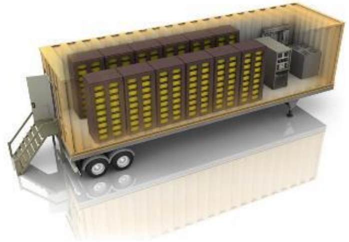
Sandia National Laboratories

Electric Utility Infrastructure and Alternative Energy

Energy Sovereignty Institute 2019

Tribal Energy Workshop



PRESENTED BY

Stan Atcitty, Ph.D.

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US Electric Utility Infrastructure

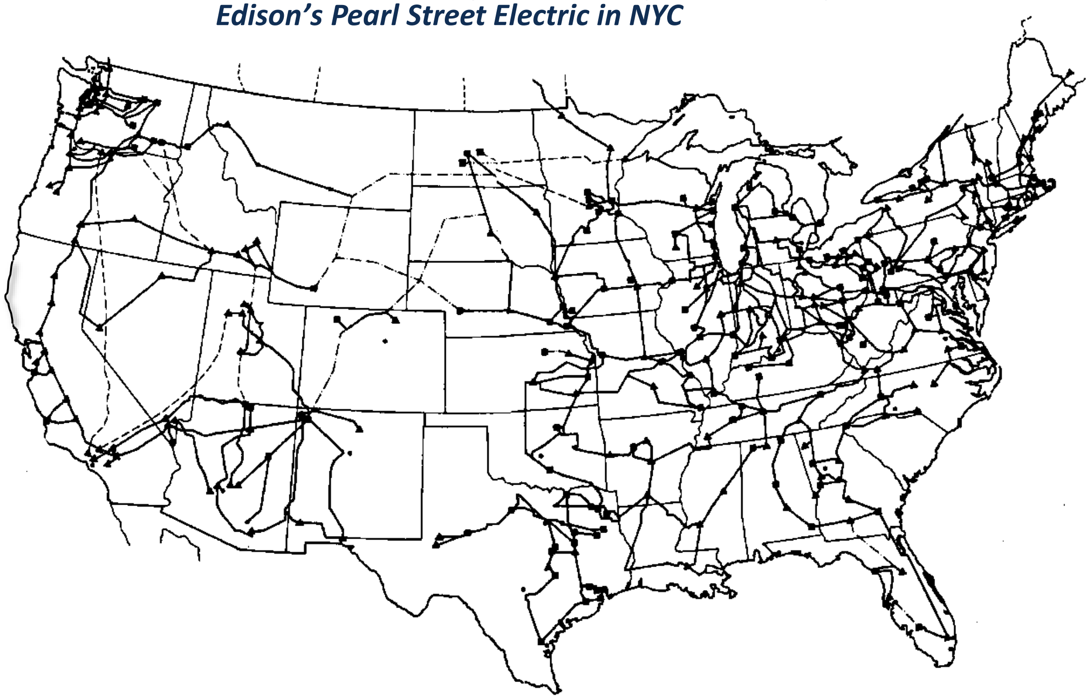
Common AC voltages

Transmission
- 765kV
- 500kV
- 345kV
- 230kV

Sub-Transmission
- 69kV
- 30kV

Distribution
- 15kV
- 4kV
- 2kV
- 600V
- 480V
- 240V
- 120V

First modern electric system developed in 1882 by Thomas Edison's Pearl Street Electric in NYC



Made up of:

Over 150 thousand miles of transmission lines (AC & DC)

10s of thousands of Generating Units totaling ~1000GW of total capacity

Millions of transformers, relays, and controls

100s of Billions of dollars in total investments in transmission and distribution

Electricity Utility Major Blackouts

San Diego/Arizona/Baja Blackout September 2011

- 5M affected, HV transmission line failure from AZ to CA

Northeast Power Blackout August 14, 2003

Source: http://www.globalsecurity.org/eye/blackout_2003.htm

~ 45M people affected US, 10M Ontario Canada

~ 6B in financial losses

Western US Blackout August 1996

- High demand, heat wave, and sagging power lines

New York City Blackout July 1977

Northeast Blackout November 1965

Electric Grid Reliability is Not Enough

North American Electric Reliability Corporation (NERC) defines grid reliability as a combination of grid adequacy (having sufficient generation to meet load) and grid security (having the ability to withstand disturbances).

Conceptually sound but incomplete framework for the nation's 21st century smart grid

Our nation requires a grid that adapts to:

- Large-scale environmental and unnatural events
- Remains operational in the face of adversity
- While minimizing the catastrophic consequences that affect the quality of life, economic activity, national security, and critical-infrastructure operations.

Concept of Reliability must be augmented with resiliency approach

- One that looks at the grid not strictly as a flow of electrons but as a grid that serves and impact people and societies in multiple ways (electric power, water, sewages, shelter, medical, food, transportation, etc.).
- It is the consequences, not outages per se, that matter.

