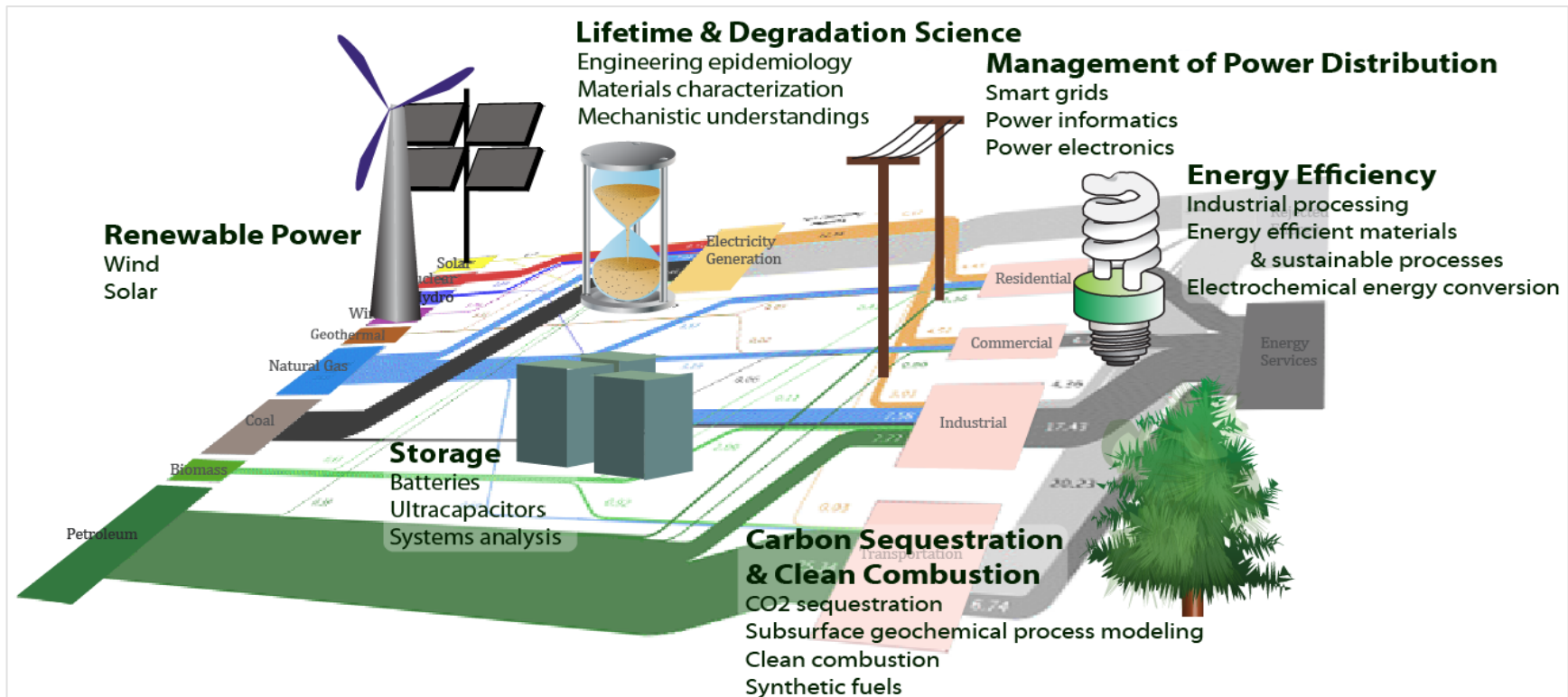


# Energy Research at Case Western Reserve University



**Kenneth A. Loparo**  
**Nord Professor of Engineering**  
**November 12, 2012**

# Energy Storage

- Capacity worldwide is ~90GW of a total production of 3400 GW
  - Energy Storage Provides Grid Security



# Utility Scale Energy Storage

## Storage Plants Are Cost-Effective Options

- Renewable- Off-Peak Storage & On-Peak Generation
- Power Quality
- Peak Shaving

## The “Best” Storage Option Depends On The Application At Hand

- Design Trade-Off Studies Are Needed to Choose Best Option

## On-Going R&D Is Improving Options Available

- Flow Batteries (for long charge/discharge time periods)
- Super-Capacitors (for heavy cycling applications)
- Power Electronics (to lower ac-dc-ac conversion)

