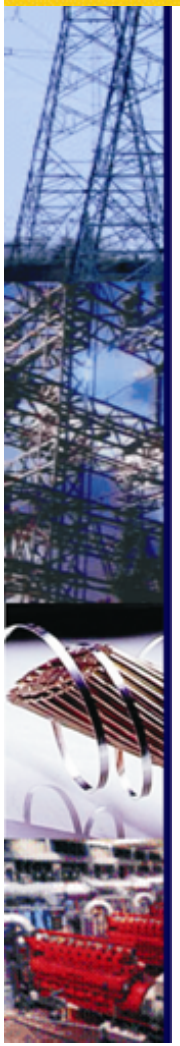
U.S. Department of Energy

Office of Electricity Delivery and Energy Reliability



Jeju 2011
Symposium on Microgrids

U.S. Department of Energy's Research & Development Activities on Microgrid Technologies

Merrill Smith

Program Manager

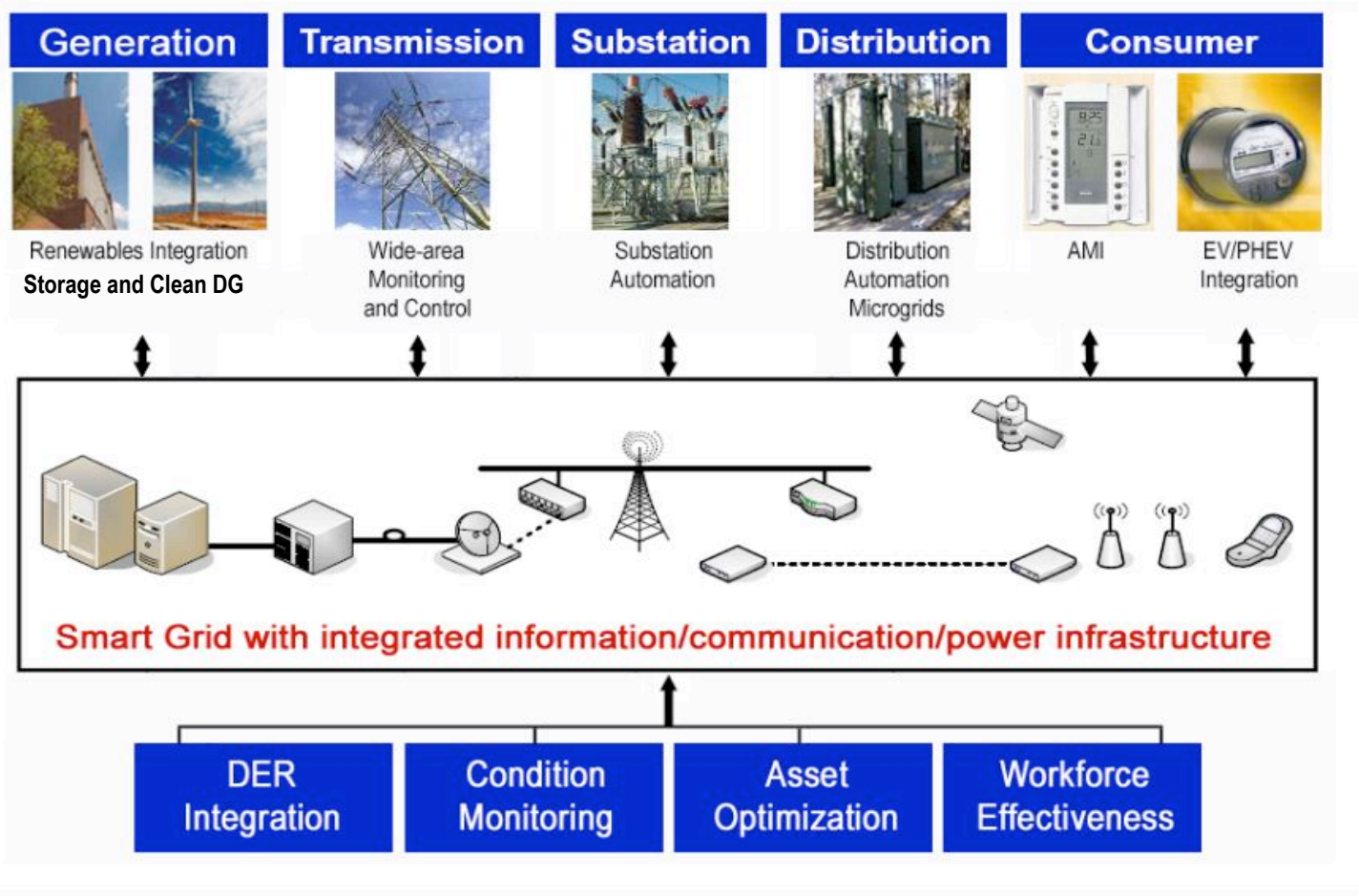
Office of Electricity Delivery and Energy Reliability