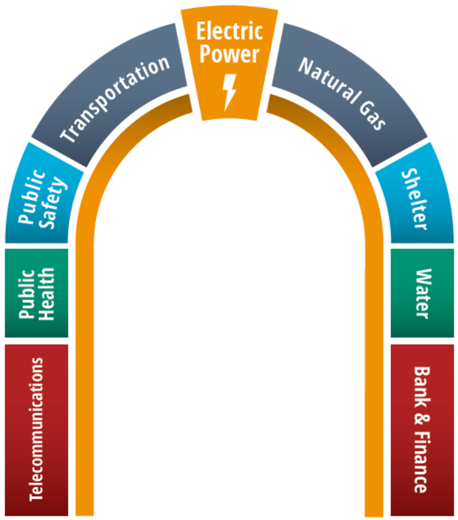
Understanding the Consequences

The complex network of electrical infrastructure is critical to

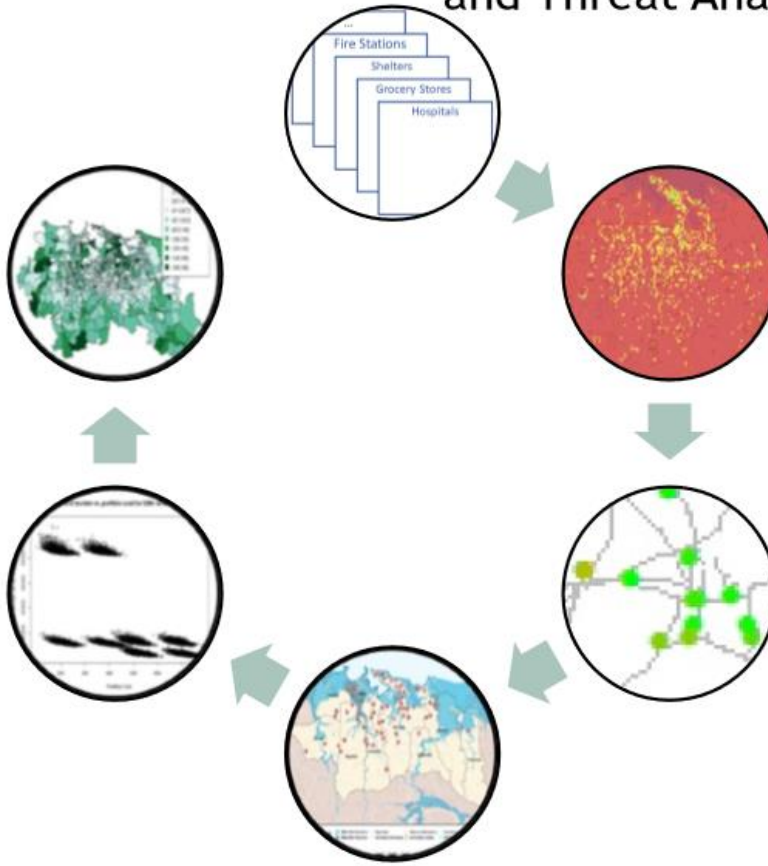
- Economic well-being
- Quality of life
- Keystone and central to interconnected systems that support life as we know it
- Grid owners and operators work hard to ensure reliable operation and able to withstand the effects of any single component failure.

To strengthen the grid resilience or ability to minimize the consequences of extreme weather (hurricanes, floods, forest fire, etc.) or malicious physical or cyber-attacks grid planners and operators must

- Understand the consequence of specific threats to the system
- Have the ability to prepare and react to them



Sandia Analysis Process



1 Infrastructure Data and Threat Analysis

2 Determine Locations Providing High Service Levels
Tool: ReNCAT

3 Examine Candidate Microgrid Locations

4 Finalize Candidate Microgrid Locations

5 Cost/Benefit Tradeoff Analysis

6 Visualize Metrics and Resilience Options
Tool: MPEx

Sandia Grid Resilience
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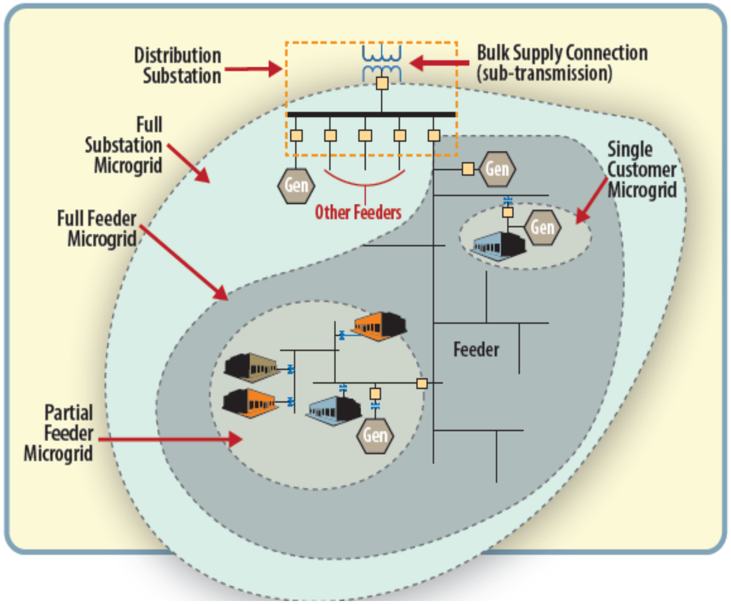
Microgrid – Resilience Node

Microgrid – hardened electrical infrastructure that the connects multiple buildings through a system of localized power generation and automatic controls, ensuring access to electricity for these buildings even if the bulk of the city's power grid goes down.

- Local generation – thermal sources (natural gas or biogas generators and renewables)
- Consumption – electricity, heat, and cooling
- Energy Storage and Power Electronics - power quality, frequency and voltage regulation, power smoothing, backup, etc.