# Energy Storage – Nationally Competitive Research

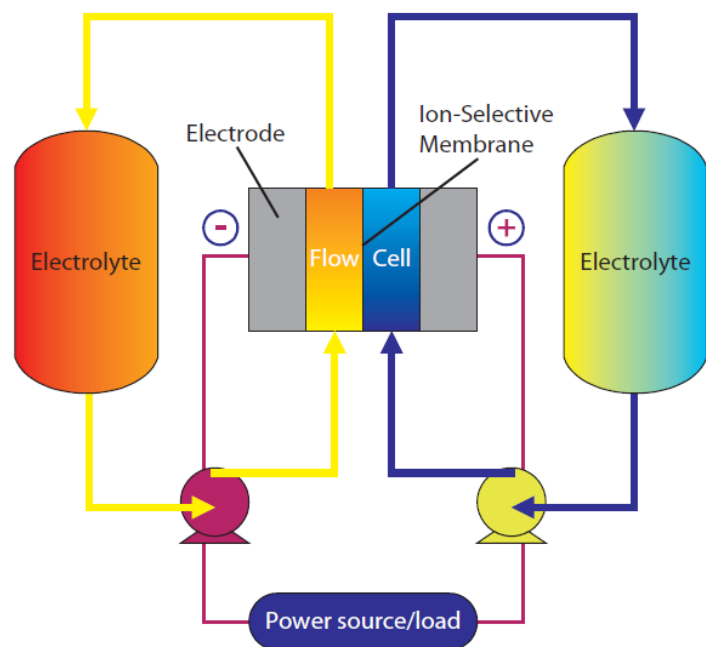
## Successes

- **DOE ARPA-E Capacitor Materials** funded \$2.2 million
- **DOE Flow Battery** test bed
- **DOE Flow Battery** \$560,000 research funded via Sandia National Laboratory
- **DoD Capacitor** work funded
- **Ohio Third Frontier Lithium-ion safety** \$1,120,000 with Novolyte
- **Ohio Third Frontier Capacitors for grid** \$490,000 with Calgon
- **Storage-Wind** integration: FirstEnergy

## Proposed

- **Flow battery: Faraday Technologies DOE STTR**
- **ARPA-E storage proposals (lithium-ion, flow battery, fuel cell)**
- **Energy Storage Validation Center** to test and validate batteries
- **NSF ERC: reliability and engineering epidemiology**

# Flow Batteries



## SIMILARITIES TO A FUEL CELL

- Electrodes do not undergo chemical change
- Reactants flow through the stack
- Membrane-centric technology

# Iron Flow Batteries

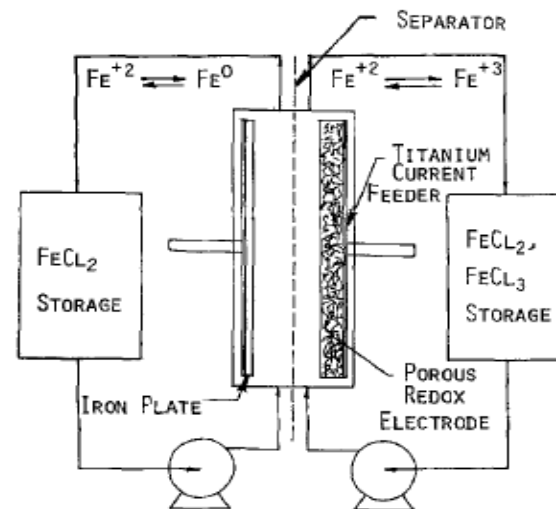


Fig. 1. Schematic of iron-redox laboratory cell and electrolyte circuit.

## Findings

- Capable of RT energy storage, 90% CE, 50% EE
- Low pH for redox, high pH for plating reaction
- Plating on Ti and C substrates

# Solar Power: the national scene

## *DOE SunShot Initiative*

- Aims to dramatically decrease the total costs of solar energy systems by 75% before the end of the decade.
- Aims to make solar energy cost-competitive with conventional forms of electricity, no subsidies, enable widespread deployment.

## *Photovoltaics and Concentrating Solar Power*

- new devices, prototype designs, and systems development and manufacturing

## *Systems Integration*

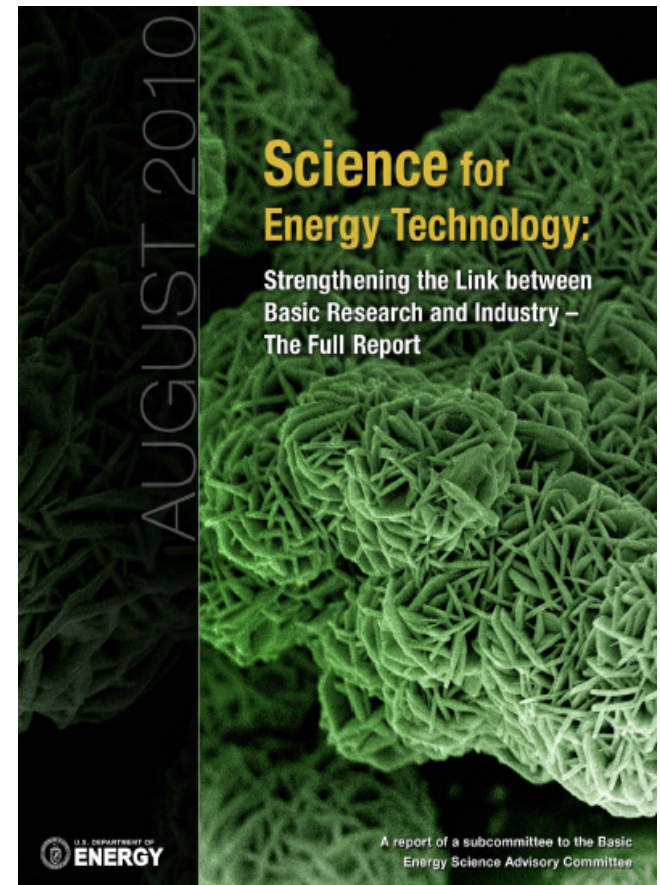
- Removing technical barriers to wide-scale deployment
- Funding smarter technology development, testing and demonstration
- Developing new codes and standards, removing economic barriers.

