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The SMART Grid – Challenges and Directions

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U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration
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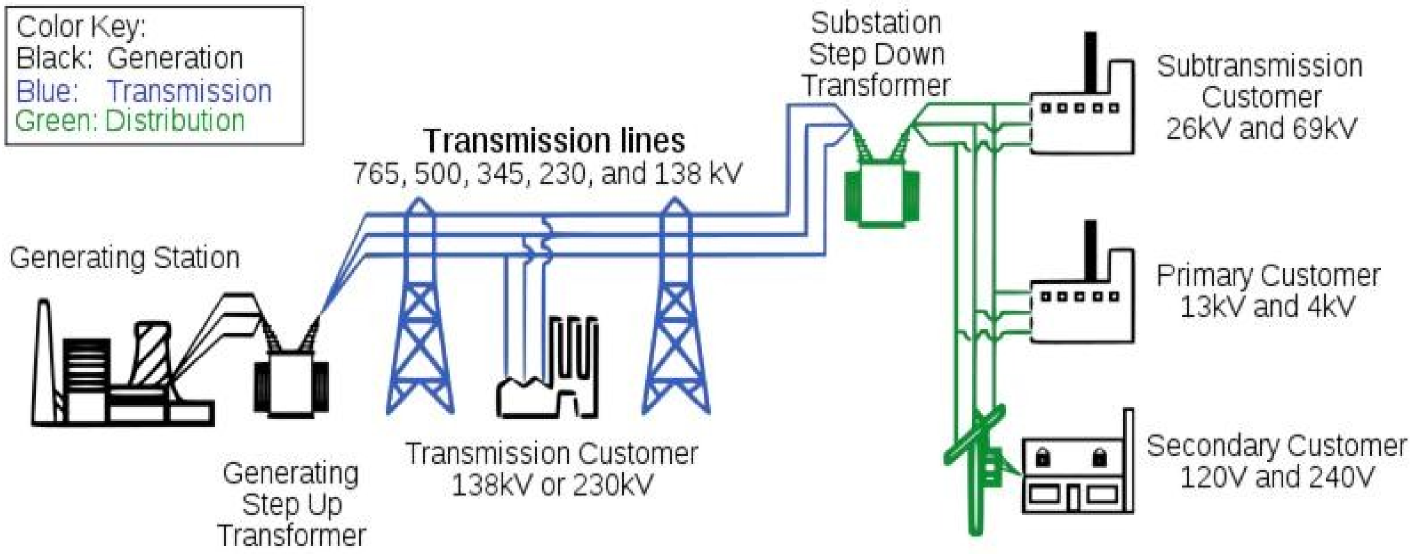
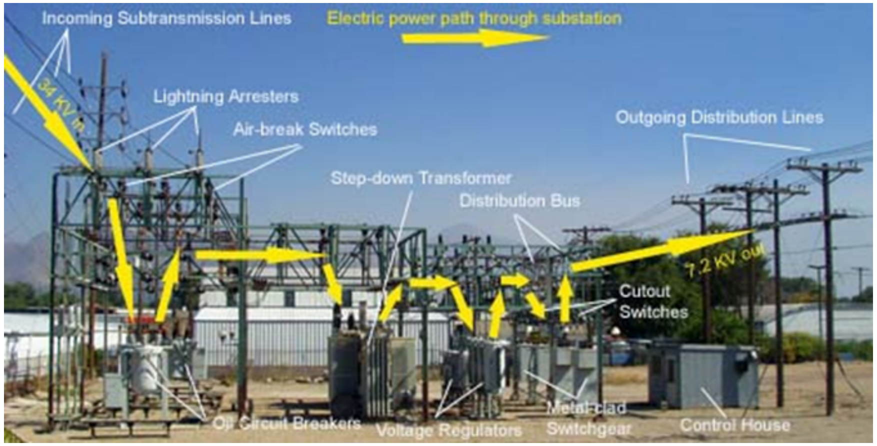
Electric Power Systems

- The purpose of a power system is to generate power, transmit this power and to distribute it to customers at voltage levels and reliability that are appropriate to various users



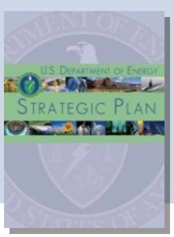
Electric Power Systems



Changing Values of Critical Infrastructures

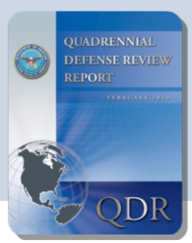
- "…the nation is so dependent on our infrastructures that we must view them through a national security lens. They are essential to the nation's security, economic health, and social well being." **President's Commission on Critical Infrastructure Protection 1999**
- Most infrastructures depend on energy for operation
  - telecom, water, transportation, government, health, agriculture
  - making energy assurance of local and regional importance