May 26-27, 2011

Electric Grid Trends and DOE Goals

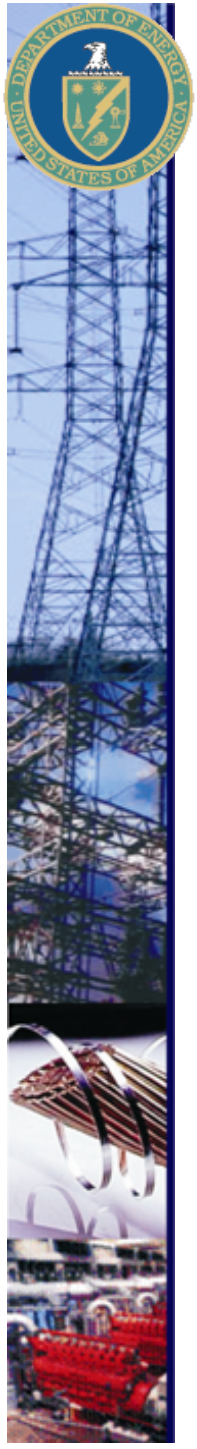
Grid Modernization Enabled Through a Smart Grid Platform

- Physical infrastructure that measures or monitors data
- Information collected from sensors used for timely decision making
- Enables communication to entire energy supply chain
- Applications that create electrical system or societal value



Defining Microgrids

Microgrid Definition	Key Attributes
A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.	1. Grouping of interconnected loads and distributed energy resources 2. Can operate in both island mode or grid-connected 3. Can connect and disconnect from the grid 4. Acts as a single controllable entity to the grid

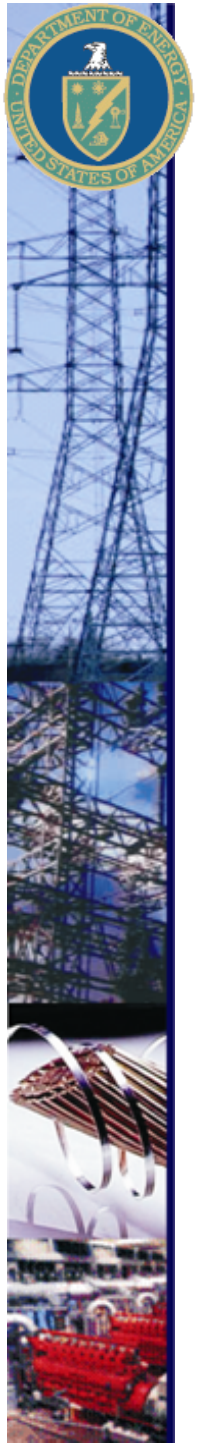


Microgrid Benefits

- Enables Grid Modernization
  - Key component of grid modernization
  - Enables integration of multiple Smart Grid technologies
- Enhance the integration of DER
  - Facilities integration of combined heat and power (CHP)
  - Promotes energy efficiency and reduces losses by locating generation near demand
  - Potential to reduce large capital investments by meeting increased consumption with locally generated power. (Local generation lowers investment in the macrogrid)
  - Encourages third-party investment in the local grid and power supply
  - Potential to reduce peak load

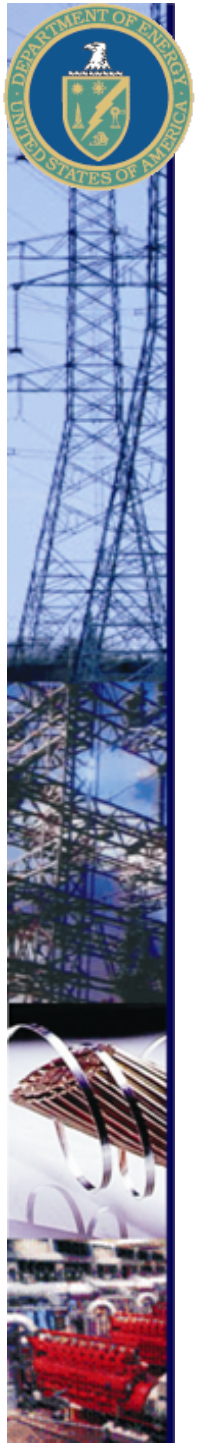
Microgrid Benefits cont'd

- Meets End User Needs
  - Ensure energy supply for critical loads.
  - Power quality and reliability controlled at the local level
  - Promotes demand-side management and load leveling
  - Promotes community energy independence and allows for community involvement in electricity supply.
  - Designed to meet local needs and increase customer (end-use) participation
- Supports the Macrogrid
  - Enables a more flexible macrogrid by handling sensitive loads and the variability of renewables locally
  - Enhances the integration of distributed and renewable energy resources including CHP
  - Potential to supply ancillary services to the bulk power system
  - Potential to lower carbon footprint by maximizing clean local generation
  - Potential to resolve voltage regulation or overload issues

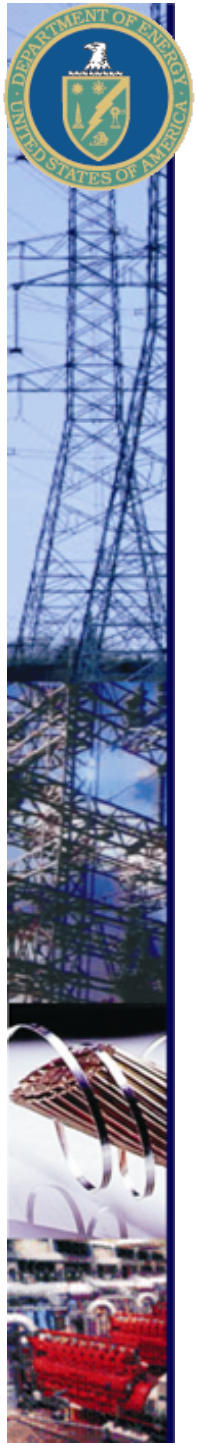


How Was the Definition Developed?