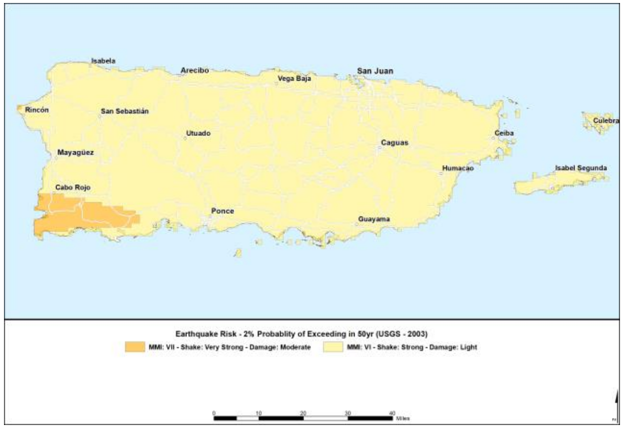
Sandia calls these microgrid hubs "resilience nodes"

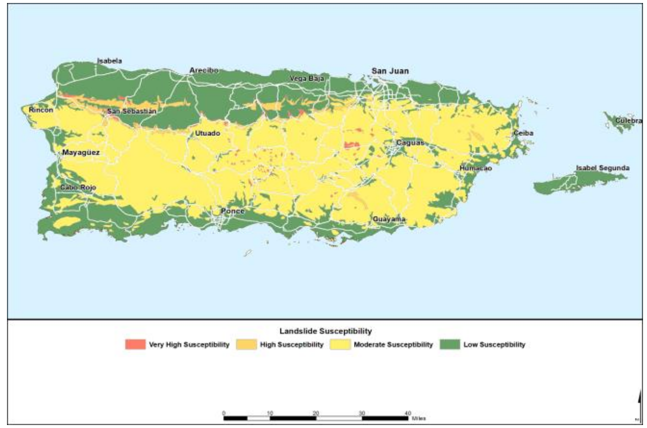
- Improves the availability of essential services (electric power, drinking water, sewerage, medical services, food, transportation, etc.) to nearby neighbors by enabling enhanced adaptation, response and recovery from electric grid disruptions



Microgrid Design Toolkit – decision support software tool for microgrid designers in the early stages of the design process.