DEPARTMENT OF ENERGY



2006 Strategic Plan

DEPARTMENT OF DEFENSE



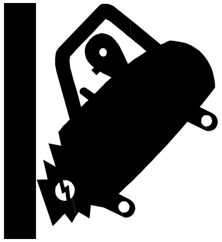
Quadrennial Defense Review Report

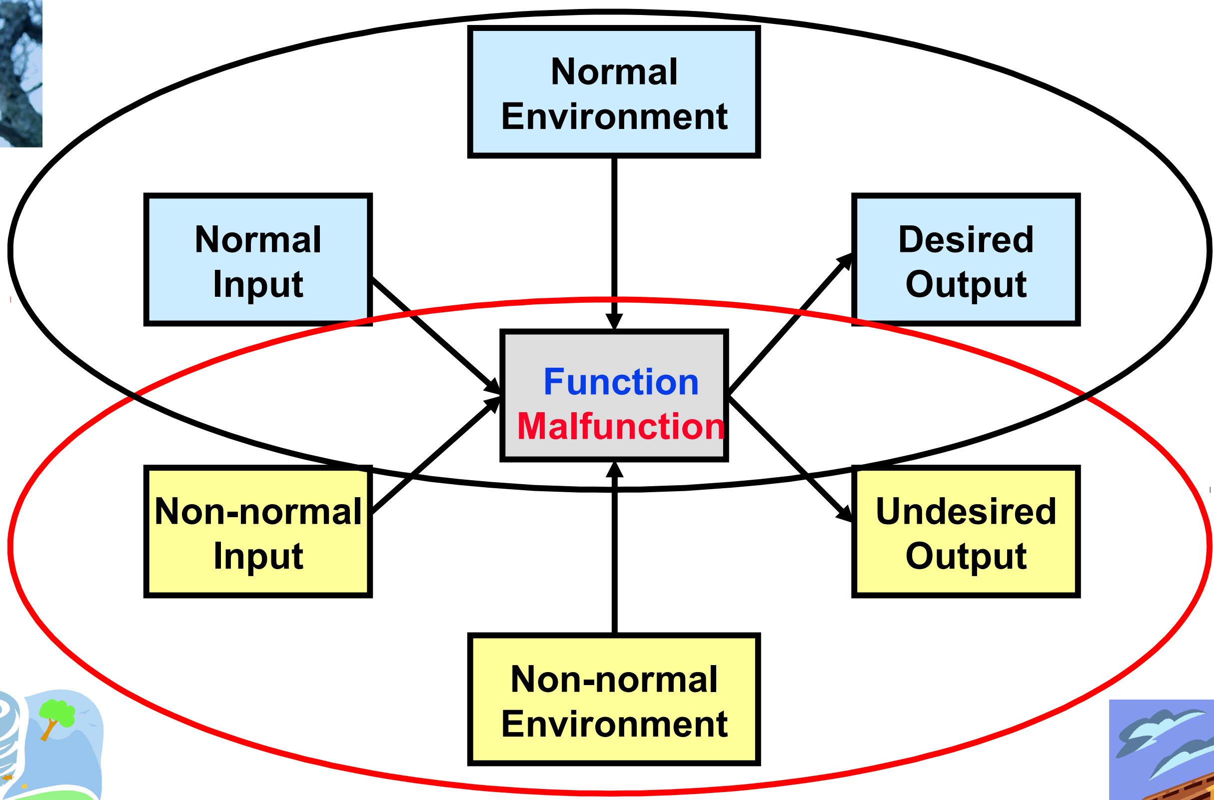
DEPARTMENT OF HOMELAND SECURITY

2008 Plan for Protecting Critical Infrastructure

More flexible, reliable, cost and energy efficient, sustainable and secure energy supplies

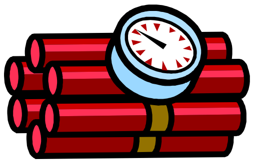
Critical Infrastructure Protection Changes in System Performance Metrics



