U.S. DEPARTMENT OF ENERGY

NETL-RUA Grid Technologies Collaborative 2013 National Conference

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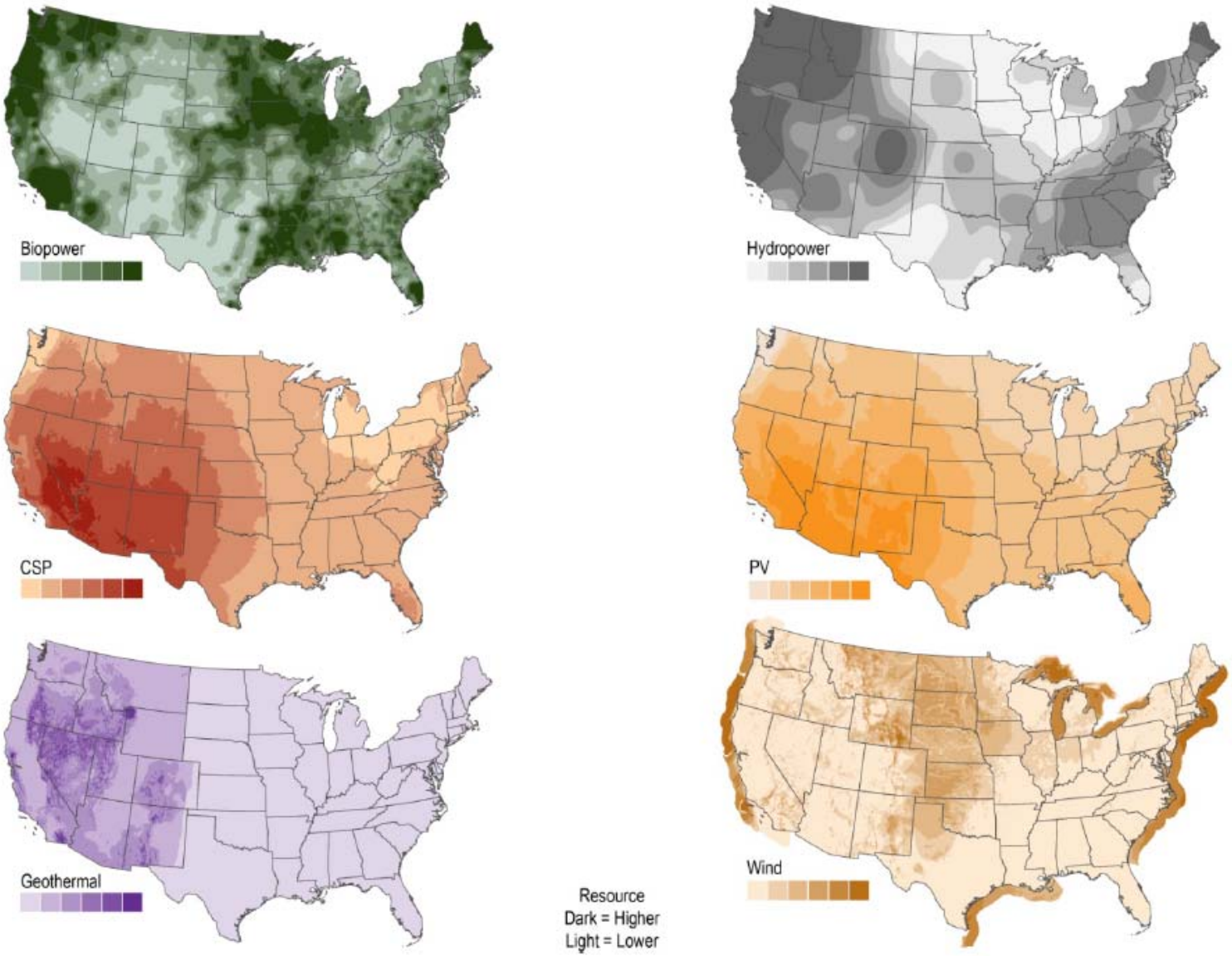
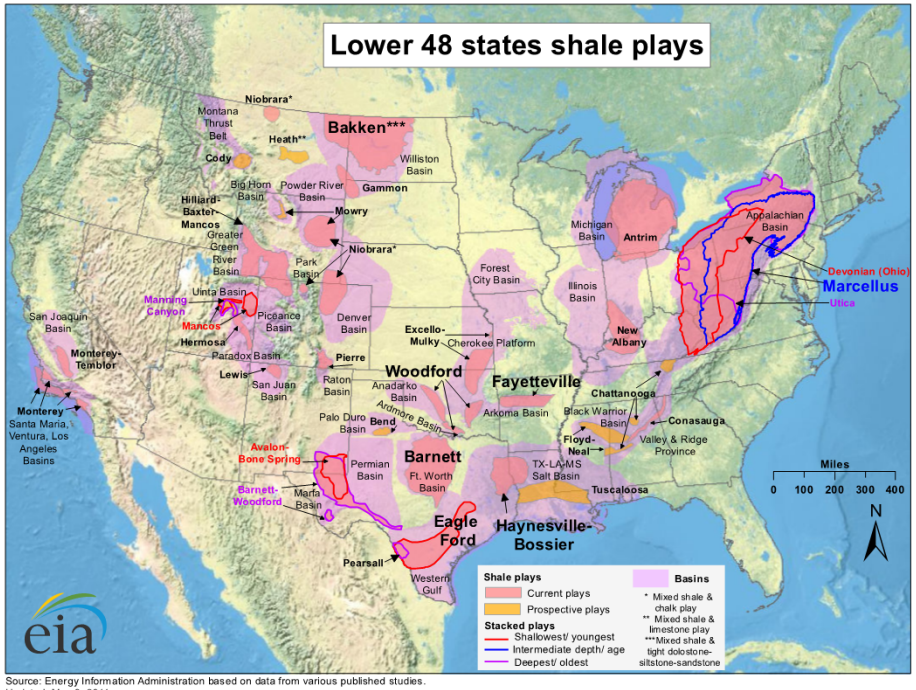
U.S. Department of Energy