Threat Characterization

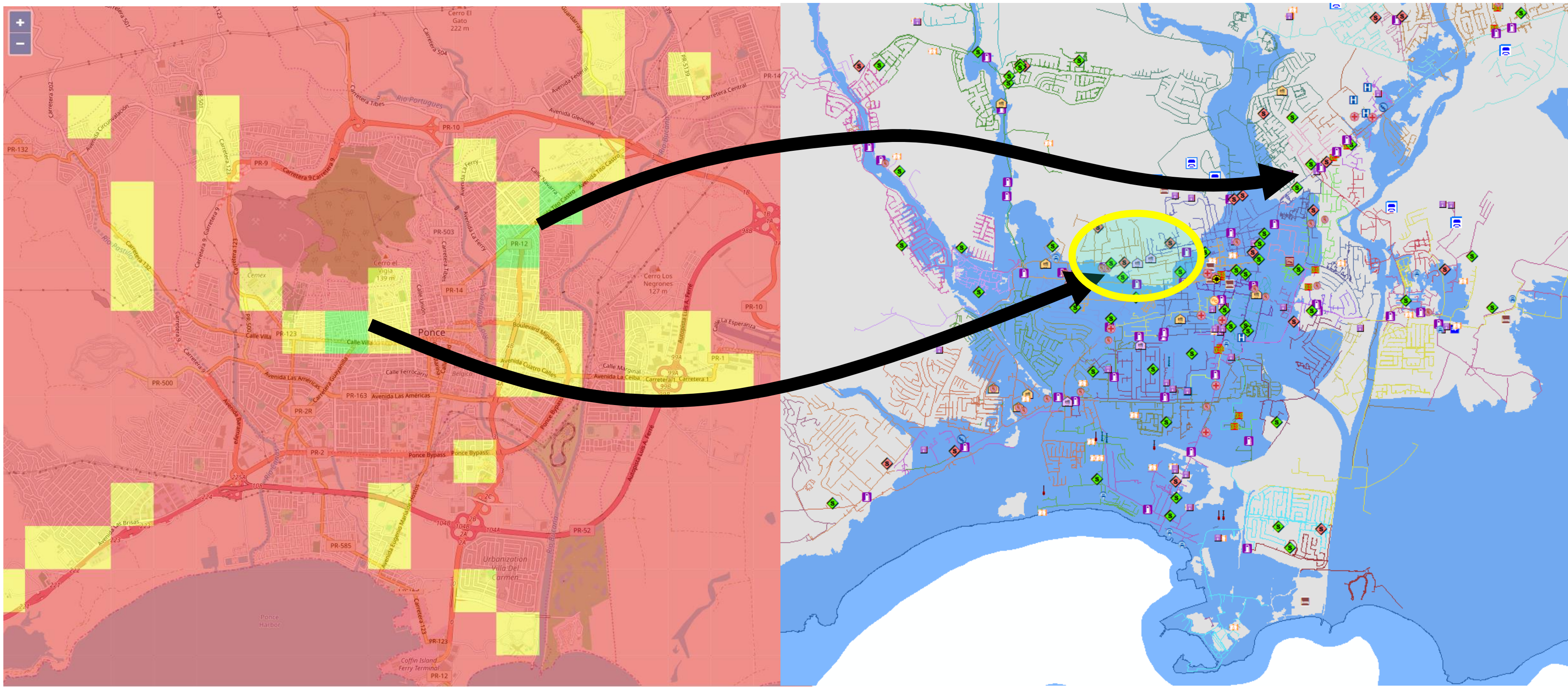




Hazard	Source	Threat Profile Used	50-yr Probability of Exceedance	Link
Flooding	FEMA FIRM	100-yr and 500-yr (return period)	39% (100-yr) 9.5% (500-yr)	www.fema.gov/flood-mapping-products
Wind	ASCE	100-yr and 700-yr (return period)	39% (100-yr) 6.9% (700-yr)	windspeed.atcouncil.org/
Landslide	USGS	Susceptibility: highest, high, moderate, low	N/A	pr.water.usgs.gov/public/online_pubs/mism_i_1148/index.html
Earthquake	USGS	Structure Damage: Moderate, Light	2%	earthquake.usgs.gov/hazards/hazmaps/islands.php#prvi

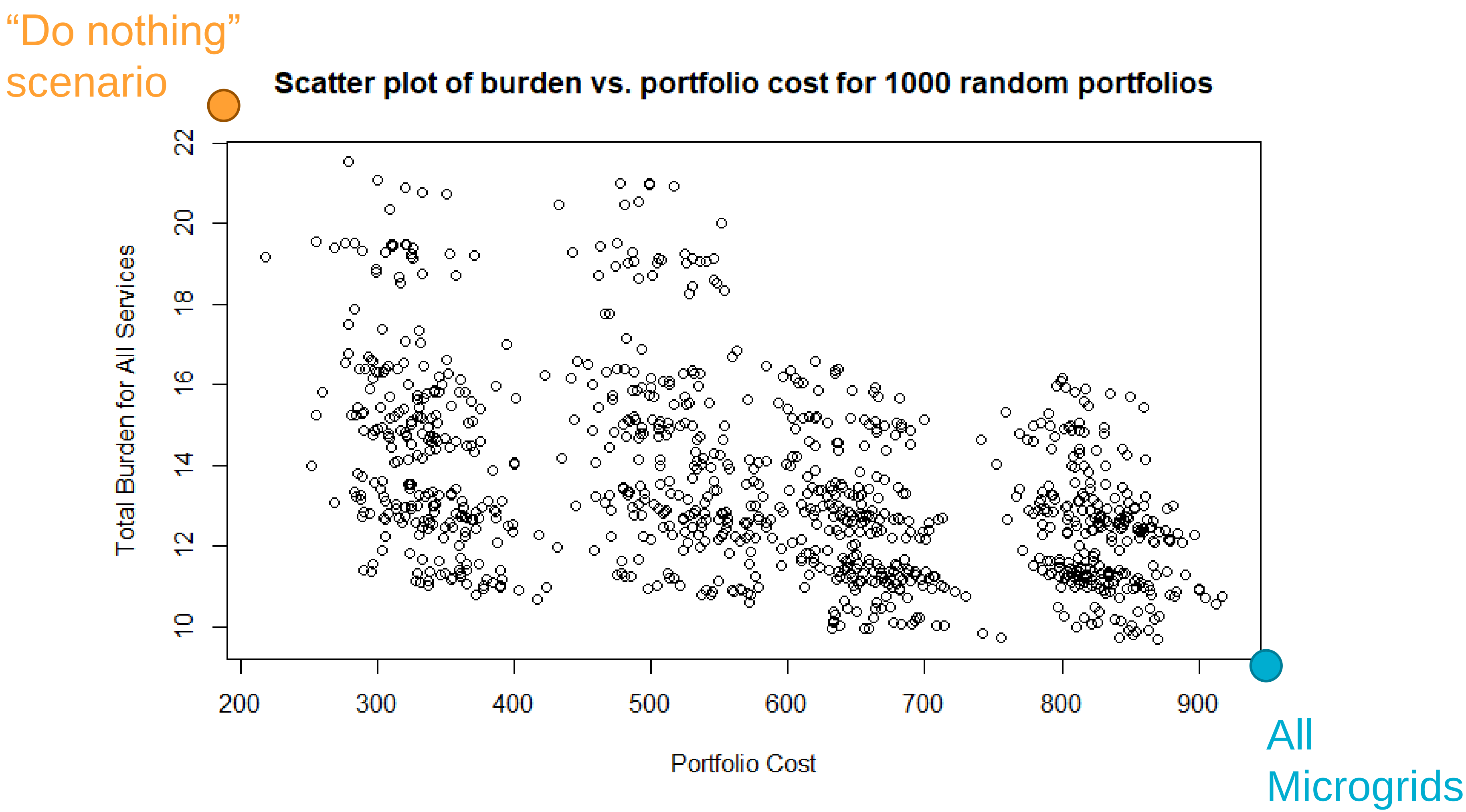
Jeffers et al. (2018) Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico. SAND2018-11145

Filtering of Highest-Value Microgrids



Jeffers et al. (2018) Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico. SAND2018-11145

Portfolio evaluation



A large decrease in burden can be achieved for relatively low cost compared to all microgrids