- Microgrid Exchange Group (MEG)
- Members: experts and implementers of microgrid technologies
- Purpose: informational exchange about microgrid technology and its implementation
- Examples of Topic Discussions
  - NIST Interoperability Standards
  - Microgrid Project Presentations
  - Microgrid Definition Development
  - Tour of Microgrid Project
  - Microgrid Switch Selection



Microgrid Research and Development



Microgrid Design, Testing, Demonstration, & Analysis

CERTS Microgrids Testing

- Seamless islanding and reconnection
- Autonomous local control
- Plug-and-play; no custom engineering
- Test the above features with integration of distributed renewable sources at the AEP Microgrid Test Bed

Energy Surety Microgrids Conceptual Designs

- Develop conceptual microgrid designs to meet military base mission critical needs
- Cost share development with military installations
- Incorporating safety, security, reliability, sustainability, and cost effectiveness

Analysis of Microgrids Performance

- Optimize & analyze the economic-environmental performance of microgrids
- Conduct policy analysis and market assessments
- Develop control tools
- Test tools in demonstrations
- Apply optimization methods

SPIDERS Joint Capability Technology Demonstration

- Cyber-security of electric grid
- Smart Grid technologies & applications
- Islanded microgrid
- Renewable integration
- Demand-side management
- Redundant back-up power systems

Microgrids Didn't Happen Overnight

- Article Published this month

  Why Two Grids Can Be Better Than One –
  How the CERTS Microgrid Evolved from Concept to Practice

- Details long history of CERTS microgrid development funded by DOE and others started in 1999


Why Two Grids Can Be Better Than One –
How the CERTS Microgrid Evolved from Concept to Practice
By Elizabeth McGowan
Contractor to the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability

Don't let the diminutive name fool you. A microgrid might sound like a tiny achievement. But designing an affordable, reliable integrated power system that can seamlessly isolate from the nation's electric grid during a blackout or a voltage excursion — and then reconnect just as smoothly — is no small feat.

And as the case with any bouncy and bouncy idea, the microgrid

guidance in the late 1990s. What started as a conversation about maximizing distributed generation to relieve stress on an aging grid has evolved into cutting-edge applications

envision limitless industrial and commercial

"Our philosophy is that when a technology such as the microgrid is ready for prime time, you need to get it out there and test it. That's part of the value added by the Department of Energy."
Steve Walls, Senior program manager

to say we bring good ideas to life," DOE senior program

Steve Walls said about the government's key role in guiding technologies such as microgrids from the laboratory to the marketplace. "Our philosophy is that when a technology such as the microgrid is ready for prime time, you need to get it out there and test it. That's part of the value added by the Department of Energy."

After years of thorough research, DOE has recently started providing funding to utilities, universities, and industry for deploying microgrid technology in school districts, universities, jails, hospitals, laboratories, military bases, industrial parks and a variety of businesses nationwide.

For instance, Chevron Energy Solutions is collaborating with several partners to deploy a microgrid at the Santa Rita Jail in Alameda County, California. And, a California public power utility will begin testing what it calls a full-fledged microgrid at its corporate headquarters in spring 2011.

The Sacramento Municipal Utility District (SMUD), a longtime pioneer with advanced technologies, will be operating a 3 MW natural gas fuel cell and a 100-kilowatt photovoltaic system. The project will also integrate storage technology – a 500kW zinc bromine flow battery manufactured by Premium Power Corporation. SMUD's system is based on DOE and California Energy Commission research and development on microgrid control technologies.

Not Just Any Microgrid

Those initial meetings at the Energy Department mentioned above led to the 1999 creation of a microgrid research and development team. Funding for this R&D effort, called the Consortium for Electric Reliability Technology Solutions, came from DOE's Office of Electricity Delivery and Energy Reliability and the California Energy Commission's Public Interest Energy Research program.

"We're helping to advance an industry that will save consumers money, ensure a more reliable grid, and protect the environment."