www.OE.energy.gov

Geographical Distribution of Renewable Resources



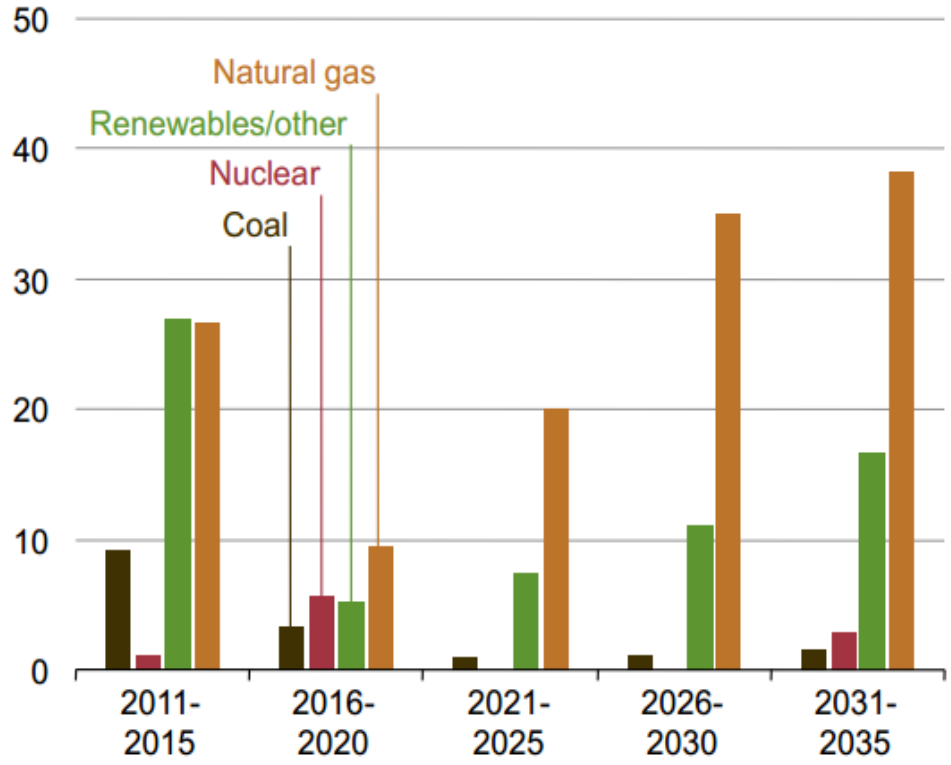
Source: NREL
http://www.nrel.gov/docs/fy13osti/52409-ES.pdf