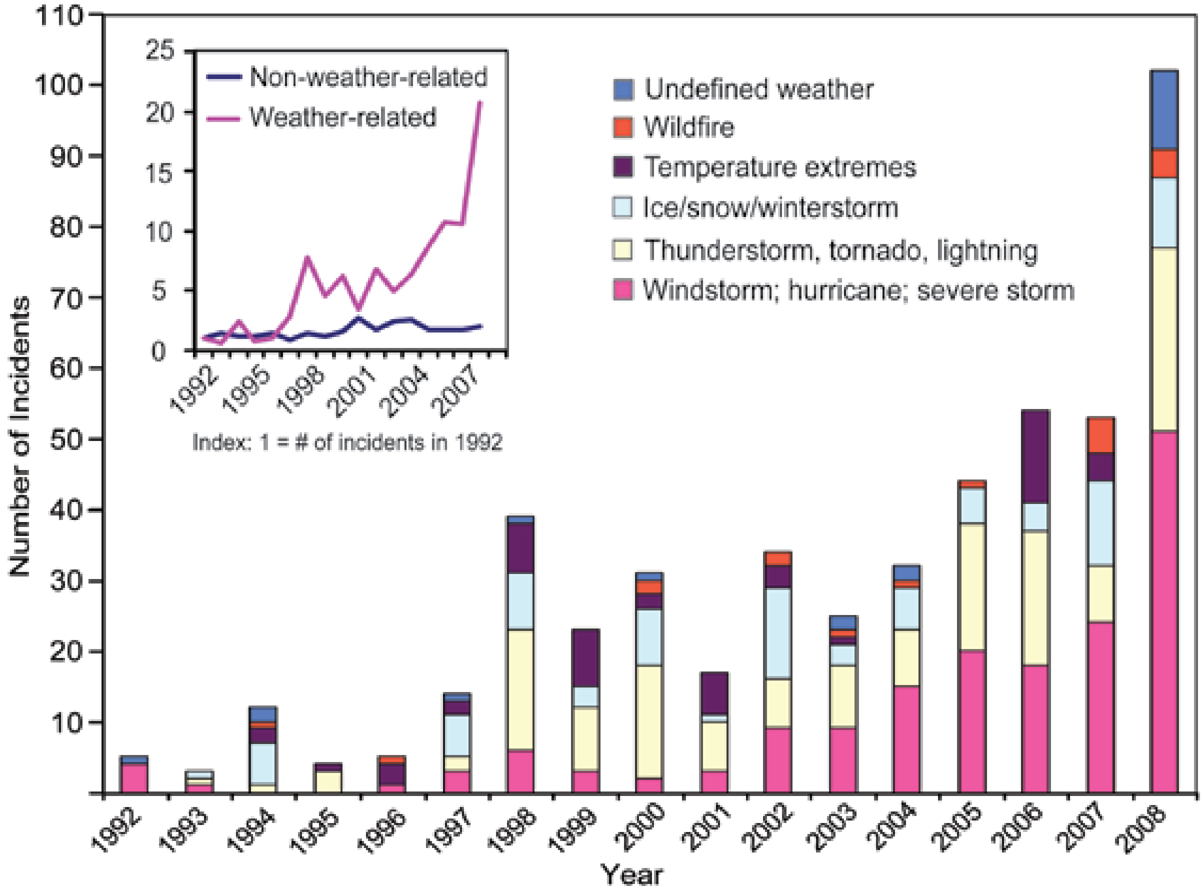


Compliance-based
High probability, low consequence

Performance-based
Low probability, high consequence



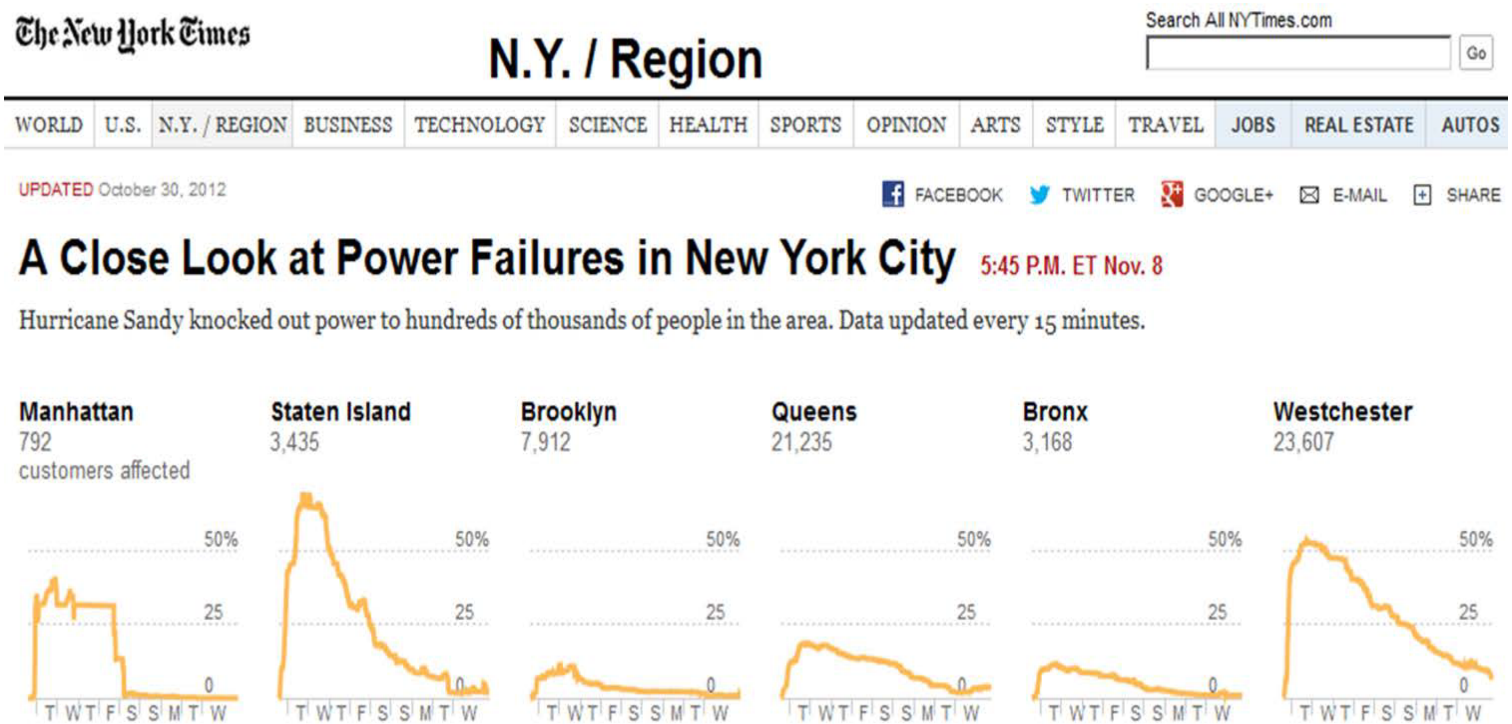
Emerging Energy Assurance Concerns



Electric Power Outage Intensity in the U.S.

Customers affected has increased by a factor of three per outage

Power Outages Can be Regionally Significant



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UPDATED October 30, 2012

FACEBOOK TWITTER GOOGLE+ E-MAIL SHARE

A Close Look at Power Failures in New York City 5:45 P.M. ET Nov. 8

Hurricane Sandy knocked out power to hundreds of thousands of people in the area. Data updated every 15 minutes.

Major outages are lasting for 5- 14 days, but these duration electric power **outages are not commonly designed for**

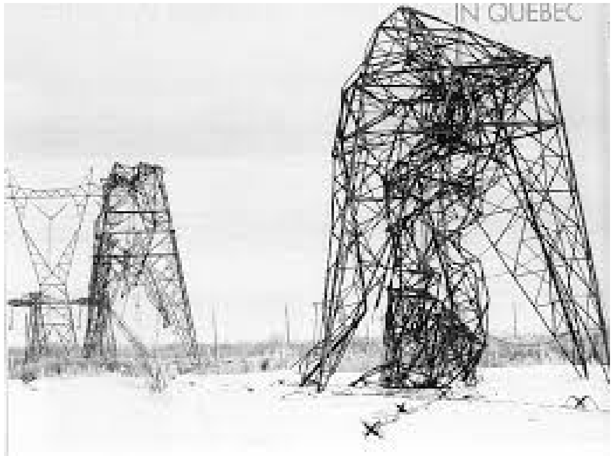
New Energy System Design Definitions

- Energy security
  - Public Law 112-81 - "*The term 'energy security' means having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet mission essential requirements.*"
- Mission assurance
  - Public Law 112-81 - *"..prioritized to provide power for assets critical to mission essential requirements on the installation in the event of a disruption.."*
  - DODD 3020.40 - Mission assurance*. "A process to protect or ensure the continued function and resilience of capabilities and assets—including personnel, equipment, facilities, networks, information and information systems, infrastructure, and supply chains—critical to the execution of DoD mission-essential functions in any operating environment or condition. "*
- Energy resilience
  - Presidential Policy Directive 21 - *"Resilience is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."*
  - Army new ES3 - "*Resilience: The capability for systems, installations, personnel and units to respond to unforeseen disruptions and quickly recover while continuing critical activities."*
  - DHS 2013 – *"Resilient infrastructure assets, systems, and networks must be robust, agile, and adaptable. <u>Mitigation, response, and recovery</u> activities contribute to strengthening critical infrastructure resilience."*

Electric Grid Assurance Strategies

Component Hardening (Protection)	Increase Component Redundancy (Mitigation)	Accelerate Outage Response (Response & Recovery)	Distributed Resources (Mitigation, Recovery)
Harden substations – guards, guns, gates, barriers	Redundant transmission lines	Real-time monitoring of substations and transmission lines	Distribution switch gear improvements to more easily move power around
Harden substation equipment	Redundant substations	Fast response, fast reconstruction	Local energy generation
Harden transmission and distribution lines	Increase connectivity	Maintain spares, extra equipment, pre-planned work around	Renewables and/or alternative fuels
High costs, events beyond design basis	High costs, regional outage issues	High costs, regional outage issues	Medium costs, outage duration issues