## *Market Transformation*

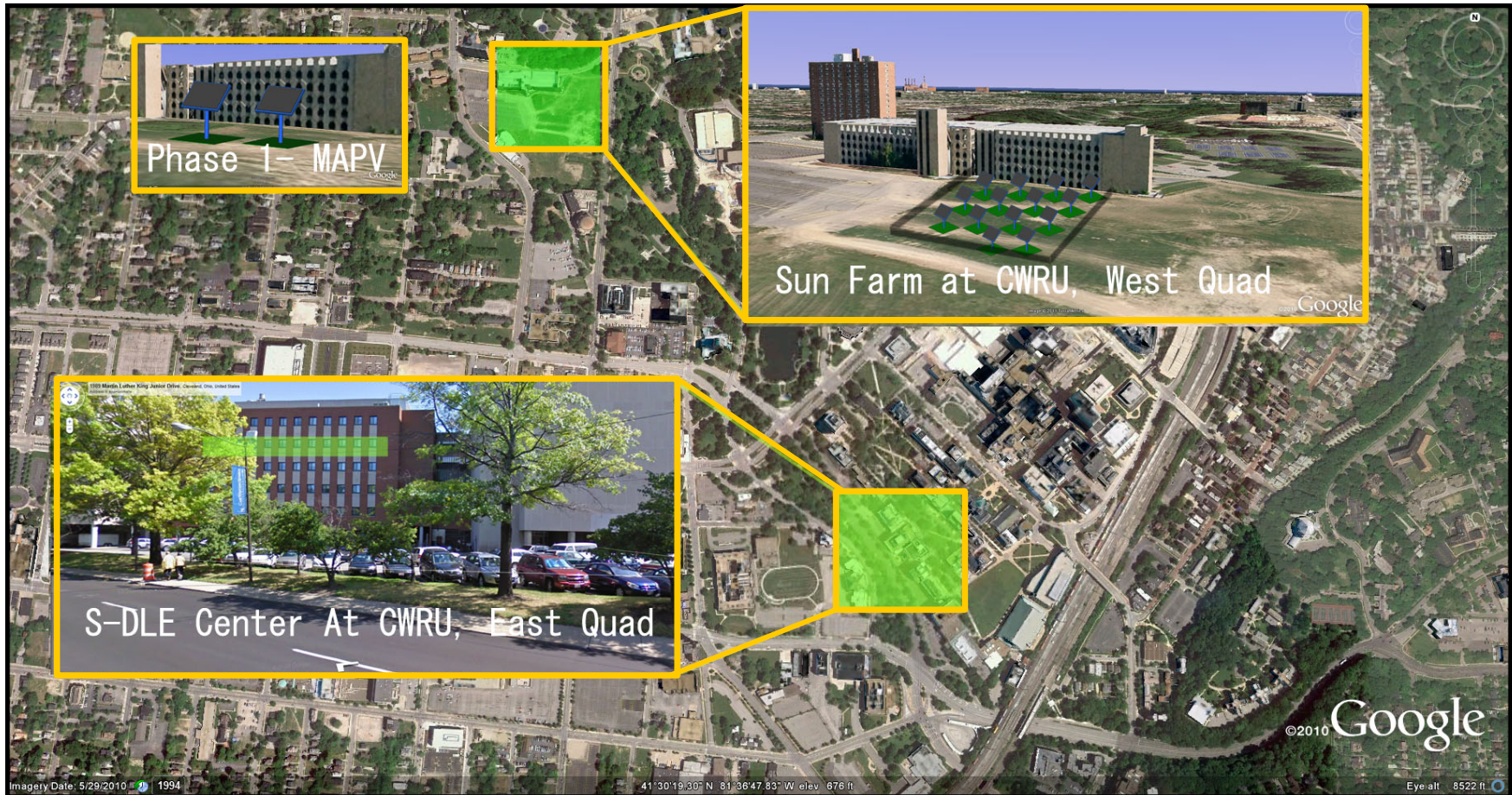
- Addresses barriers to the widespread adoption of solar technologies and reduce non-hardware installation costs