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

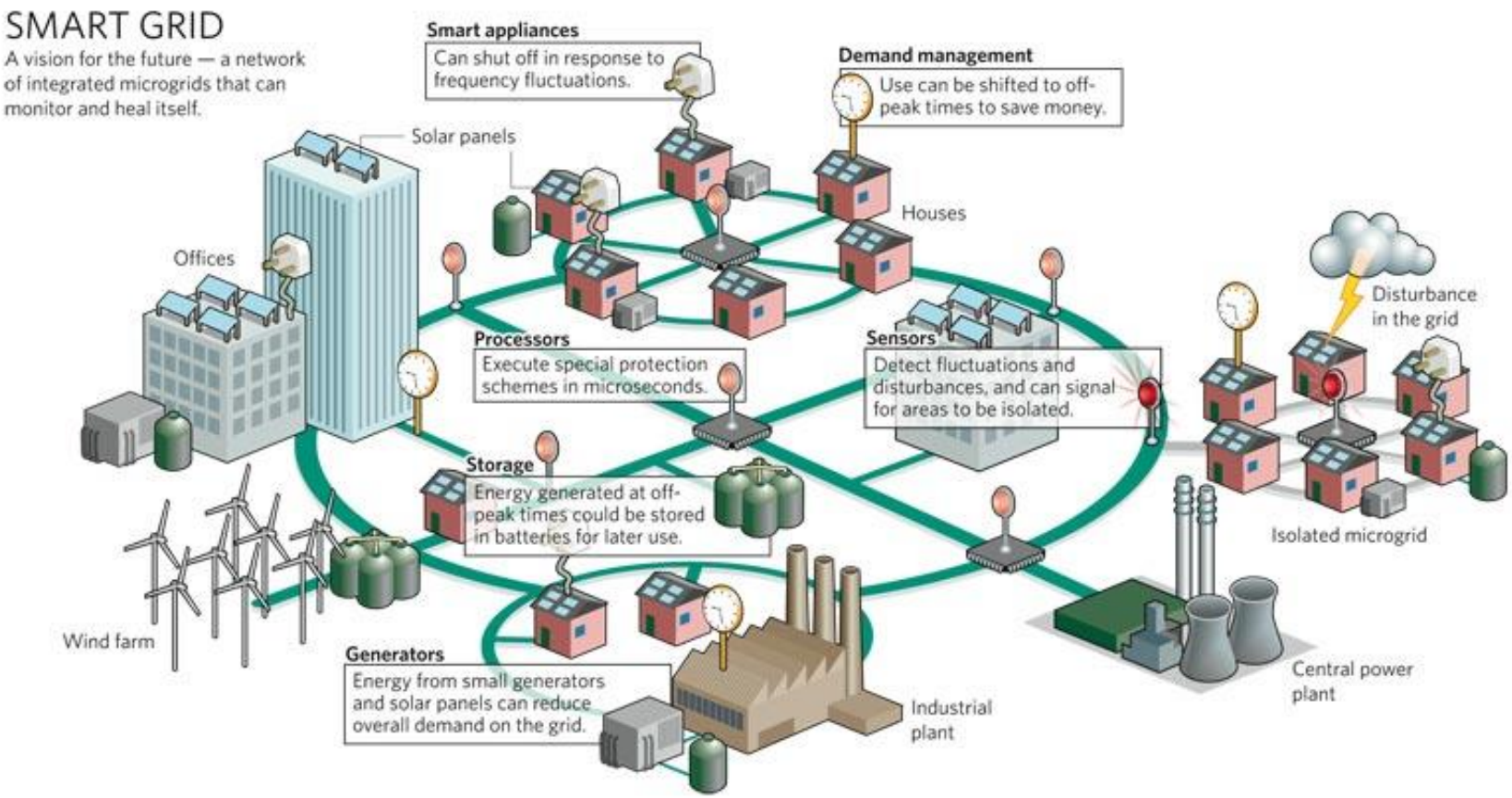
Most new capacity additions use natural gas and renewables

Figure 95. Electricity generation capacity additions by fuel type, including combined heat and power, 2011-2035 (gigawatts)



Source: EIA Annual Energy Outlook 2012

Grid Modernization Strategy: Advancing the Grid as a Whole, Not Just Parts of the System



Adapted from http://www.consumerenergyreport.com/wp-content/uploads/2010/04/smartgrid.jpg

Strategy

Advance Grid Functionality/flexibility AND Build in security and resiliency

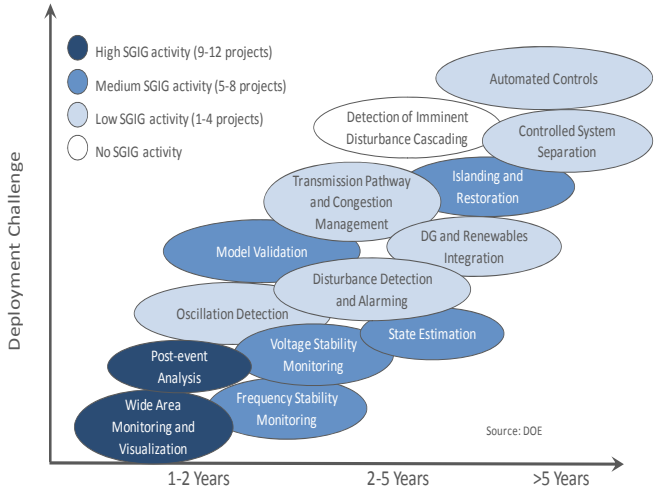
Systems	Now	Near-term	Long-Term
Generation	Coal, Natural Gas, Nuclear, Central	Dash to Gas Generation	Balance central/distributed Optimized Generation
Transmission	System monitoring by based on limited parameters	Sensor-based monitoring by operators (ARRA) Transmission – difficult to build	Expanded Contingency Analysis Clear justification of Transmission and who benefits
Distribution	Utilities perform operations – limited functionality	Real-time tools to improve reliability and system efficiency-more predictive (ARRA)	Integration of PEVs, real-time operations and dynamic reconfiguration and protection-ability to microgrid or create an active distribution system
Customer	Some demand-response programs, especially among commercial and industrial customers; most residential customers on fixed rates	All customers being offered a variety of technologies and pricing policies to better establish demand-side management practices (ARRA)	Customers are partners with utilities in the management of electricity.

