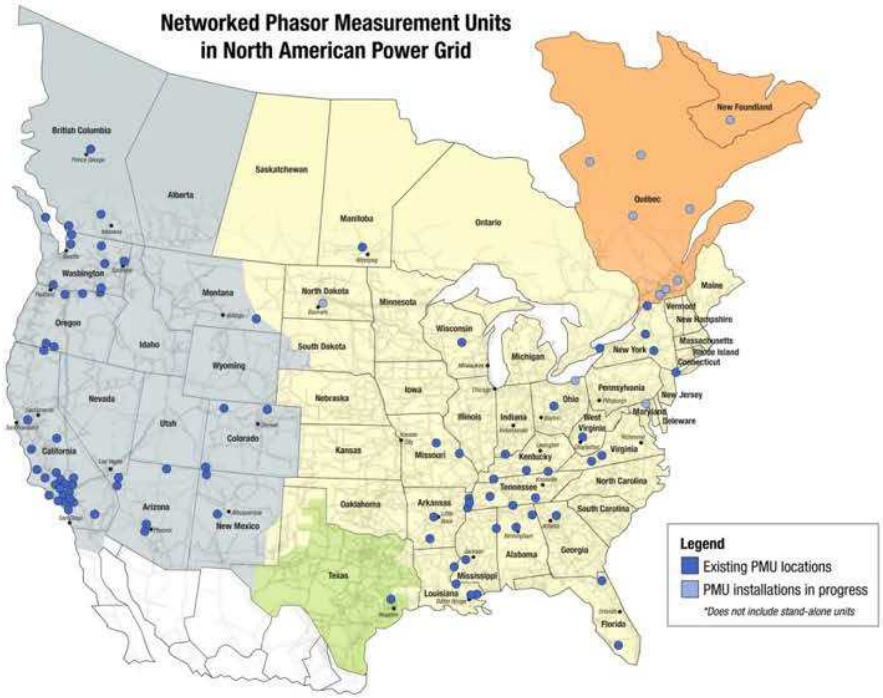
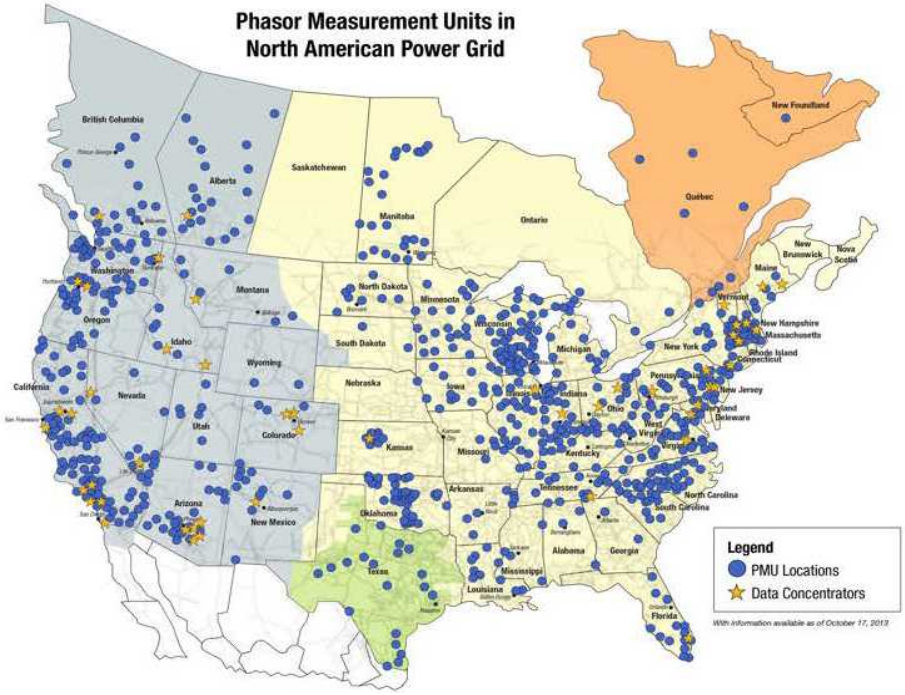
PMUs (2009)



PMUs (2014)