# A National Need: Lifetime & Degradation Science for PV

- Qualification testing of systems not sufficient for reliability & lifetime
  - To avoid excessively high degradation rates
  - Dramatically reduced service lifetimes
- Must determine degradation mechanisms and rates
  - Scientific underpinning of reliability and qualification standards
- Quantitative degradation rate modeling
  - Connects materials, components, system to overall degradation rate
  - System lifetime performance
- Science For Energy Technology Workshop
  - Convened by U. S. DOE, Basic Energy Sciences
- Science challenges across 9 areas of energy
- PV prioritized research directions
  - **Photovoltaic module lifetime and degradation science**
  - **Fundamental properties of photovoltaic interfaces**
  - **Advanced photovoltaic analysis and computational modeling**



# CWRU Solar Durability & Lifetime Extension Center



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Roger French

Ohio Third Frontier Wright Center



# Solar Trackers



- Opel Solar SF-20  
With GPS  
Tracking  
SunSensor
- DayStar Multi-  
tracer For Time  
Series Analysis



Mock-up of the S-DLE Sun Farm Outdoor Exposure Capability

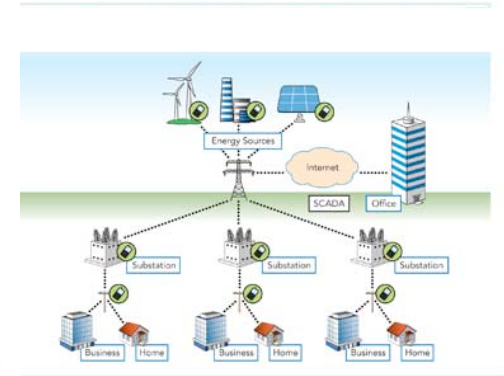
- 2 Trackers on Mirror Augmented PV
- Proposed Trackers from the S-DLE Project

# ELECTRICITY SYSTEMS RESEARCH

Generation



Transmission



Distribution

# CWRU ELECTRICITY SYSTEMS EXPERTISE

Systems Approaches to Smart Energy

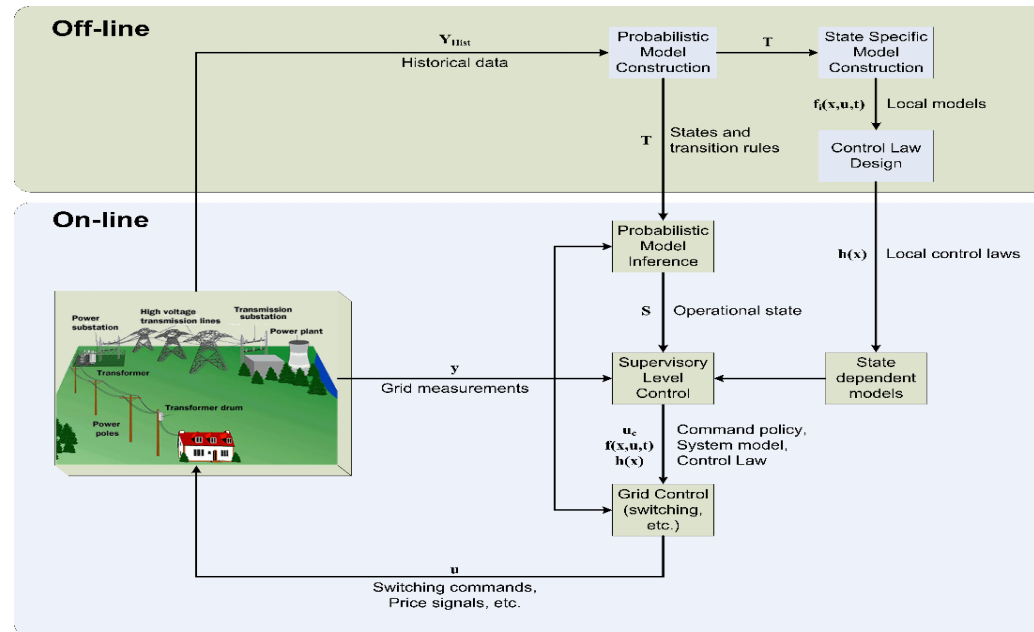
Stability and Security Enhancement through  
advanced sensing, communications and control  
Integration and Real-Time Energy Management  
of Distributed Renewable Energy Resources  
Transmission and Distribution System  
Automation

Demand Management Systems including Energy  
Economics, Optimization, and Decision-Making