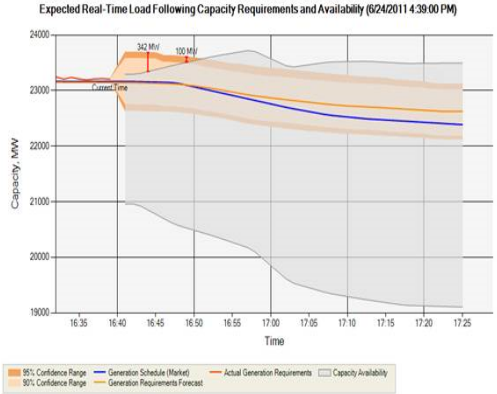
ARRA- American Recovery and Reinvestment Act

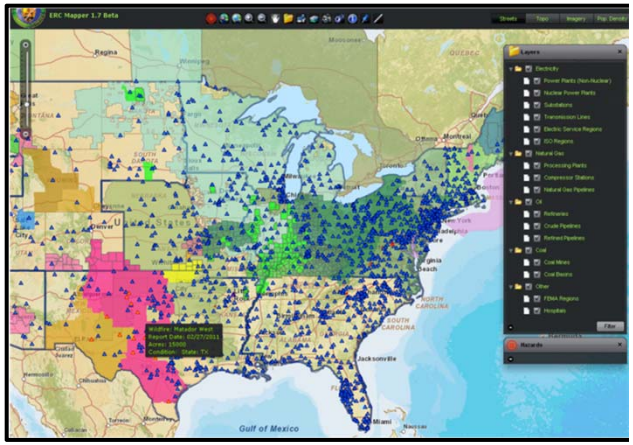
Grid Modeling and Energy Analytics

- Modeling and Simulation for Emergency Response and Restoration (Energy Resiliency and Risk Analysis
  - Energy Risk “Criticality” Analysis Project
  - Expand Eagle- I’s Capability
- Predictive Modeling and Controls for Cascading Events (System Dynamics)
  - Synchrophasor (visualization, operator tools and next generation EMS)
  - Implement recommendations from the 2003 and 2011 Blackouts.
- Energy Reliability Assessments.

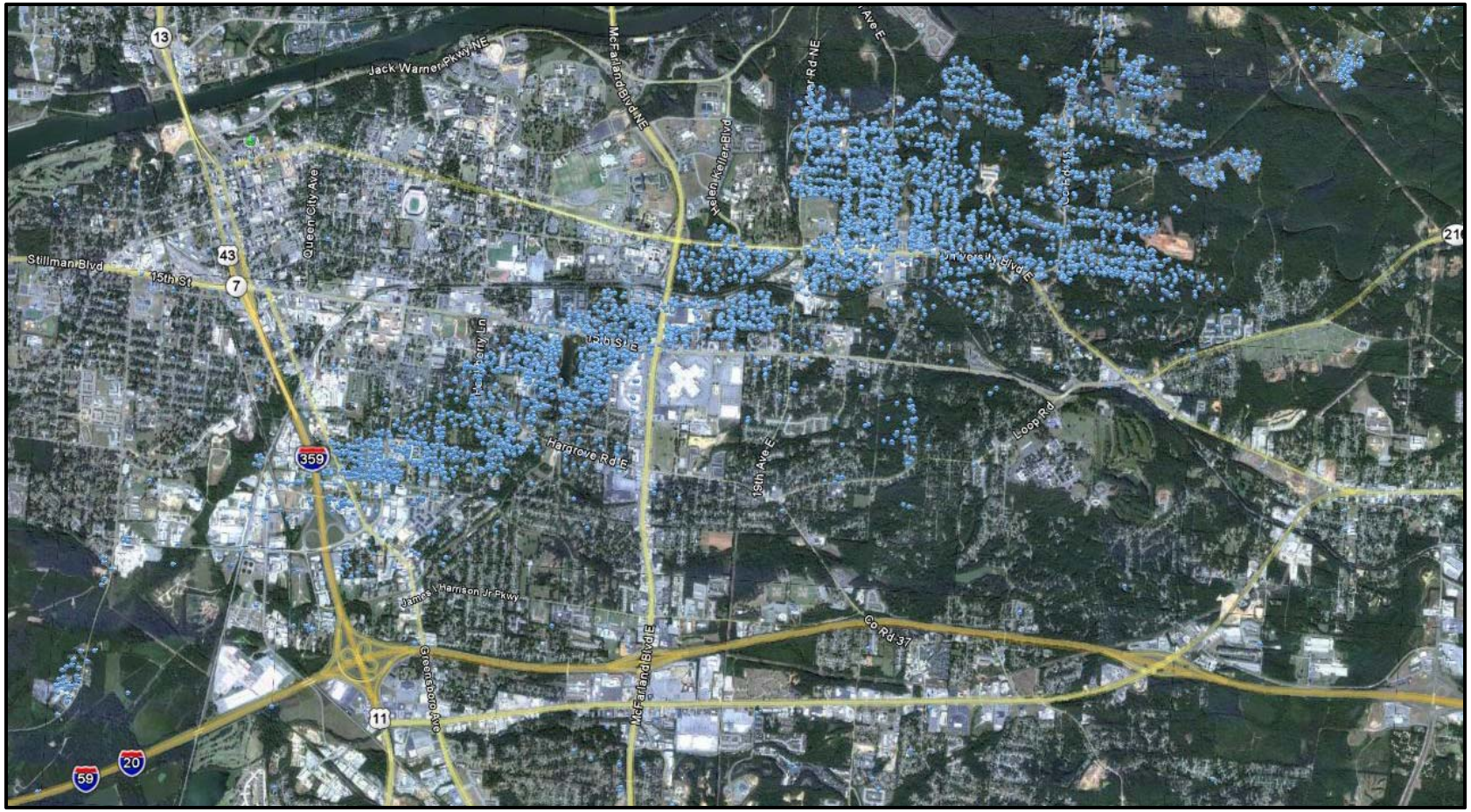
Data consistency, Model convergence, CIM standards are important issues.