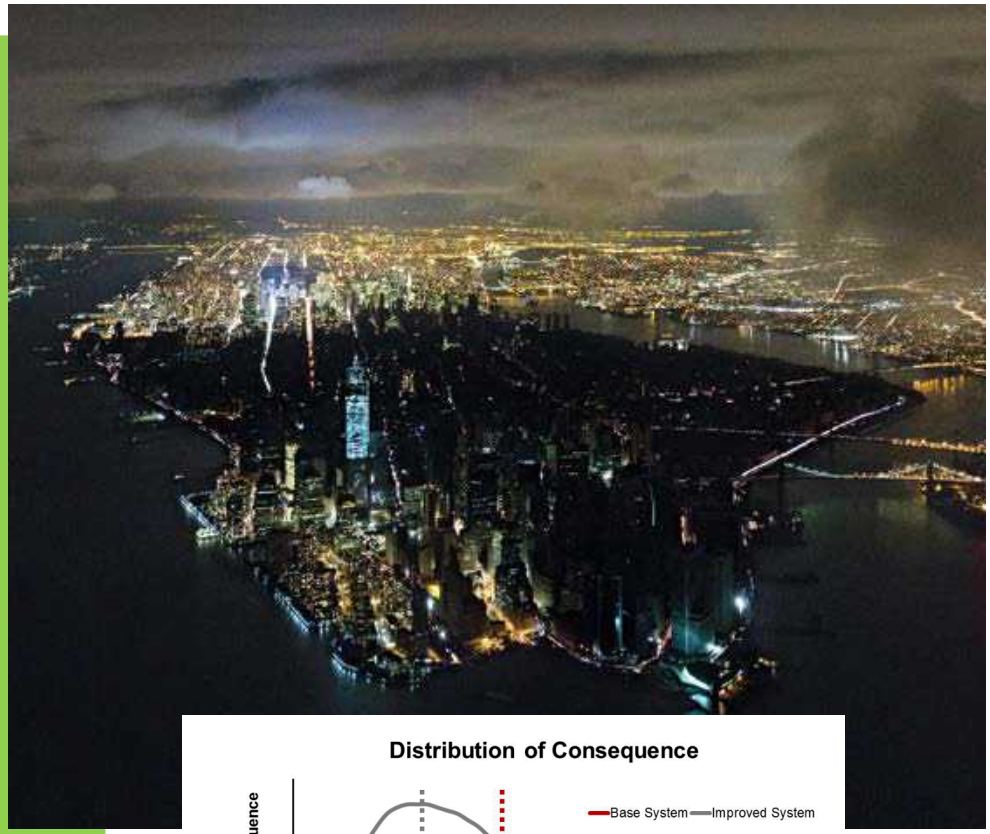


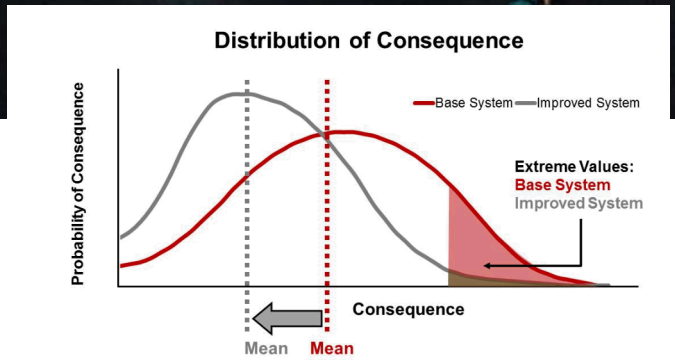
Microgrids and Energy Resilience R&D

Sandia National Laboratories

- 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

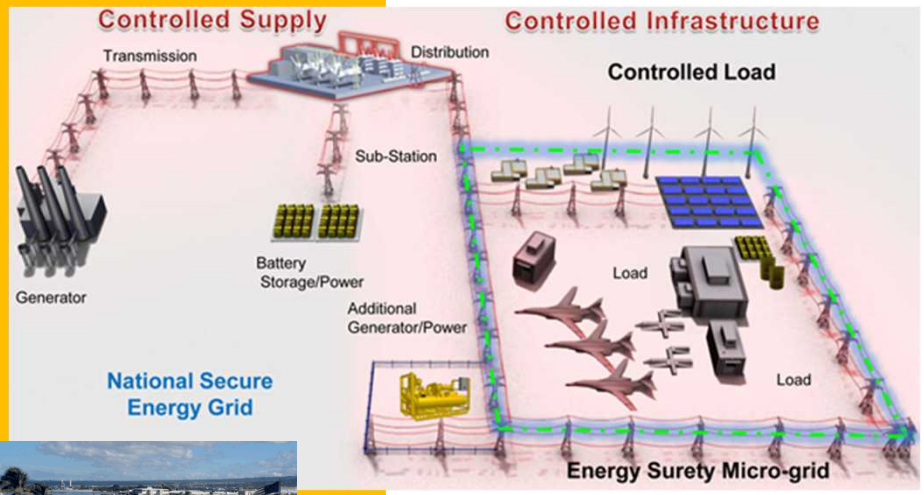




Microgrids and Energy Resilience R&D

Sandia National Laboratories

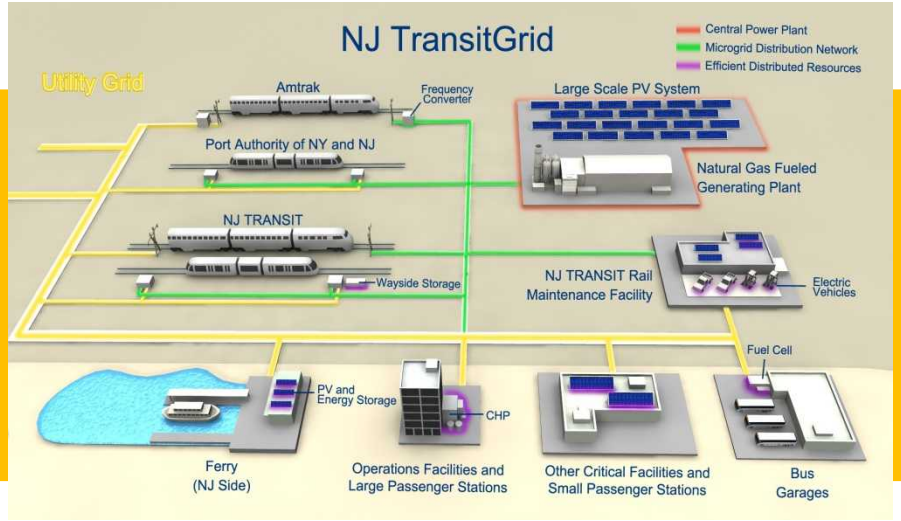
- Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS)

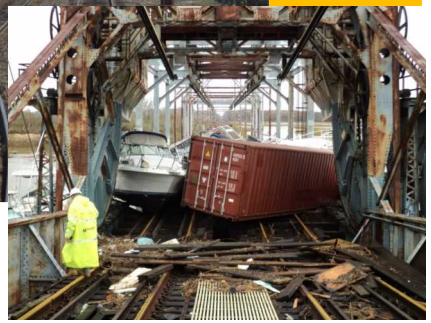


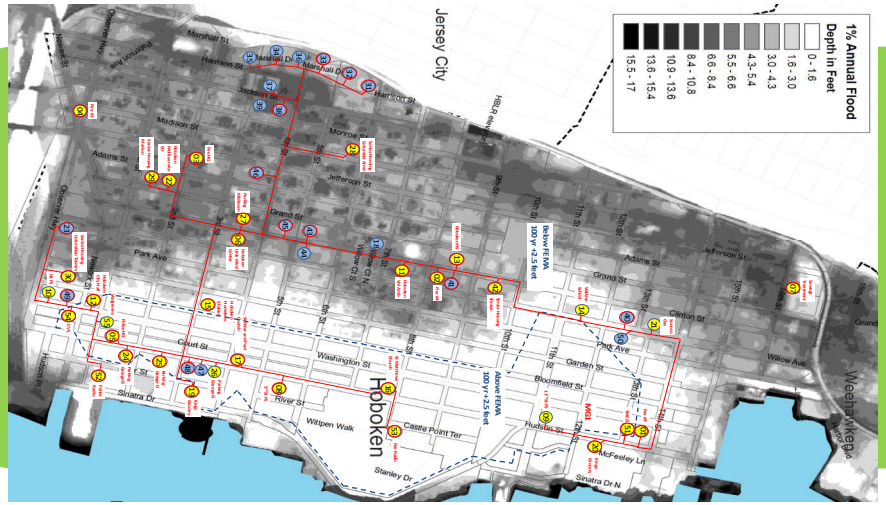
Microgrids and Energy Resilience R&D

Sandia National Laboratories

NJ TransitGrid Transportation Microgrid







City of Hoboken, NJ Energy Resilience Microgrid

Thank You

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