Information and Control Architectures for Smart  
Generation



# Integrated Electricity Systems: Command, Communications and Control

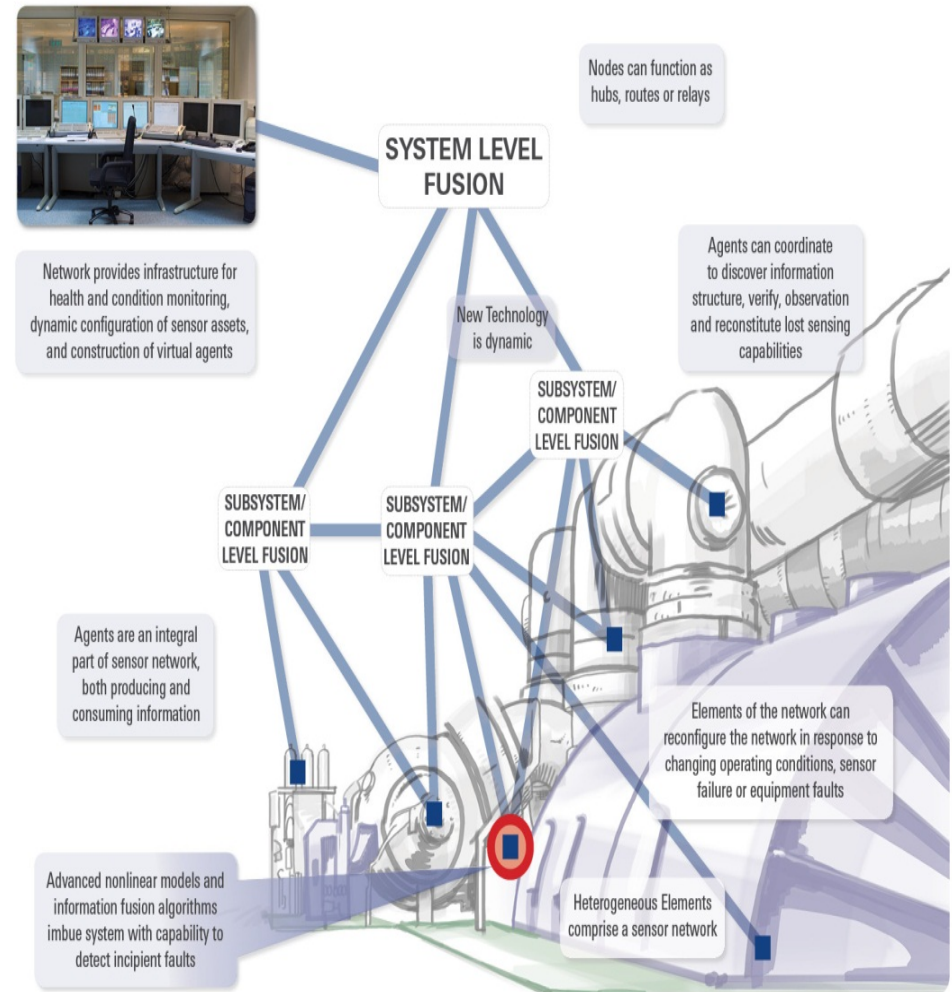


- Integrate, Test & Evolve Scalable Power Systems Management & Control Tools, Smart Sensor Systems, Advanced Communications, Control Algorithms, and Enabling Software
- Utility-Grade Generation, Transmission & Distribution for Consumers and Markets
- Intelligent Sensors and Devices
- Systems Targeting Specific Grid Operations and Support
- Collaborative Management, Planning, and Operations
- Enable Instantaneous Communications, Situational Awareness, and Control



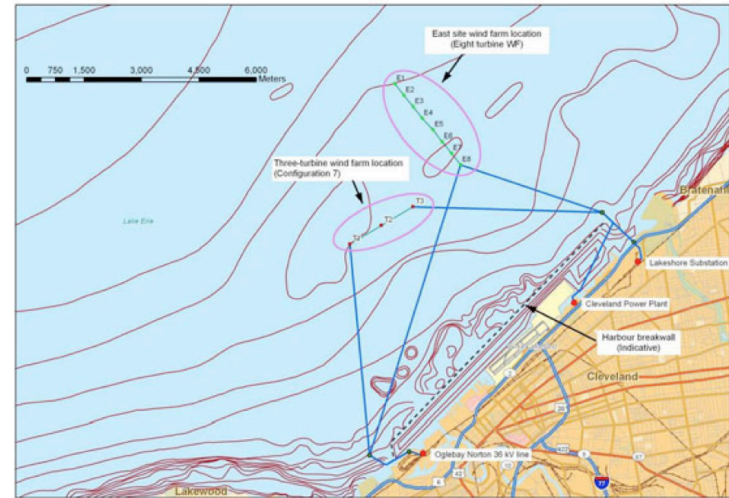
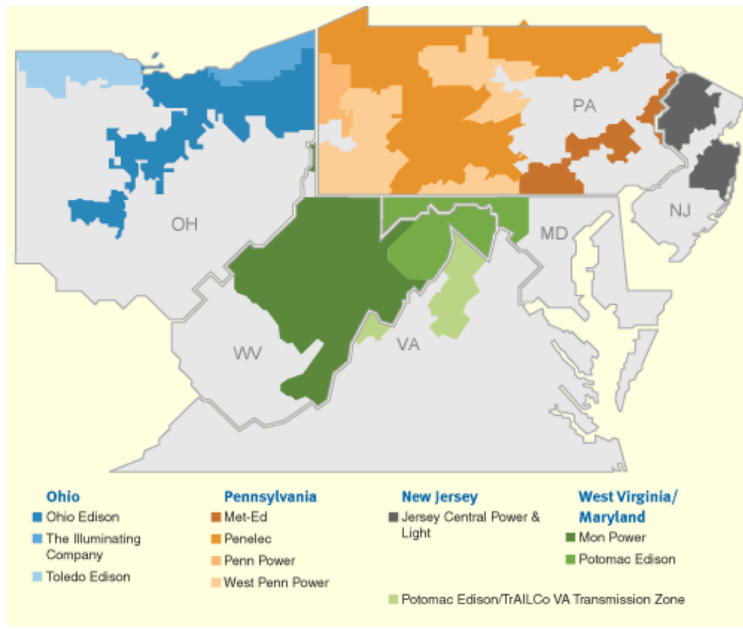
# DOE 518-An Information-theoretic Framework and Self- organizing Sensor Network for Power Plant Monitoring/ Control