Resiliency



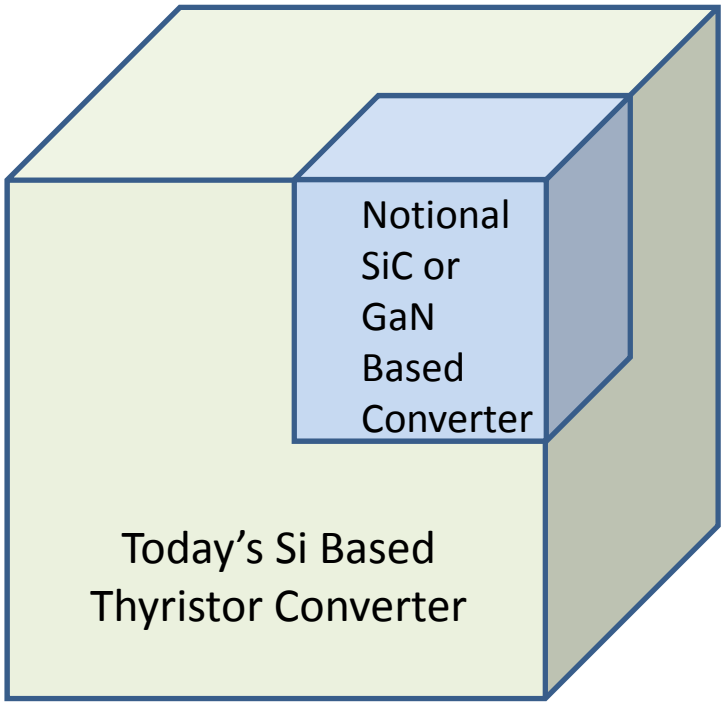
Jack Warner Pkwy NE
McFarland Blvd NE
Helen Keller Blvd
Queen City Ave
Stillman Blvd
15th St
University Blvd E
Hargrove Rd E
19th Ave E
Loop Rd
James I Harrison Jr Pkwy
Co Rd 37
Greensboro Ave
McFarland Blvd E
13
43
7
359
11
20
59

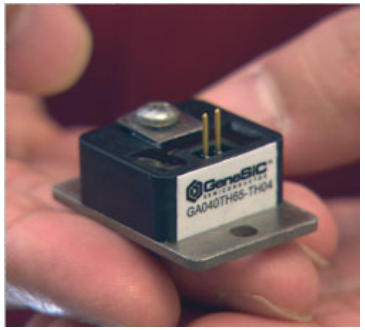
Advanced Materials and Components are Critical

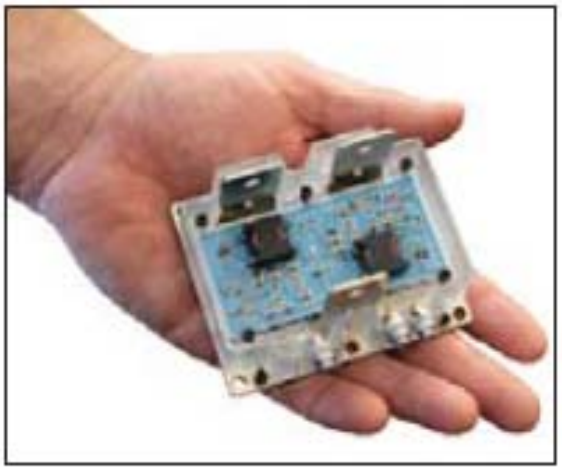
- Flow Control
- Storage
- Transformers
- HVDC
- Other.