Energy Assurance Challenges



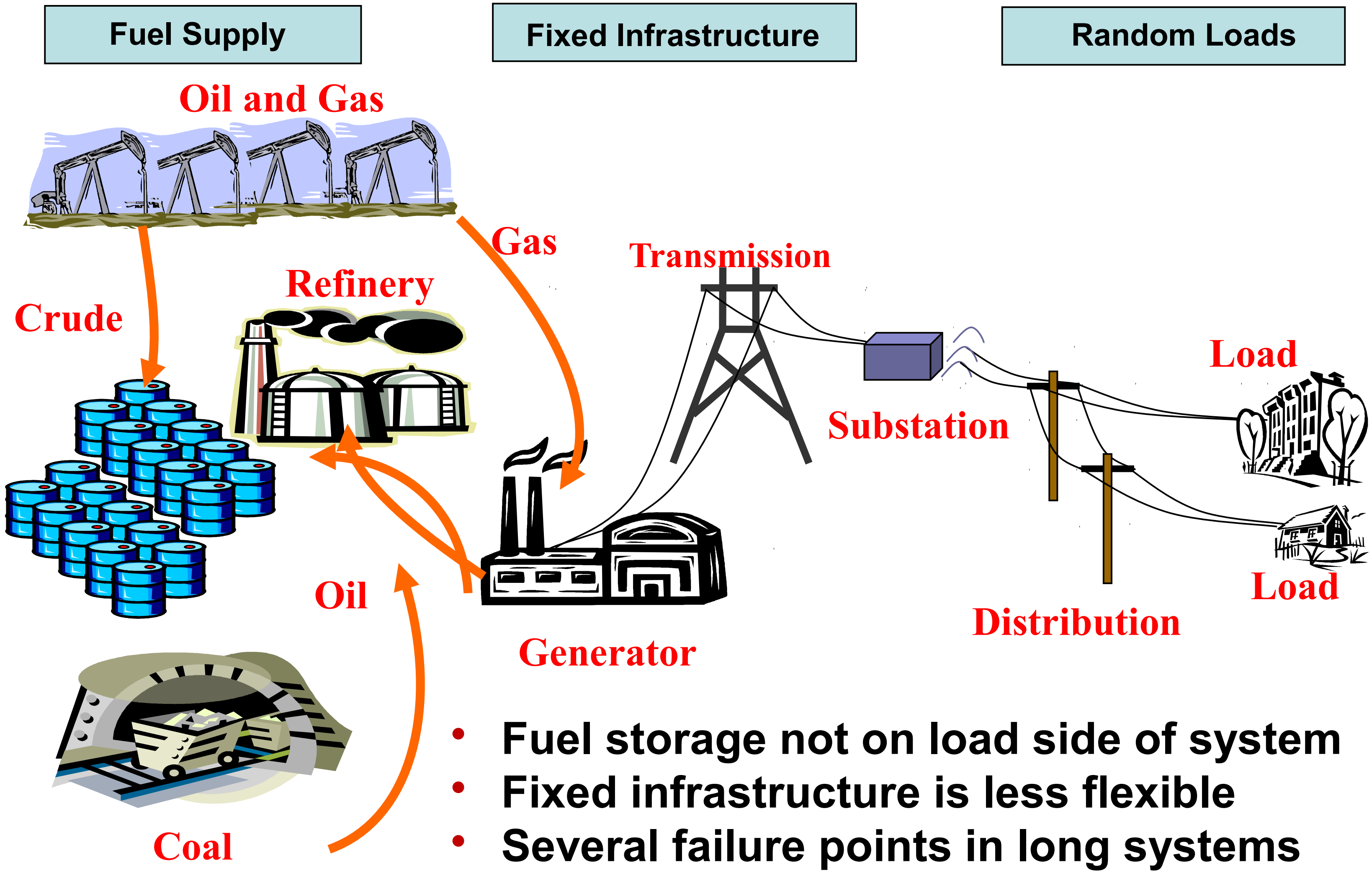
Energy Assurance Strategy Concerns

- Army base served by two feeders
- Hurricane takes out both feeders
- Base down for 16 hours
  - Est. cost $3M
  - Loss of mission capability

- Semiconductor plant served by two feeders
- Forest fire takes out both feeders
- Chip fab shuts down for 6 months
  - High-value customers cancel orders due to delay
  - Economic loss forces plant to shut down permanently

Regional outages, slow repair, remote locations impact options and costs

Today's Power Grid is Limited in the Ability to Easily Meet New Energy Assurance Requirements



- Fuel storage not on load side of system
- Fixed infrastructure is less flexible
- Several failure points in long systems

General attributes of the Smart Grid were defined in the Energy Independence and Security Act of 2007

"..which together characterize a Smart Grid:

(1) Increased use of digital information and control technology to improve <u>reliability, security</u>, and efficiency of the electric grid,

(2) Dynamic optimization of grid operations and resources, with <u>full cyber-security</u>,

(3) Deployment and integration of <u>distributed resources and generation</u>, including <u>renewable resources</u>,

(4) Development and incorporation of demand response, demand-side resources, and energy-efficiency resources,

(5) Deployment of "smart" technologies…for metering, communications concerning grid operations and status, and <u>distribution automation</u>

(6) ..smart appliances…

(7) …advanced electricity storage,

(8) ..consumer timely information and control options,

(9) Development of standards for communication and interoperability of … equipment connected to the grid, including the infrastructure serving the grid,