Energy Storage is Critical to the Stability and Resilience of the Electric Grid

Traditional Grid

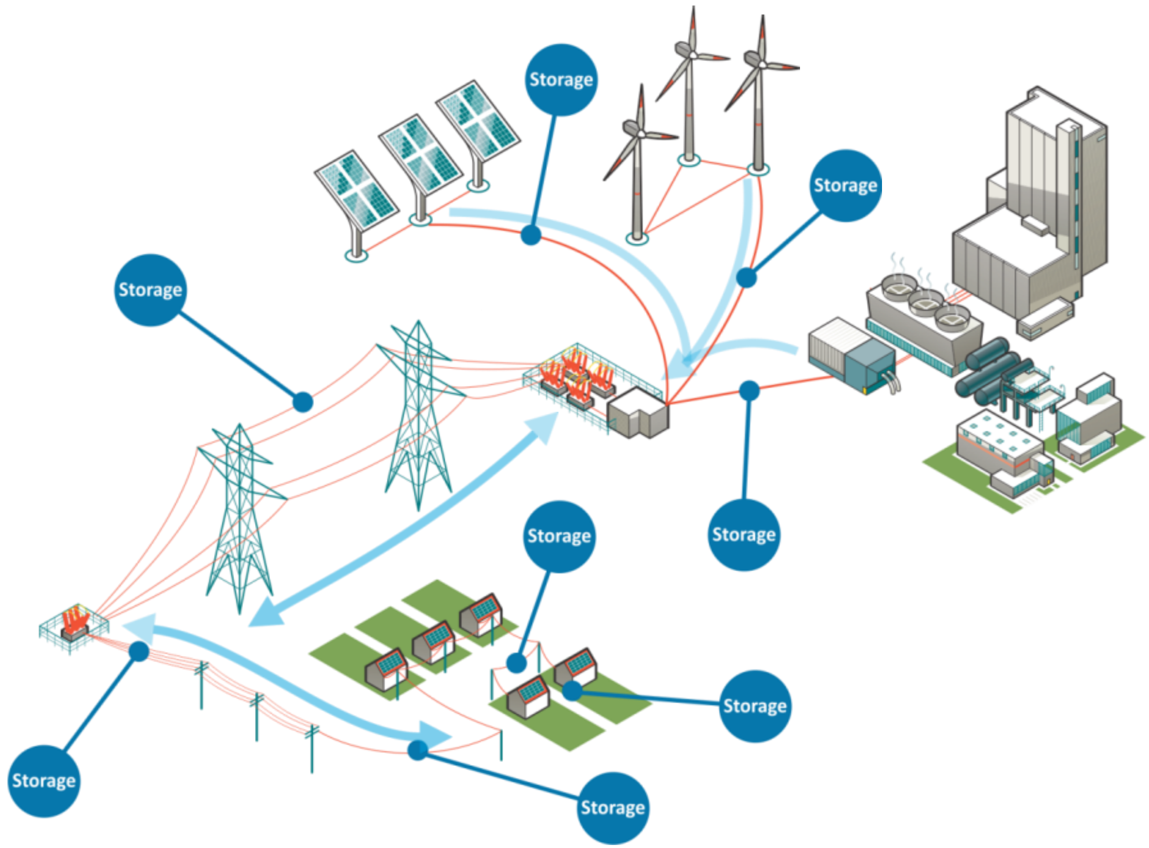
- One way flow
- Little/no renewable energy

Today's Grid

- Integration of grid-scale and distributed renewable generation beginning, but with limited penetration