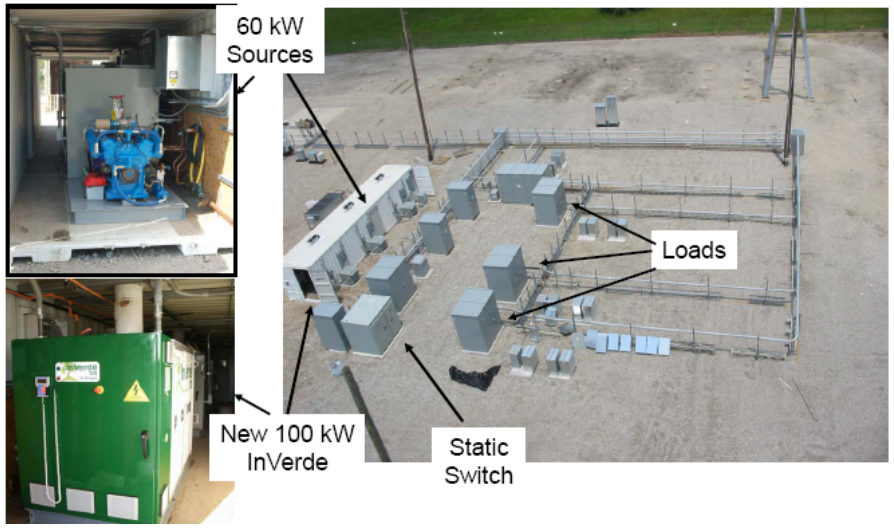
Joe Eto, Lawrence Berkley National Lab

http://www.oe.energy.gov/DocumentsandMedia/CERTS_Article_May2011.pdf

CERTS Microgrid – Test Bed

Objective

Expand CERTS Microgrid concepts to address system integration challenges presented by need to accommodate intermittent, distributed renewable electricity sources within utility distribution systems



Technical Scope

The CERTS Microgrid Test Bed is being expanded through the addition of new hardware elements: 1) a PV emulator and inverter; 2) a more flexible energy management system for dispatch; 3) a commercially available, stand-alone electricity storage device with CERTS controls; 4) a CERTS compatible conventional synchronous generator.

Design Characteristics

Designed for high reliability

- Insures redundancy: n + 1 sources.
- Based on autonomous local control for fast events (No central controller)
- Maximizes flexibility: uses plug-and-play peer-to-peer models; no custom engineering

Promotes intentional islanding

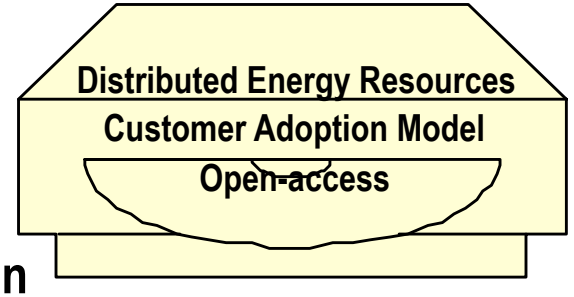
- Insures stability for multi-sourced systems.
- Seamlessly separates and automatically resynchronizes with the grid.