WBG Semiconductor Based Power Electronics

- Power electronics built using WBG materials such as SiC or GaN are smaller because they operate at higher temperatures , frequencies and voltages; and do not require complex control circuitry.







HVDC Converters

- Nearly 140,000 MW of HVDC transmission capacity is either in operation or under construction in some 145 projects around the world

250 MW converter (250 kV, 1000 A) with 8 kV thyristors at Moyle HVDC converter station

1,000 MW converter (500 kV, 2000 A) at Latina Italy HVDC converter station

WBG PE HVDC Cost Savings

- $1 Million per year for a 250 MW HVDC Converter station
  - Half from reduced energy losses
  - Half from reduced electricity consumption due to the elimination of active liquid cooling

Thank you

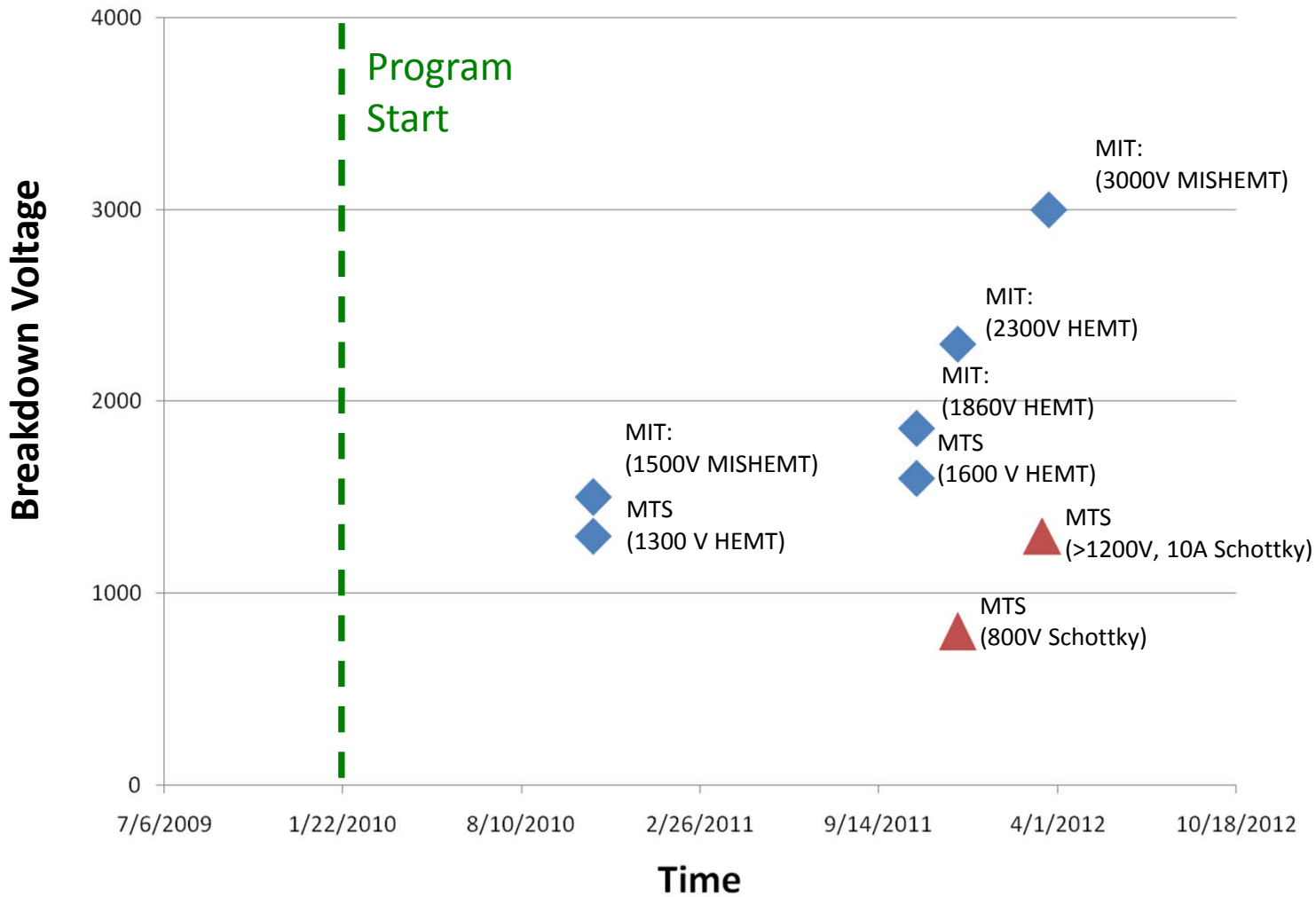
Key Program Areas

- **Design, Fabrication and Manufacturing High Power GaN on Si Based Devices**
  - Team: Lincoln Laboratory – MIT – M/A Com Technology Solutions; various substrate suppliers
    - Lincoln Laboratory - Advanced Materials
    - MIT – Device Physics
    - MTS – Manufacturing and Testing