NETL:DE-FE0007270



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# DOE 414-Great Lakes Offshore Wind: Utility and Regional Integration Study



**CASE WESTERN RESERVE UNIVERSITY** EST. 1826

Institution of Higher Education



**DOE: DE-EE0005367**



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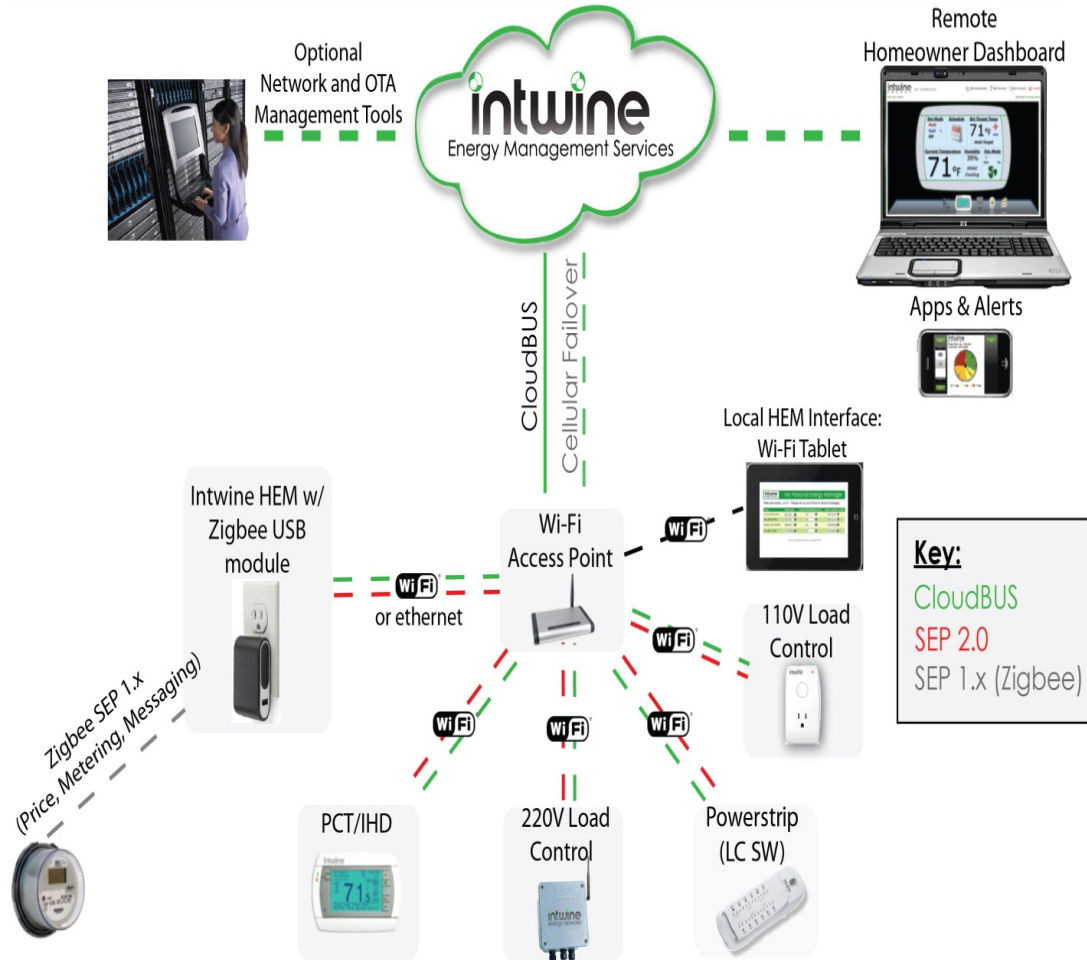
# Increasing the Efficiency of Coal-fired Power Plants-Loss on Ignition Sensing

## Approach

- Develop and demonstrate a highly reliable self-cleaning sampler system (Draper)
- Develop rapid and accurate sample analyzer based on direct measurement of LOI (Draper and CWRU)
- Integrate LOI with SCADA system (CWRU and Rockwell)



# Home Energy Management



**Key:**  
 CloudBUS  
 SEP 2.0  
 SEP 1.x (Zigbee)

**PLUG IN TO SAVINGS!**

**PROGRAM DETAILS**

2 **SMART Shift Plus™**

This new, optional rate plan rewards residential customers with Smart Moments for using electricity wisely. With SMART Shift Plus™, you'll pay special, lower rates for electricity used during "off-peak" times when demand for electricity declines and higher rates for electricity used during "on-peak" times when demand for electricity is greatest.