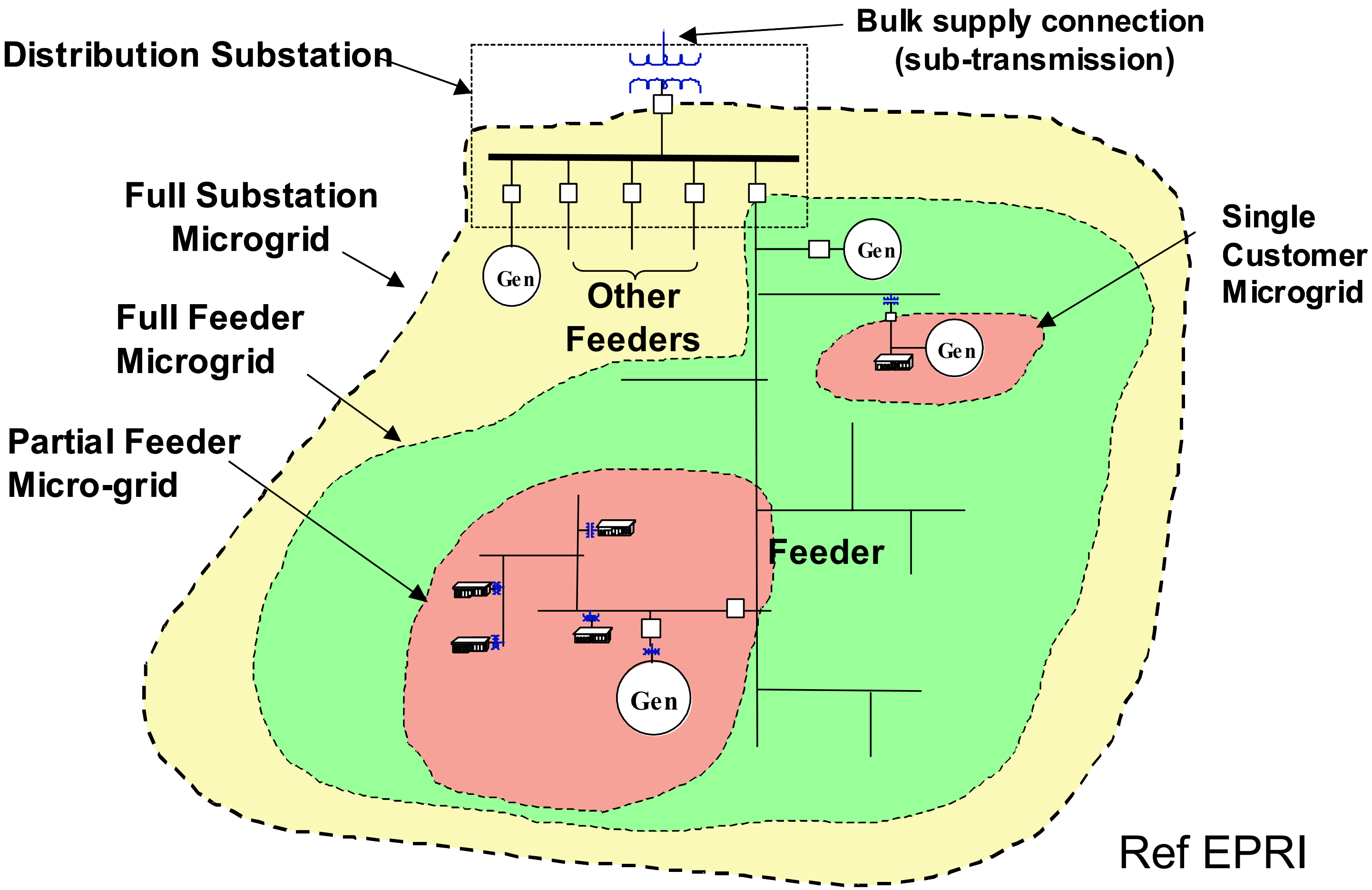
(10) Identification and lowering of unreasonable barriers to adoption of smart grid technologies, practices, and services."

Missing attributes of Safety and Cost Effectiveness

NYC After Tropical Storm Sandy

Energy assurance designs at work

Advanced Microgrids To Support Smart Grid Initiatives



Ref EPRI

Nanogrid	Less than 10-kW, single-phase, residential
Small microgrid	From 10-kW to 500-kW, typically three phase
Commercial microgrid	Greater than 1 MW up to 20MW

Mathematically - What is a microgrid?

Grid Definition	Generation Size	Commonly Considered Size	Common Attributes
U.S. Grid	~1 Tera watt (1x 10^{12} watts)		High to medium voltage, 12 kVa- 700 kVa
Microgrid	1 x 10^{-6} (US Grid) 1 x 10^{6} watts ~1 MW	1 MW-20 MW	Medium voltage 4 kVa - 34 kVa, three-phase, 4-20 buildings
Nanogrid	1 x 10^{-9} (US Grid) 1 x 10^{3} watts ~1 kW	1-200 kW	Low voltage 120/480 V, often single phase, 1-2 houses or buildings