- **Silicon and WBG Semiconductor Based Devices and Materials**
  - Team: Oak Ridge National Laboratory; various materials & device manufactures, utilities
    - Modeling
    - Packaging
    - Testing
    - Systems
  - Solid State Fault Current Limiter with EPRI and Silicon Power

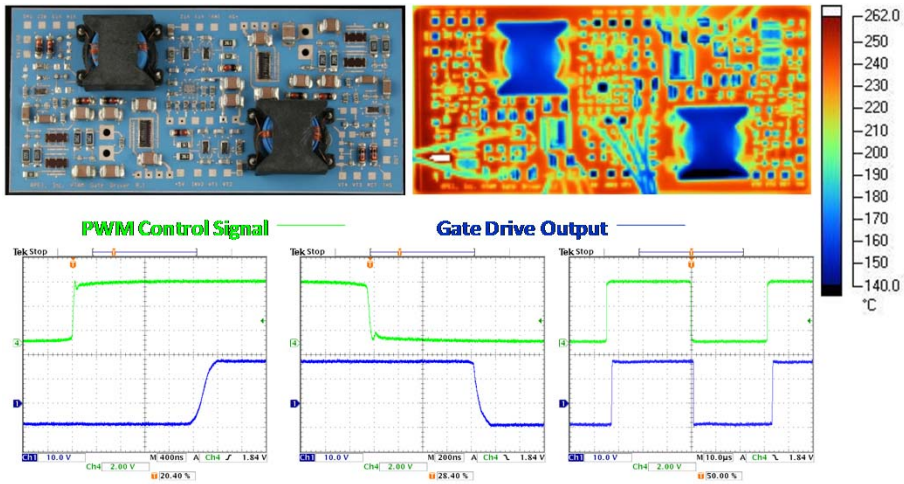
- **WBG Semiconductor Based Devices**
  - Team: Sandia National Laboratory; various materials & device manufactures, utilities
    - Modeling
    - Reliability Testing
  - Electrochemical Solution Growth (ESG) Technique for Bulk GaN Substrates

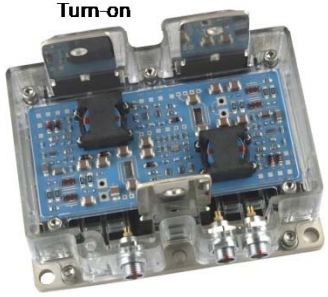
Program Progress – GaN on Silicon



APEI *High-temperature Silicon Carbide (SiC) Power Module*

Brief Description: It is the world's first commercial high-temperature (250 °C) silicon-carbide (SiC) based half-bridge power electronics module, with an integrated gate driver. The 50-kW (1200-V/150-A peak) SiC power modules are rated up to 250 °C. They can reduce system size and weight up to an order of magnitude over present state-of-the-art silicon-based solutions and can reduce energy losses by more than 50%. **SBIR Phase I, II, and III**





APEI SiC Power Module

2009 R&D100 Winner

Power Electronics Reliability

DOE Energy Storage Power Electronics Program

Background:

Power electronics comprises the high-stress tie between the electric grid and *all* energy storage technologies.

Purpose:

Increase the reliability of post-silicon semiconductors (SiC and GaN) which are key technologies for achieving higher performance/cost power electronics.

Impact:

Reliable, high performance/cost power electronics will enable energy storage to support high penetration of distributed energy resources while adding stability to the grid.

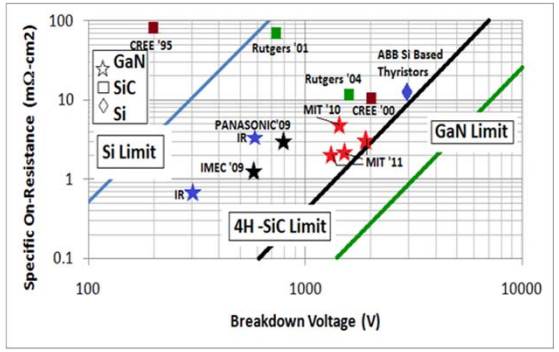
Key Deliverables:

1. Device stress testing results and reliability modeling for material and device design improvement.
2. Condition monitoring of power electronics devices for use in conjunction with reliability models for prognostics of failure.