CERTS Test Bed
Results in Products and Projects

Inverter –Based CHP

Microgrid compatible with licensed CERTS power balancing control software

DER-CAM



Commercial Product

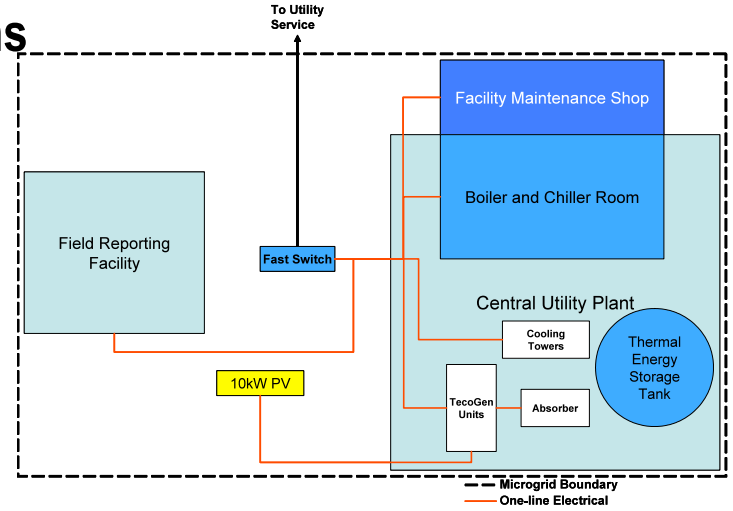
Optimization Software

CERTS Microgrid Test Bed

Microgrid Demonstrations

Santa Rita Jail

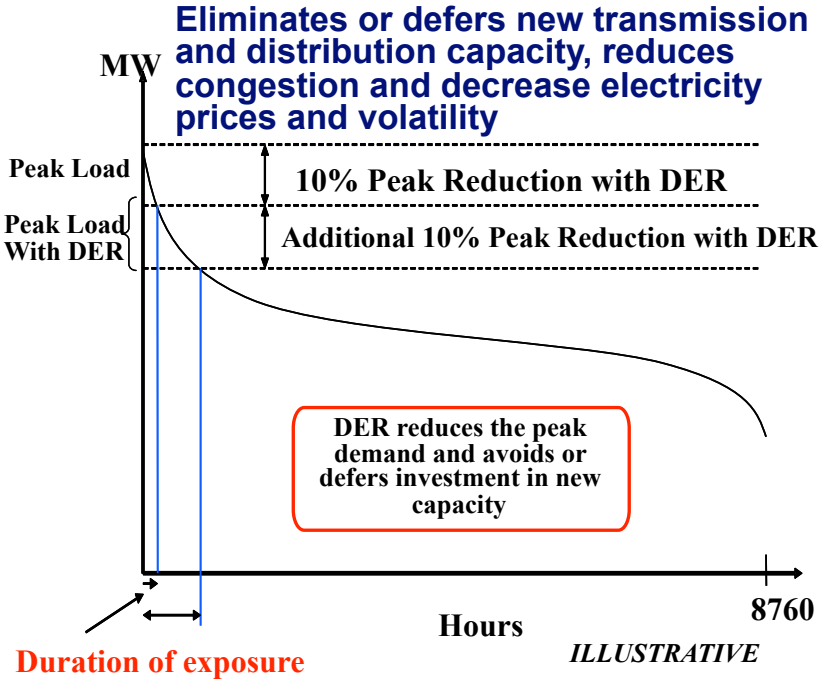
SMUD Headquarters



Renewable and Distributed Systems Integration (RDSI)

9 RDSI demonstration projects

- Demonstrate use of distributed resources to achieve a minimum of 15% peak load reduction on distribution feeder or substation
- Projects are either microgrids or are developing technologies that will advance microgrids



Hawaii Clean Energy Initiative

- Apply dynamic simulation model to assess Maui bio-fuels scenarios for dispatchable renewable power
- Provide technical assistance on design, selection, and implementation of energy storage projects
- Conduct Lanai island-wide interconnection study focusing on new PV installations
- Develop steady-state and transient models for PV system to analyze PV system integration
- Leverage resources to support the Hawaii-Okinawa Smart Grid Demonstration project for PV/PEV integration

RDSI Projects

Over halve of these demos will have equipment installed and operating by the end of 2011

- **Chevron Energy Solutions**—CERTS Microgrid Demo at the Santa Rita Jail - large-scale energy storage, PV, fuel cell
- **SDG&E**—Borrego Springs - demand response, storage, outage management system, automated distribution control, AMI
- **U of HI**—Transmission Congestion Relief, Maui - intermittency management system, demand response, wind turbines, dynamic simulations modeling
- **UNLV**—"Hybrid" Homes - Dramatic Residential Demand Reduction in the Desert Southwest - PV, advanced meters, in-home dashboard, automated demand response, storage
- **ATK** Space System—Powering a Defense Company with Renewables - Hydro-turbines, compressed air storage, solar thermal, wind turbines, waste heat recovery system
- **City of Fort Collins**—Mixed Distributed Resources - PV, bio-fuel CHP, thermal storage, fuel cell, microturbines, PHEV, demand response

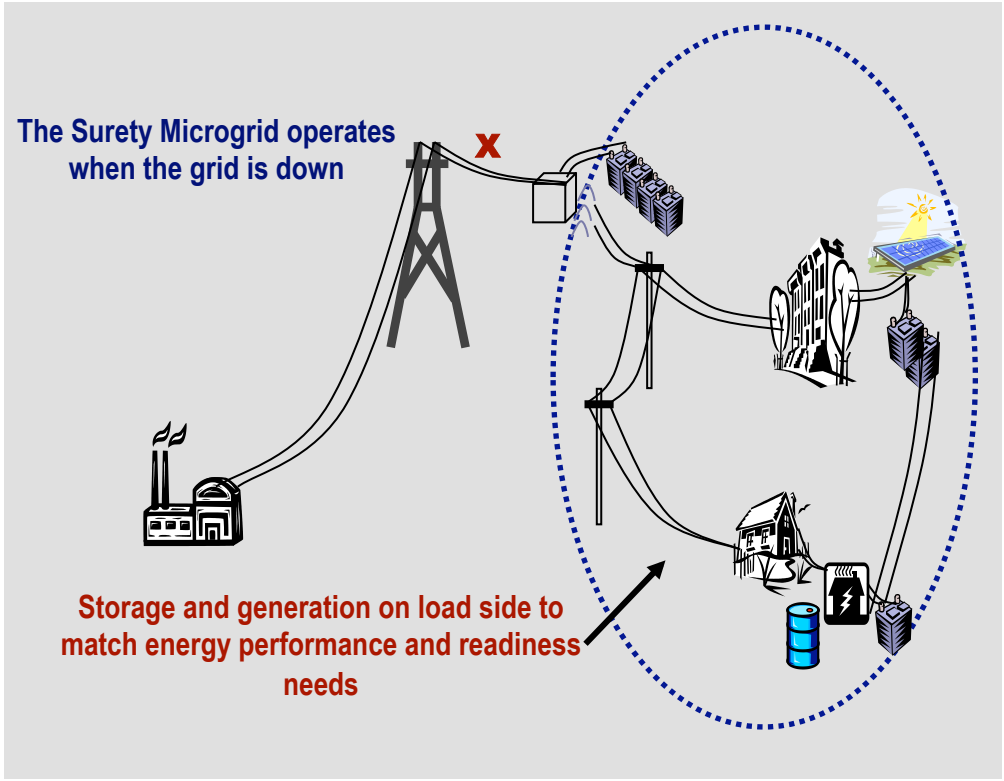
- **Illinois Institute of Technology**—The Perfect Power Prototype - advanced meters, intelligent system controller, gas fired generators, demand response controller, uninterruptable power supply, energy storage
- **Allegheny Power**—WV Super Circuit Demonstrating the Reliability Benefits of Dynamic Feeder Reconfiguration - biodiesel combustion engine, microturbine, PV, energy storage, advanced wireless communications, dynamic feeder reconfiguration
- **ConEd**—Interoperability of Demand Response Resources - demand response, PHEVs, fuel cell, combustion engines, intelligent islanding, dynamic reconfiguration, and fault isolation