With SMART Shift Plus™, not only can you shift your electricity use to times in the day when rates are lower, you can also manage your usage with a **FREE Home Energy Management System** – a suite of energy-saving devices that will help you learn more about your electricity use so you can make decisions that can save you money and energy.

- Get a special, **RATE** of as low as 5¢ per kWh during low cost hours for electricity used during the Summer months, and 24 hours a day the rest of the year.
- Manage electrical usage throughout your home with a **HOME ENERGY MANAGEMENT SYSTEM** including **FREE PROGRAMMABLE COMMUNICATING THERMOSTATS**.
- Comes with your Home Energy Management System (HEM) with a **FREE ANDROID™ TOUCH SCREEN TABLET**.
- Control your oven power size on your water heater or pool pump with a professionally installed load control switch.
- **All equipment and installation is yours for NO CHARGE.**

**PUBLIC SERVICE COMPANY OF OHIO**

**HOW IT WORKS!**

▶ **SMART SHIFT PLUS™ RATES:**

**Summer Billing Hours: June 1st – October 31st (Monday – Friday):**

Lower cost hours:	11PM-6AM	5¢ per kWh (including weekends and holidays)
Medium cost hours:	10AM-2PM	6¢ per kWh
	3PM-11PM	6¢ per kWh
Higher cost hours:	3PM-7PM	13¢ per kWh
Critical Peak Pricing:	During called Event	95¢ per kWh

**Winter Billing Hours: November 1st – May 31st:**

Fast 47¢ kWh:	8:20a
Next 175 kWh:	5:30a
All additional kWh:	4:54a

▶ **NOTE:** Unless a critical peak event is called, all kWh consumed during the summer months on weekends (all hours of the day on Saturdays and Sundays) and the local holidays, Independence Day and Labor Day, are billed at the low cost level.

If you would like to speak to a representative call 1-888-548-4376



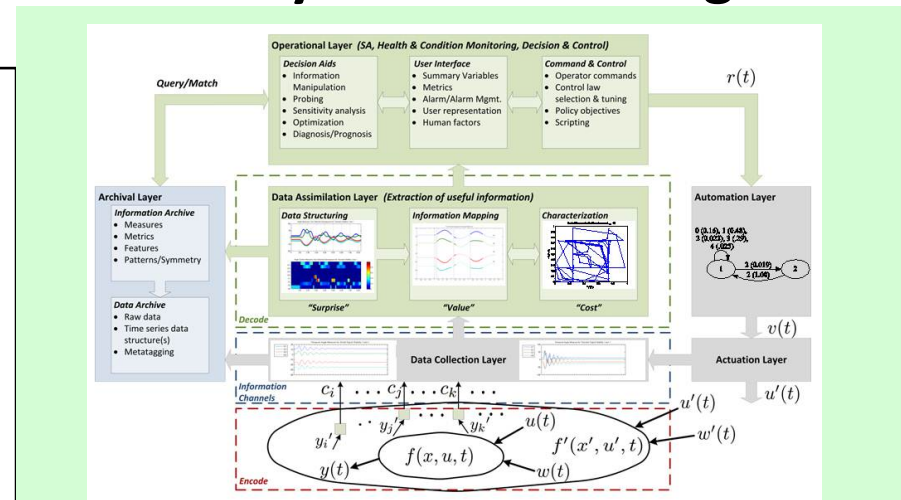
# Smart Grid Algorithms for Enhanced Reliability and DNER Integration

## Technology Summary

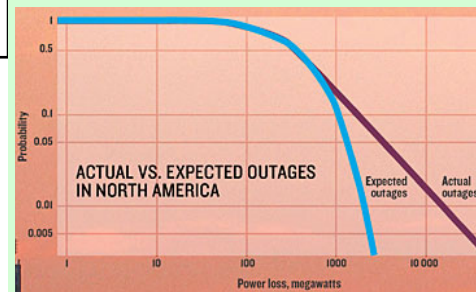
- Breakthrough software to integrate heterogeneous data streams to manage future grid operations by providing resolution, fidelity, and computational power for real-time monitoring, decision-making, and control
- Innovative method, *system structuring*, provides a computational framework for integrating data across diverse time-scales
- 3 year project includes phases for *Architecture Development, Software and Algorithm Development, and Test and Evaluation*