Dissemination of Work to Public:

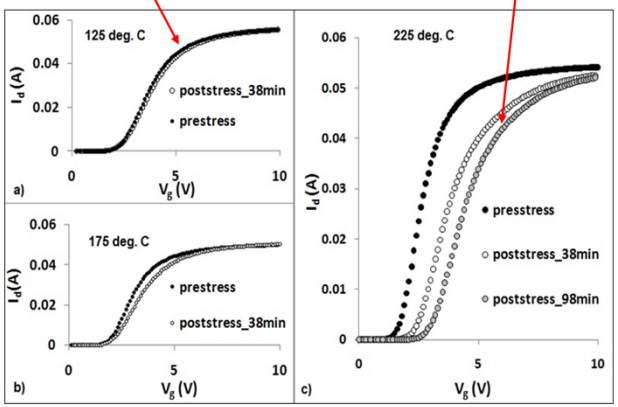
Currently there are ten journal articles / conference presentations published in respected applied physics and power electronics venues

SiC, GaN have potential for higher performance switching than Si



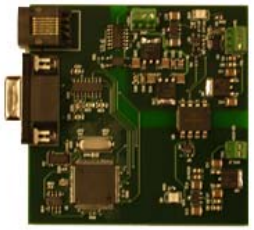
SiC MOSFET reliability evaluation

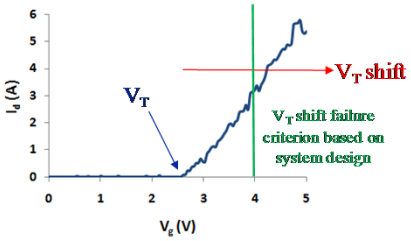
Minimal degradation at rated T; severe degradation at high T



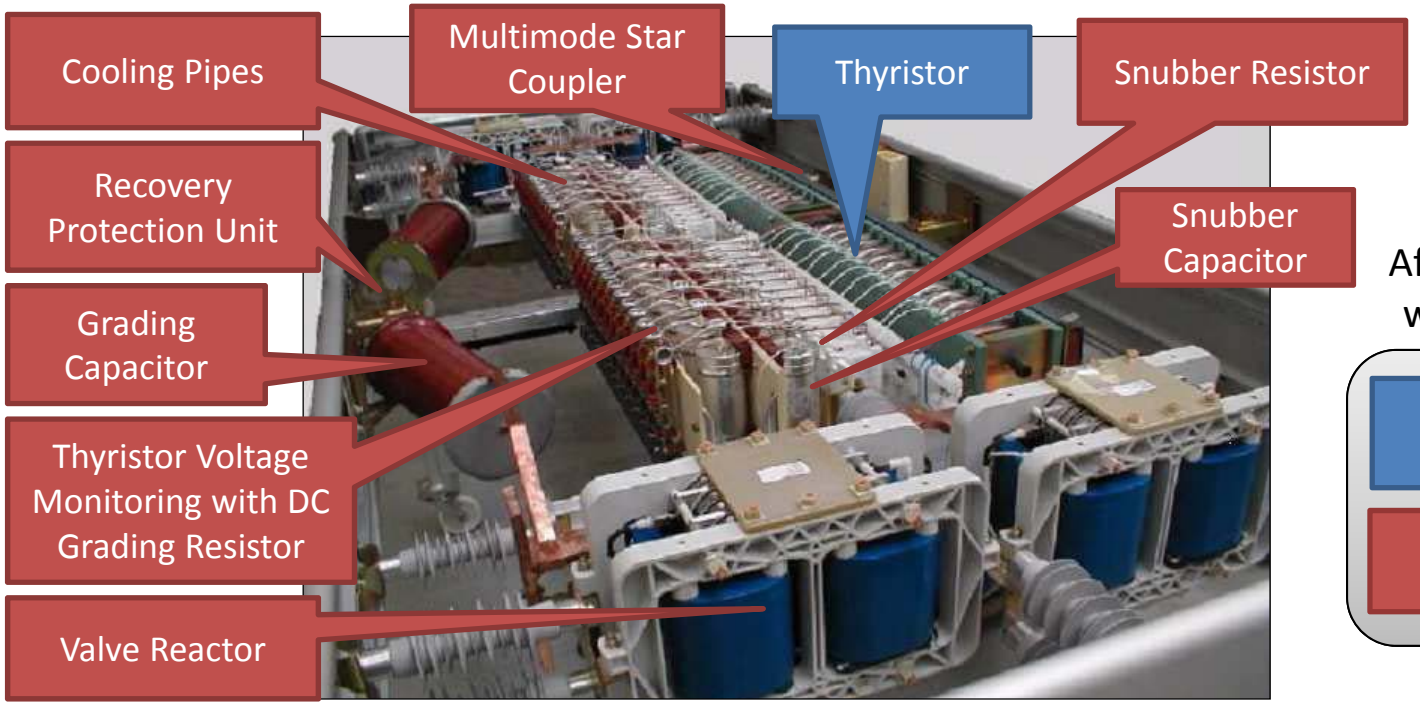
Stress: $V_{GS} = +20$ V, $V_{DS} = 0.1$ V

Power device condition monitoring for system-level health management





WBG Based Devices Require Much Less Engineering



Affect on Components when using WBG PE:

- Stays the same, or equivalent required
- Can be removed completely