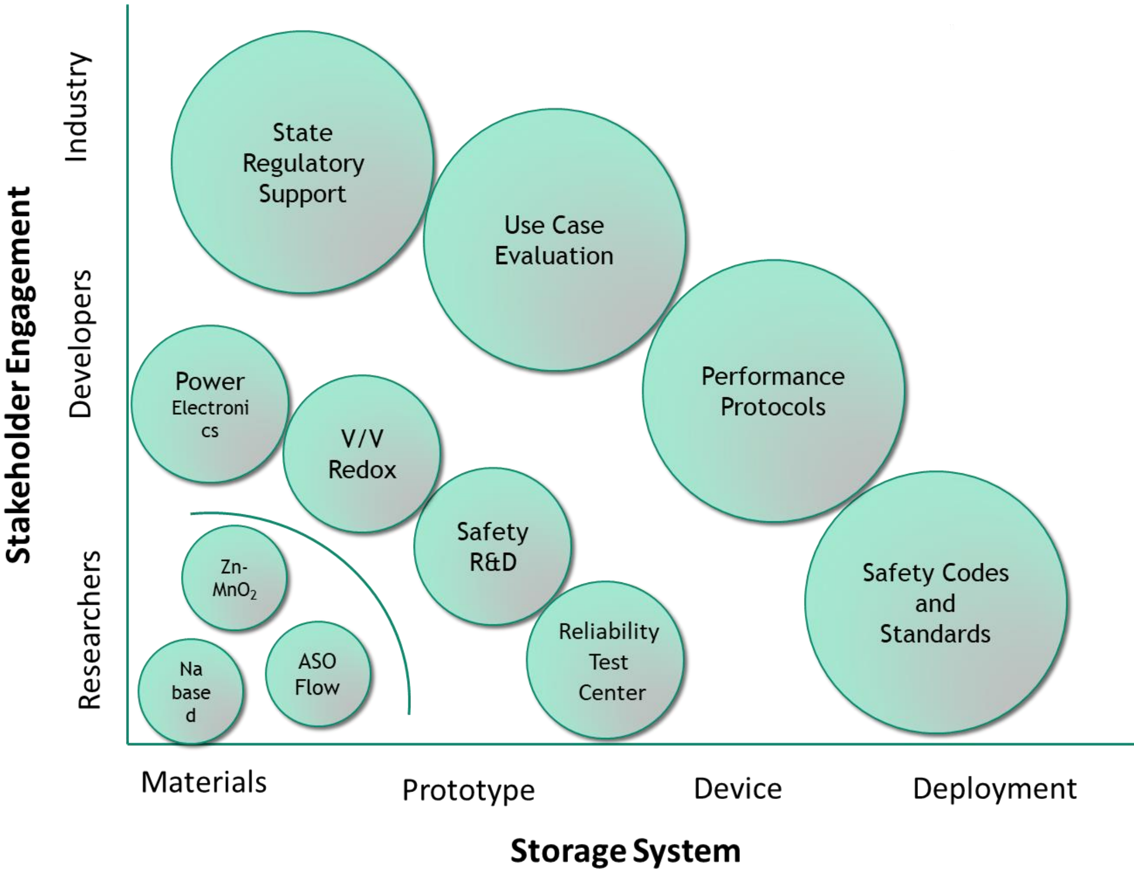
Future Grid

- Storage provides buffering capability to enable high penetration of variable renewables and asset deferral for T&D systems (load management, ancillary services)
- Efficient two-way flow



DOE Office of Electricity Energy Storage Program

U.S. DEPARTMENT OF ENERGY



The goal of the DOE Energy Storage Program is to develop advanced energy storage technologies and systems, in collaboration with industry, academia, and government institutions that will increase the reliability, performance, and competitiveness of electricity generation and transmission in the electric grid and in standalone systems.

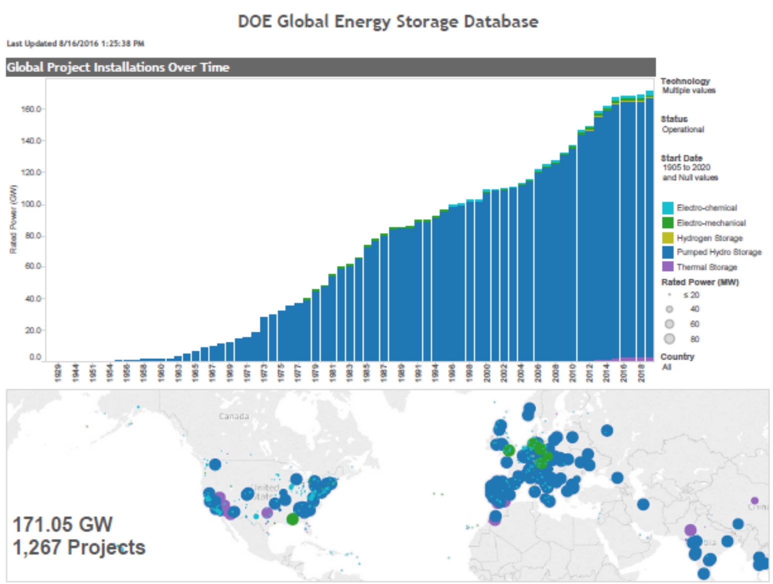
This program is part of the DOE Office of Electricity Delivery and Energy Reliability (OE).

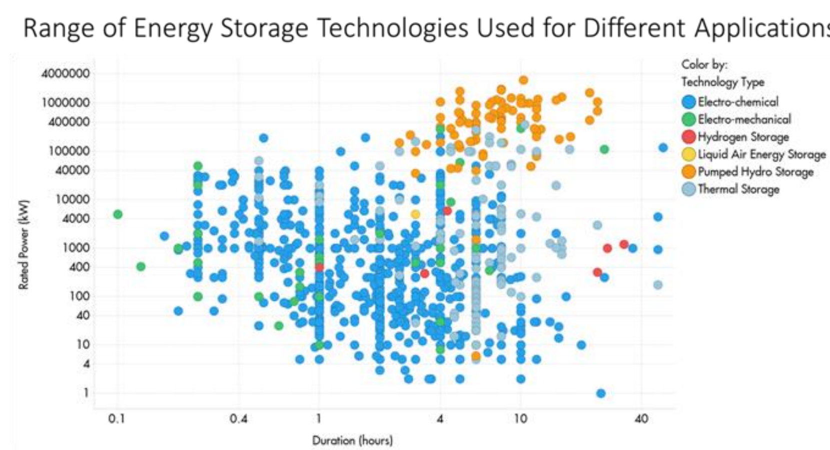
The Energy Storage Program is managed by Dr. Imre Gyuk.

http://www.sandia.gov/ess/

DOE Global Energy Storage Database

- 1,576 total energy storage project profiles
- Over 178 GW operational capacity
- 9,600 unique users have exported the data 70,000+ times
- There is no widely available alternative source of information – all known private data sources reference data from DOE's Global Energy Storage Database



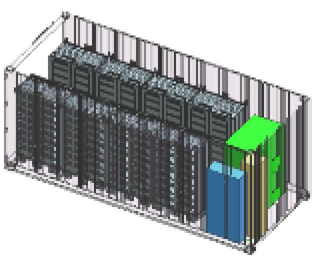


Source: US DoE Energy Storage Database, June 2018, https://www.energystorageexchange.org/
Analysis by Shell International Exploration & Production (US) Inc.; presented by Shell 11 March 2019, ARPA-e DAYS kickoff meeting

Elements of Energy Storage Systems

Storage

- Cell
- Battery Management & Protection
- Racking



Integration

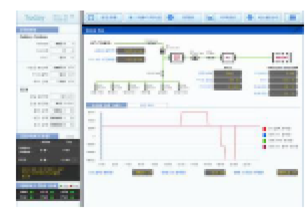
- Container / Housing
- Wiring
- Climate control

PCS

- Bi-directional Inverter
- Switchgear
- Transformer
- Skid

EMS

- Charge / Discharge
- Load Management
- Ramp rate control
- Grid Stability



Designing a Business Case

The **Cost** of a Storage System depends on the Storage Device, the Power Electronics, and the Balance of Plant

- Power Electronics 20-25%
- Energy Storage Device 25-50%
- Facility 20-25%

The **Value** of a Storage System depends on Multiple Benefit Streams, both monetized and unmonetized

- Arbitrage
- Freq. Reg.
- Dem. Charges month, year
- Resiliency

Metrics will depend on locality!