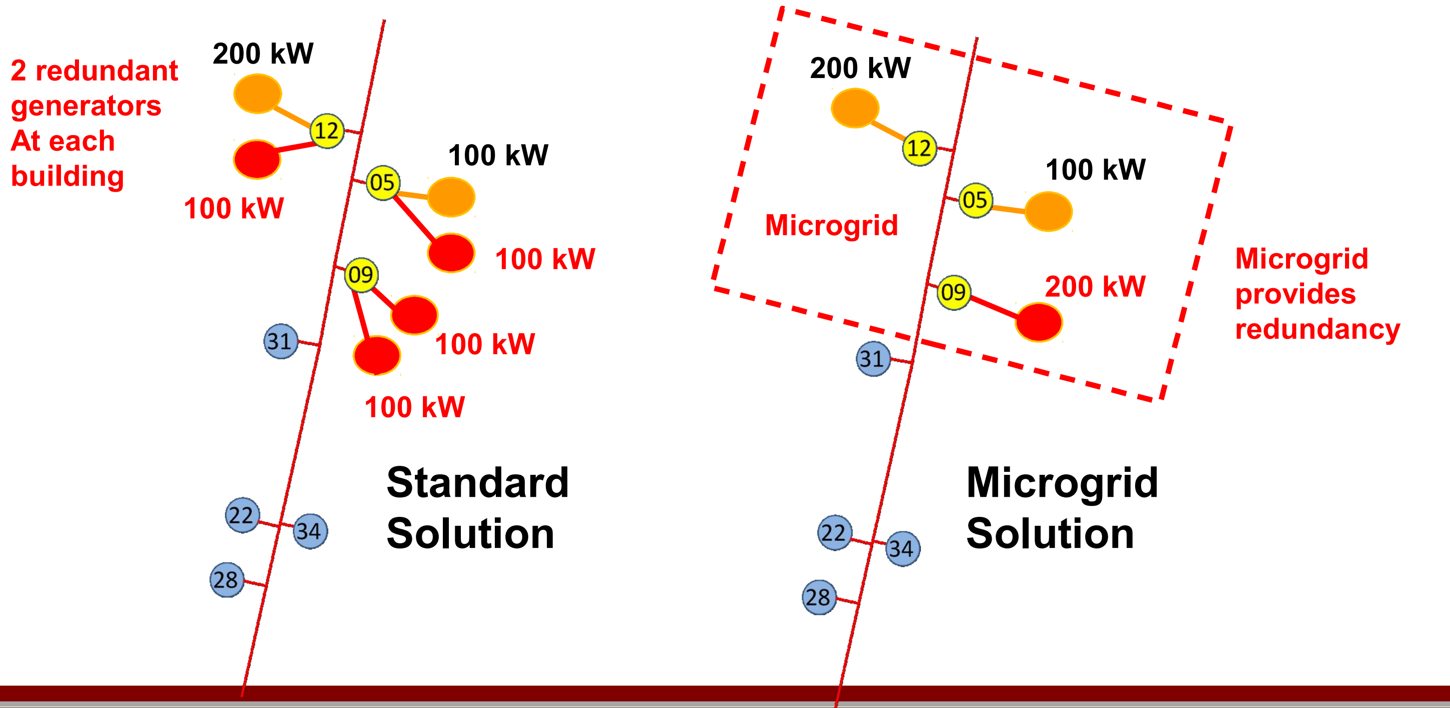
Functionality and Types of Microgrids

STANDARD MICROGRID	• Operates where there is no large grid or operates generally islanded from the larger grid • Often used with a central power plant or CCHP plant to balance power supplies and demand locally (universities, industries) • Minimal grid interaction or support
ADVANCED MICROGRID	• Can operate islanded or grid-tied • Can integrate distributed and renewable generation and manage and control power demand and distributed resource allocation • Supports optimal use of distributed energy resources during both power outages and for grid support
SMART GRID NODE	• Same functional capabilities as an advanced microgrid • Control capabilities to federate with other microgrids, if needed • Grid-tied operations are coordinated through the grid operator to support grid operations and performance, and provide ancillary benefits to the grid