Energy Surety Microgrids

- DOE and DOD jointly fund Sandia National Laboratory to work with military bases to develop energy surety microgrid conceptual designs
  - Electric Power Reliability Impacts Mission Performance
  - Microgrids can improve mission readiness and alleviate disruptions
- Approach and Benefits

– Identify base energy infrastructure changes to increase energy supply reliability to support base critical mission readiness

– Supports base energy security by improving utilization of on-site distributed generation resources and supports integration of renewables



Energy Surety Microgrids

DOE and DOD jointly fund Sandia National Laboratory to work with military bases to develop energy surety microgrid conceptual designs.

<u>2011 Activities</u>

- Document Lessons Learned to benefit other bases considering microgrids
- Continue and complete additional conceptual designs for military facilities
- Develop tools (sensors and models) for greenhouse gas benefits for post-ESM installation

- Army - Ft Sill, Ft. Bliss, Ft. Belvoir, Ft. Devens, Ft. Carson, IMCOM exploring 2 additional
- Navy/Marines - Indian Head, Camp Smith, Guam/Okinawa potential
- Air Force – Maxwell, Kirtland, Schriever, Vandenberg

SPIDERS= Smart Power Infrastructure Demonstration for Energy Reliability and Security

- Technically sound, commercially viable secure microgrid demonstration with mixed generation including renewables
- First complete DoD installation with a secure, smart microgrid capable of islanding
- Template for mission critical asset energy security for an entire installation and transition to commercial use

STAIRWAY TO ENERGY SECURE INSTALLATIONS

FY 11

HICKAM AFB CIRCUIT LEVEL DEMO
- Renewables
- Hydrogen Storage
- Hydrogen Fuel Cell
- Energy Management
- VSE SCADA Test at Idaho Lab

FY 12

FT CARSON MICROGRID
- Large Scale Renewables
- Vehicle-to-Grid
- Smart Micro-Grid
- Critical Assets
- CONUS Homeland Defense Demo
- COOP Exercise

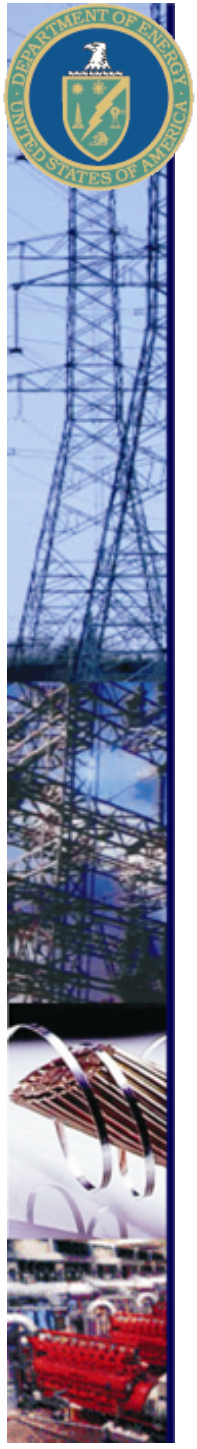
FY 13

CAMP SMITH ENERGY ISLAND
- Entire Installation Smart Micro-Grid
- Islanded Installation
- High Penetration of Renewables
- Demand-Side Management
- Redundant Backup Power
- Makana Pahili Hurricane Exercise

TRANSITION
- Template for DoD-wide implementation
- CONOPS
- TTPs
- Training Plans
- DoD Adds Specs to GSA Schedule
- Transition to Commercial Sector
- Transition Cyber-Security to Federal Sector and Utilities