Making Energy Storage Cost Competitive

Critical challenges for energy storage are high system cost and cycle life

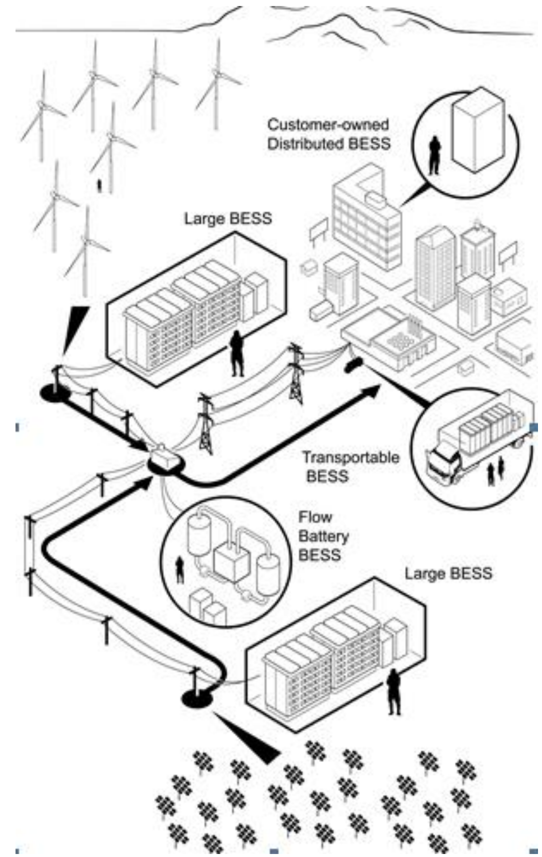
- Existing storage solutions are expensive
- Deep discharge and longer cycle life
- Safe and reliable chemistry
- Scalable technology to cover all markets

To make storage cost competitive, we need advances across all major areas:

- Batteries, power electronics, PCS
- BOS and Integration
- Engineered safety of large systems
- Codes and Standards
- Optimal use of storage resources across the entire electricity infrastructure