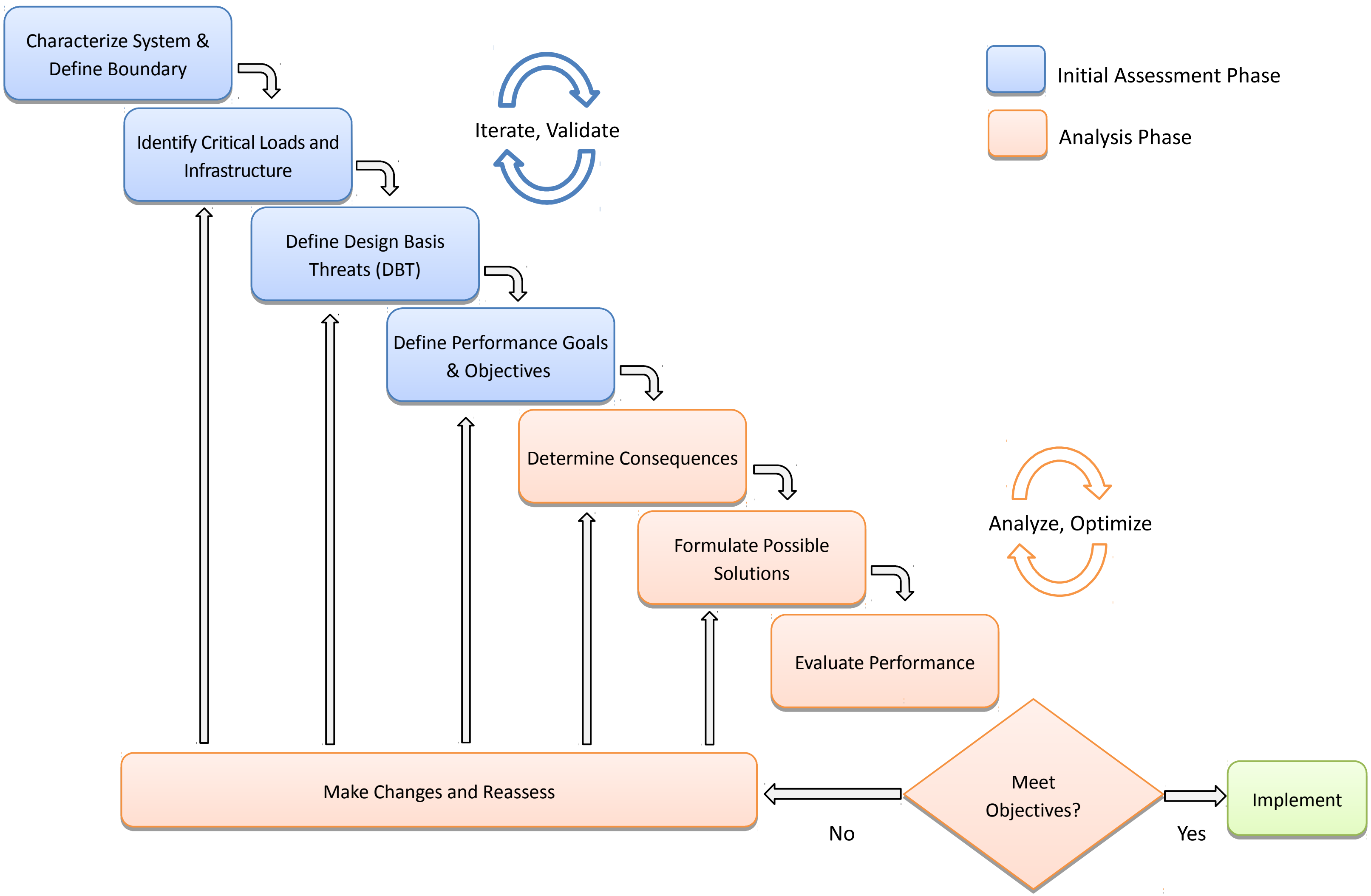
Advanced microgrids are the building blocks for Smart Grid Nodes, which in turn is one of the major power utility building blocks for the Smart Grid

How can Microgrids Help

- A standard solution (left) would require installing a minimum of two redundant generators at each building for redundant backup power or four new (red) 100 kW generators, each only supporting one building
- A microgrid solution would require only one new (red) 200 kW generator at one of the buildings for redundant power
  - Loss of any of the three generators would still be able to supply the 300 kW load required for the 3 buildings
  - The combined resources in a microgrid can be used to support the grid



Energy Surety Design Methodology



Example of Critical Municipal Services that Should be Considered

Municipal Controlled Services	Community Controlled Services
Communications (Radio and Phone)	Telecommunications (cell towers)
Data Service / Internet	Community media (radio)
Local Emergency Response Coordination	Existing shelters - heat/cold
Regional E/R Coordination	Hospitals
Civil order	Assisted living services
Road Clearing / Management	Pharmacies/Medication supply
Equipment maintenance	Fuel (Natural Gas / propane / Gasoline / Diesel)
Emergency Services	Food / provisions
Potable Water	
Waste Water	
Flood Control	
Temporary Housing / Shelters	
Safety systems (lighting etc.)	

Example Stakeholder Rankings of Critical Assets Needed for a 2-day and a 5-day Power Outage

Asset	Building or Asset Name	Group A	Group B	Group C
1	Public Works Garage			
2	Fire Department - HQ			
3	Police Department - HQ			
4	WTP + Low Lift Pump			
5	WWTP			
6	Radio Towers and System: Fire/Police			
7	High School (Emergency Shelter)			
8	WWTP Flood Control System			
9	Flood Control - Remote Sewer Pump System			
10	Municipal Building			
11	Food and Gas			
12	Fuel Company			
13	Cell Towers			

Building additions for a 5-day outage

Note: Stakeholders have different views of critical functions

Smart Grid Thoughts and Directions

- Better integration of neighborhood distributed generation and demand response into microgrids
  - Roof top solar, smart meters, pricing benefits
- Integration/networking of neighborhood microgrids to support regional energy assurance
  - 20-30 Smart Grid Nodes
- More focus on resilient critical circuits, critical services, critical infrastructures in homes, businesses, and communities
- Grid designs will transition to support faster recovery rather than focus on standard hardening and standard redundancy