CYBER-SECURITY SYSTEMS IMPLEMENTED

RIGOROUS ASSESSMENT WITH RED TEAMING IN EACH PHASE



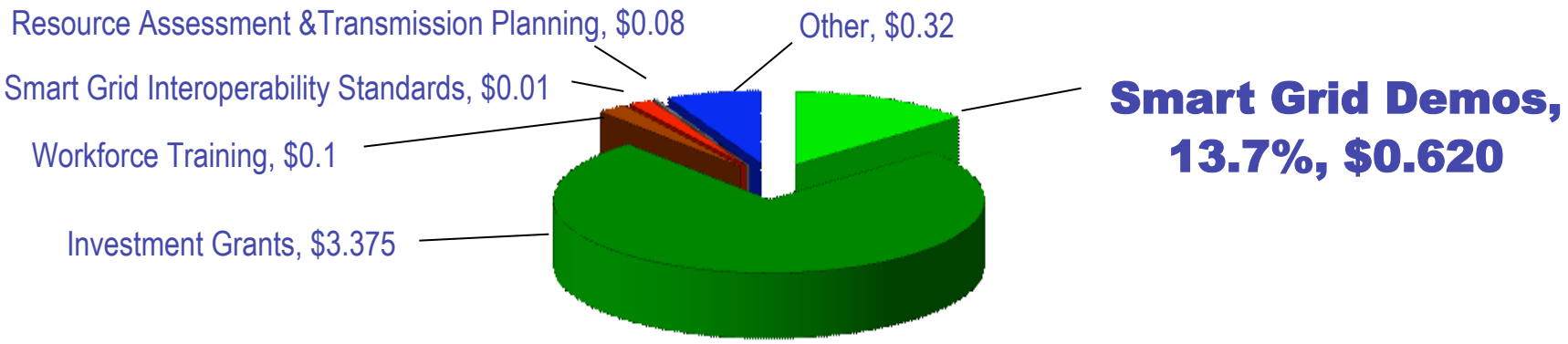
Spiders Results to Date

- Phase 1 Pearl Harbor-Hickam preliminary design nearly completed
- Conceptual designs for Ft.Carson and Camp Smith in progress
- Army TARDEC awarded $1.5M contract for five Smith electric vehicles and charging stations for Ft. Carson
- Completed initial experiment of cyber strategy
- Issued Request for Information (RFI), and held two industry days

American Recovery and Reinvestment Act

Smart Grid Demonstration Program

Results and findings from Smart Grid Demonstrations may be applicable to microgrids



$4.5 Billion for Electricity Delivery

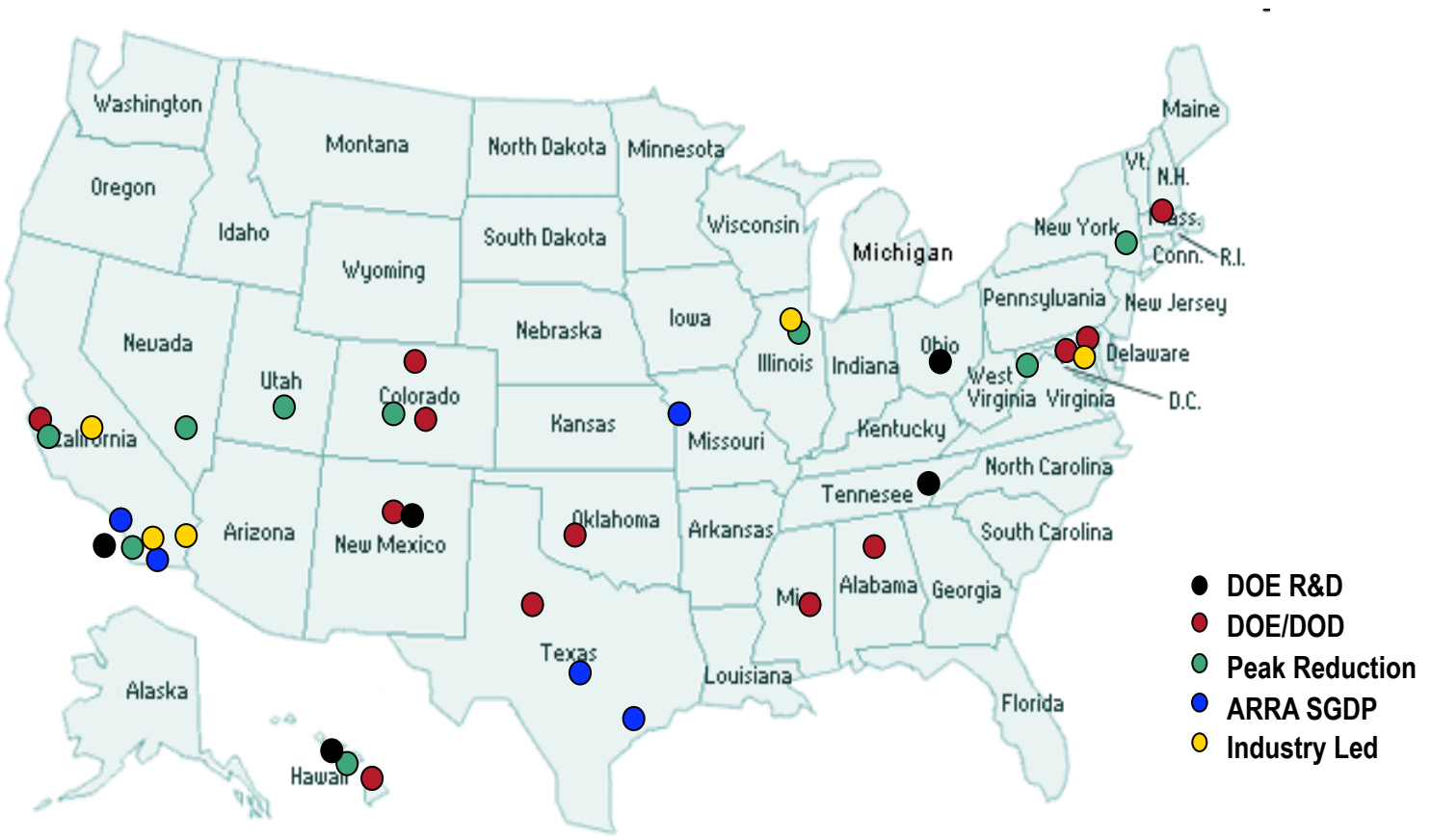
- 32 Demonstration Projects/$620 million
- Projects include
  - large-scale energy storage
  - Distributed generation and renewables
  - smart meters and other customer devices
  - distribution and transmission system monitoring devices,
  - range of other smart technologies, and will act as models for deploying integrated Smart Grid systems on a broader scale
- Demonstrate advanced Smart Grid technologies and integrated systems to build a smarter, more efficient, more resilient electrical grid