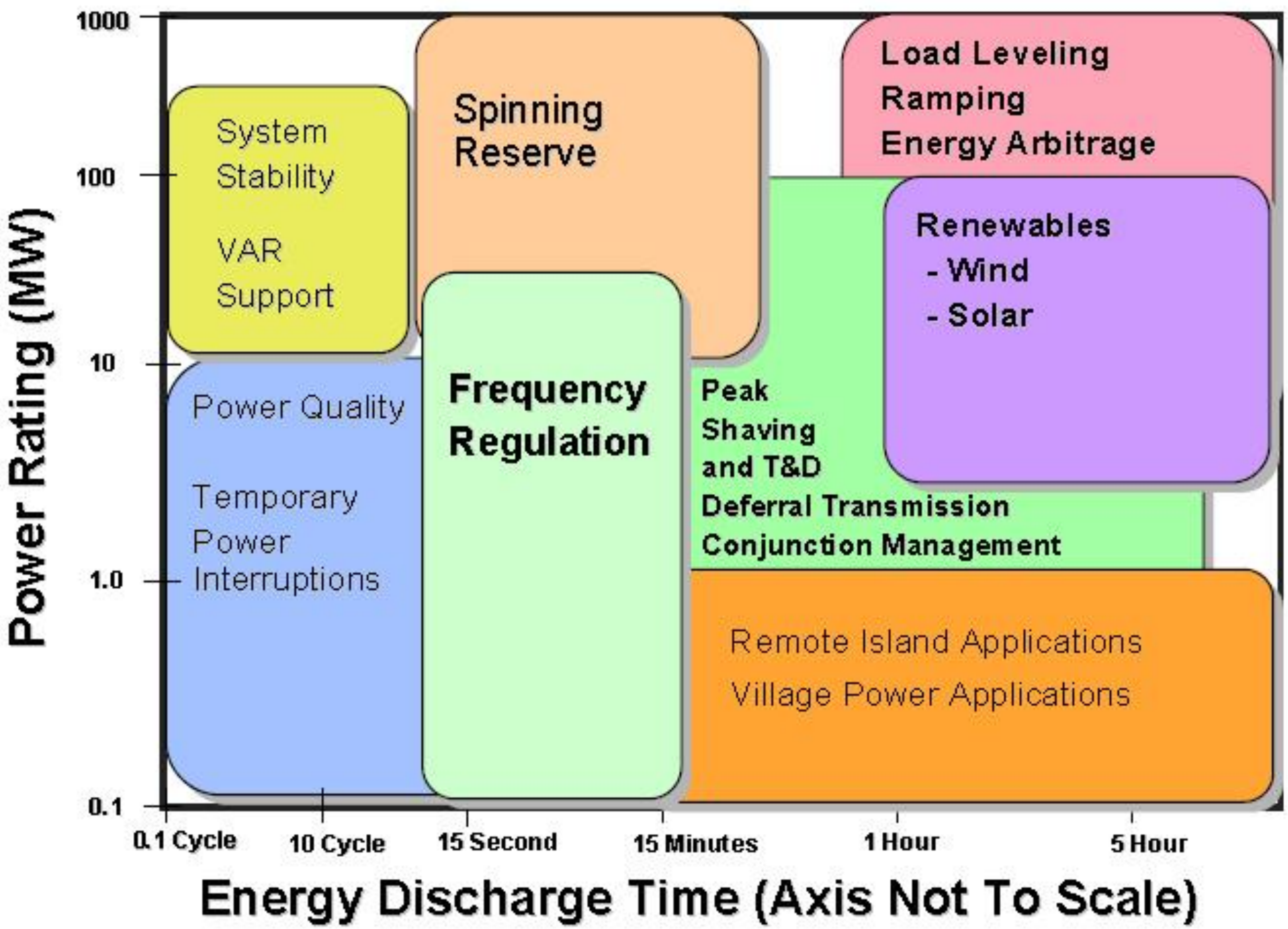
Benefits of Energy Storage

- Maintain quality power and reliability
- Provide customer services — cost control, flexibility, and convenience
- Improve T&D stability
- Enhance asset utilization and defer upgrades
- Increase the value of variable renewable generation



Source: Power Electronics for Renewable and Distributed Energy Systems: A Sourcebook of Topologies, Control and Integration

Electric Utility – Power and Energy



Source: Electric Power Research Institute

Energy Storage Technologies

Energy

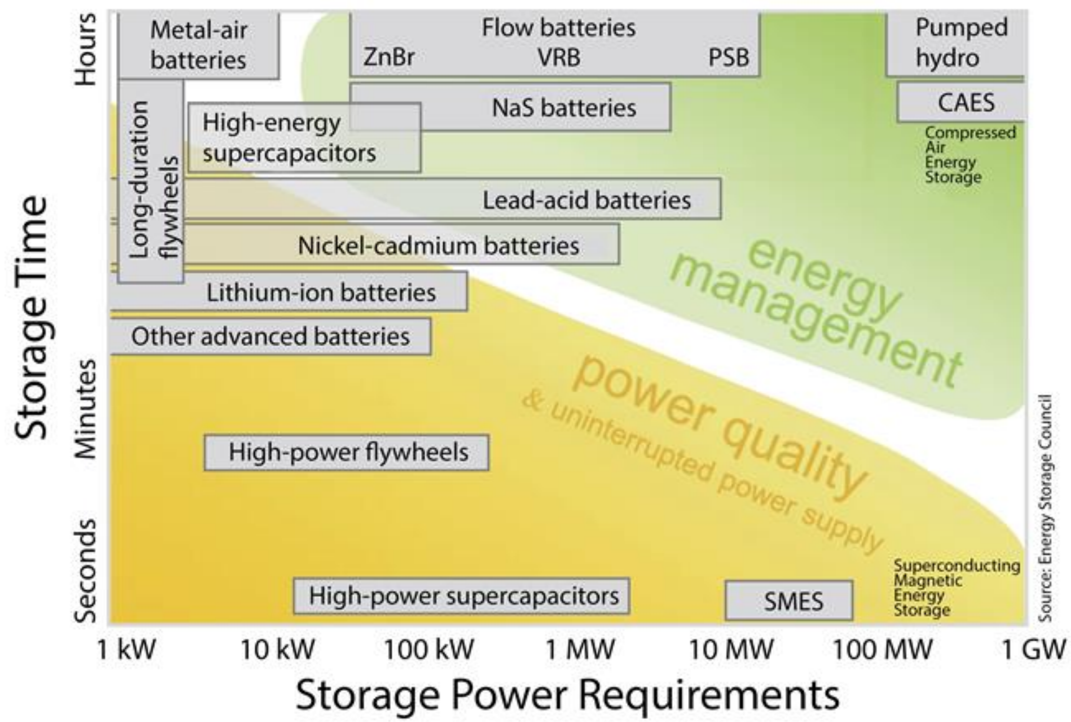
- Pumped Hydro
- Compressed Air Energy Storage (CAES)
- Batteries
  - Sodium Sulfur (NaS)
  - Flow Batteries
  - Lead Acid
  - Advanced Lead Carbon
  - Lithium Ion
- Flywheels
- Superconducting magnetic energy storage (SMES)
- Electrochemical Capacitors

Power

Two regimes, multiple technologies:

Power – short discharges (sec to min):
flywheels, capacitors, SMES, some batteries

Energy – long discharges (min to hr):
batteries, H_2 fuel cells, CAES, pumped hydro



Remote Power Systems – Tribal Lands

Sandia Tribal Student Programs

NNSA Minority Serving Institute Program

Salish Kootenai College – Education • Leadership • Wisdom

Cankdeska Cikana Community College
Spirit Lake Dakota Nation
Start Here • Go Anywhere

Bay Mills Community College

Navajo Technical University

Turtle Mountain Community College

Advanced Manufacturing Network Initiative

U.S. DEPARTMENT OF ENERGY

Office of Indian Energy Policy and Programs

Sandia Summer Internship Program

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