## Technology Impact

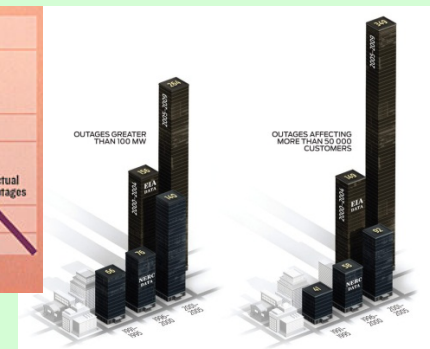
- Maintains U.S. leadership in \$4.3B market (2012), growing at 15.2% (CAGR)
- Enables higher penetration of renewable energy devices (>25%)
- Reduces number and severity of grid outages (10X)



## Information-Theoretic Framework for Integrated Distributed Sensing, Communication, and Control

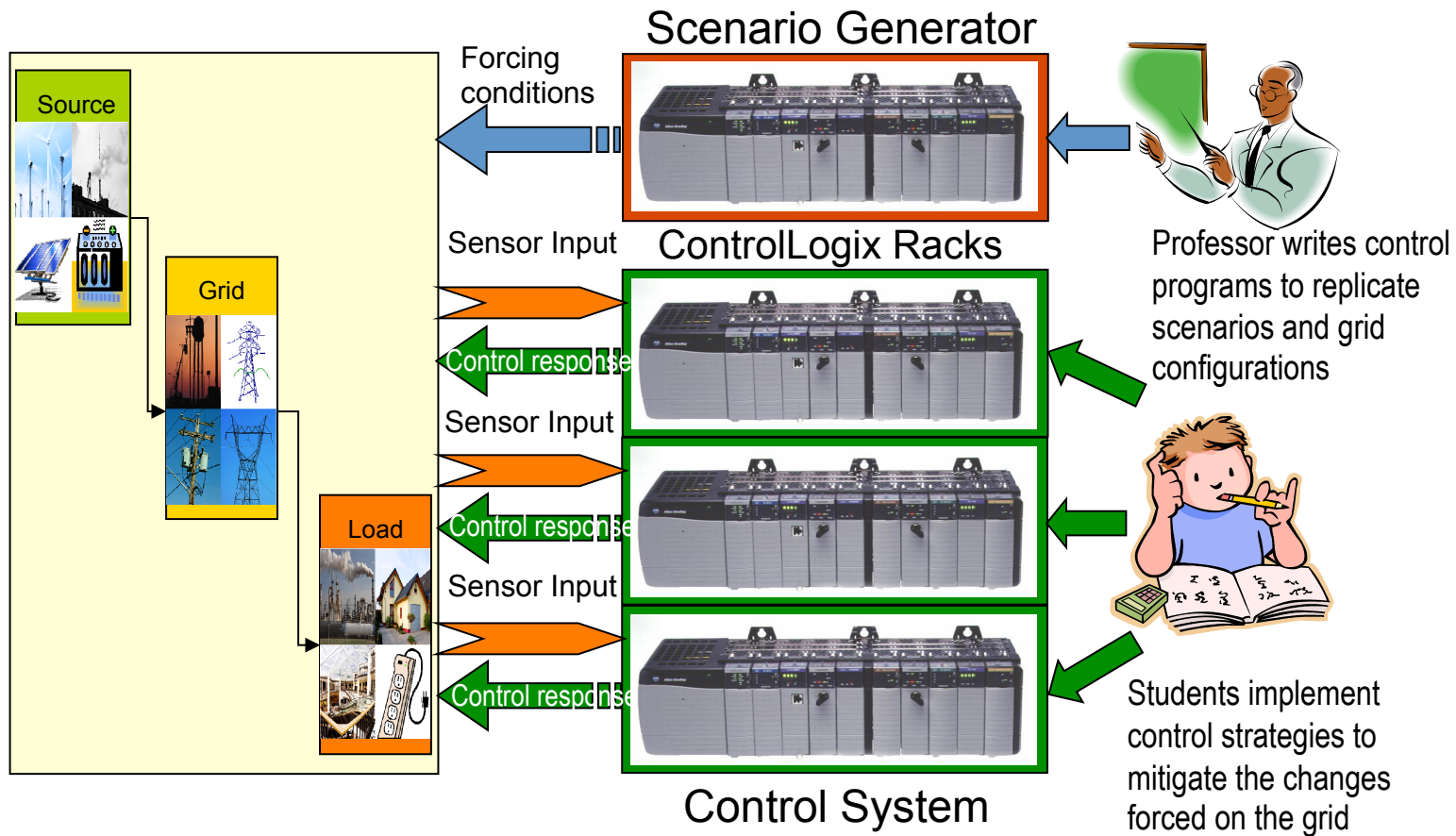


IEEE Spectrum, Aug. 2004



Frequency and severity of outages is increasing. †A major contributor to this increase is lack of methods to detect and classify anomalies and to prognosticate their severity in a timely manner.

# Laboratory Test System for Future Electricity Systems Education and Research



# Laboratory Test System for Education and Research



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Number of Loads: 40  
Number of Power Sources: 8  
Number of I/O: 300 approx.