ARRA Smart Grid Demonstration Projects Microgrid Technologies

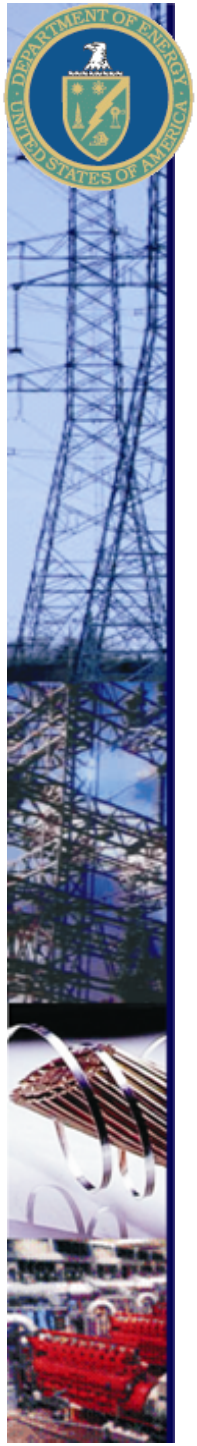
- **Los Angeles Dept of Water and Power**—Fully integrated SG – demand response, consumer energy use data/behavioral studies, PHEV
- **Kansas City Power and Light**—Green Impact Zone – urban end to end SG, roof-top solar, storage, EV charging, distribution automation, customer programs and energy management interfaces
- **Pecan Street Project**—Brownfield redevelopment – mixed use development with green building initiatives, EV charging and V-2-G, PV, customer energy management, distribution optimization
- **Center for Commercialization of Electric Technologies**—Technology Solutions for Wind Integration and Texas Future Community – community energy storage, demand response programs, load interruptible appliances smart meters, residential PV, green building standards, EV charging
- **Southern California Edison**—Irvine Smart Grid Demo – end to end SG from transmission to customer devices, looped distribution topology, societal/environmental efficiencies

- **AEP**—Fully integrated SG including new distribution management system, Integrated Volt-VAR control, Distribution Automation, AMI, Home Area Network, Community Energy Storage, NaSu Battery, Renewable Generation

Current Microgrid Landscape

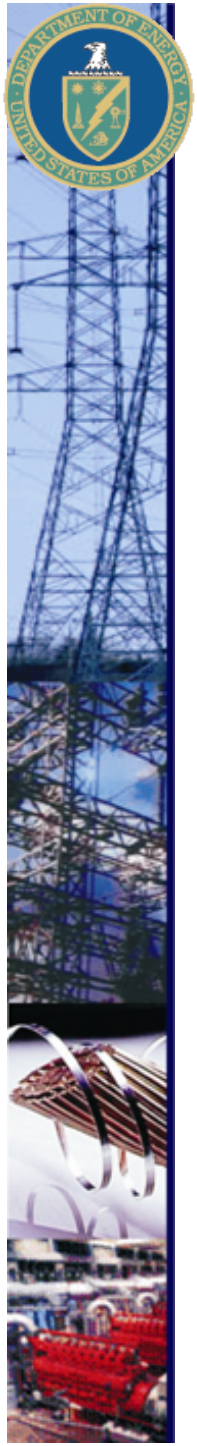


Federal programs, institutions, and the private sector are increasing microgrid development and deployment. The number of successfully deployed microgrids will verify the benefits and decrease implementation risks further expanding the market for microgrids.



Future Plans

- Continue ongoing demonstrations and data collection to quantify benefits
- 2011 Solicitation for Smart Grid capable Electric Vehicle equipment for smart charging
- 2011 Workshop on Microgrid Development (goal setting and technology development pathways)
- 2012 Solicitation to support Microgrid workshop findings



Information Sources

Office of Electricity Delivery and Energy Reliability
http://www.oe.energy.gov

Smart Grid
http://www.smartgrid.gov

Sandia National Laboratory – Energy Systems
http://www.sandia.gov/ERN/fuel-water/index.html

Microgrids at Berkley Lab
http://der.lbl.gov/