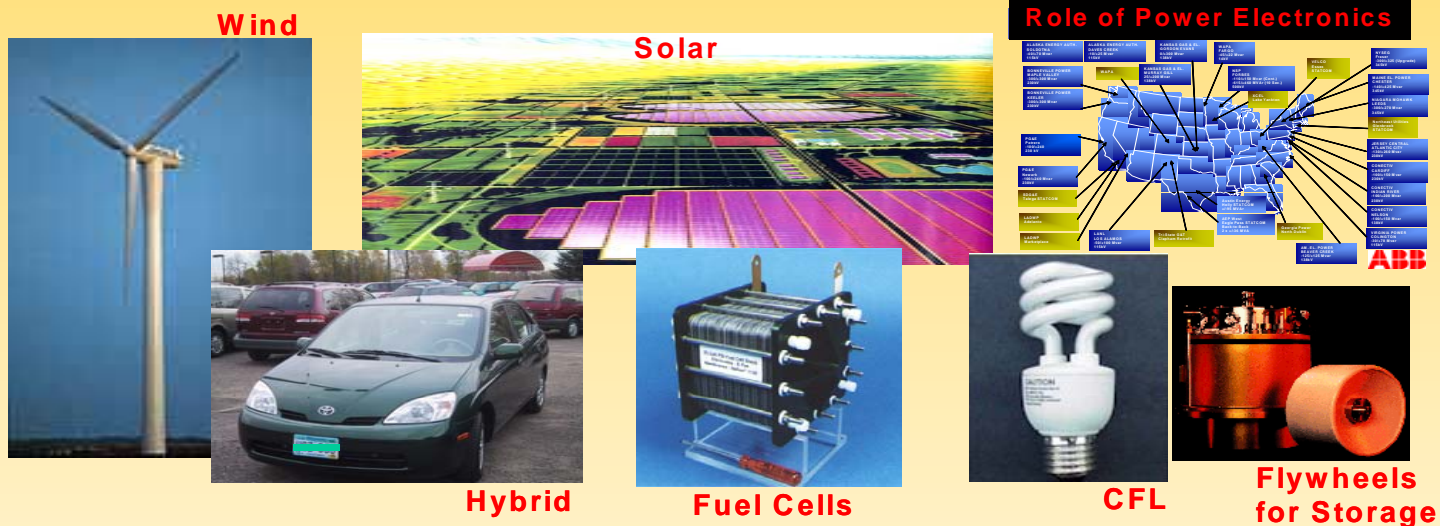


Workshop on Curricular Reform in Electric Energy Systems



**ONR/NSF-Sponsored Workshop
Tucson, AZ February 4-6, 2010**



Group Effort:

- Ned Mohan
- Bill Robbins
- Bruce Wollenberg
- Paul Imbertson
- Tom Posbergh
- Dr. Nari Hingorani (Consultant)
- Heather Dorr and Josette Barsness (Organization)
- Students

www.ece.umn.edu/groups/power



Workshop Mission

- Discuss reforming the Electric Energy Systems Curriculum to be forward-looking with emphasis on
 - Renewables/Storage
 - Smart Delivery
 - Efficient End-Use
- Create a large and a vibrant learning community



Past Sponsors

- Center for Electric Energy
 - Established in 1981
 - Supported by 7 Regional Utilities
 - Budget: ~175 k\$/year
- Laboratory Development
 - NSF
 - NASA
 - ONR



Present Dissemination Grant

- Office of Naval Research (ONR)
 - Program Officer: Terry Ericson
 - 1.23 million dollars over 5 years





DARPA-RA-10-3

Introduction

The United States has entered into a significant national decline in the number of college graduates with STEM degrees. This downward trend is an issue of national importance as it affects our capacity to maintain a technological lead in critical skills and disciplines related to CS-STEM. Our ability to compete in the increasingly internationalized stage will be hindered without college graduates with the ability to understand and innovate cutting edge technologies in the decades to come.

- **Funding Profile** – DARPA anticipates 1-3 awards. The funding allotted for Cooperative Agreements under this RA is approximately \$1-2 million for the first year (for each award), increasing at a rate of approximately \$500k each year.



Additional Support

- NSF
- AEP
- Center for Electric Energy



Curricular Reform - Why?

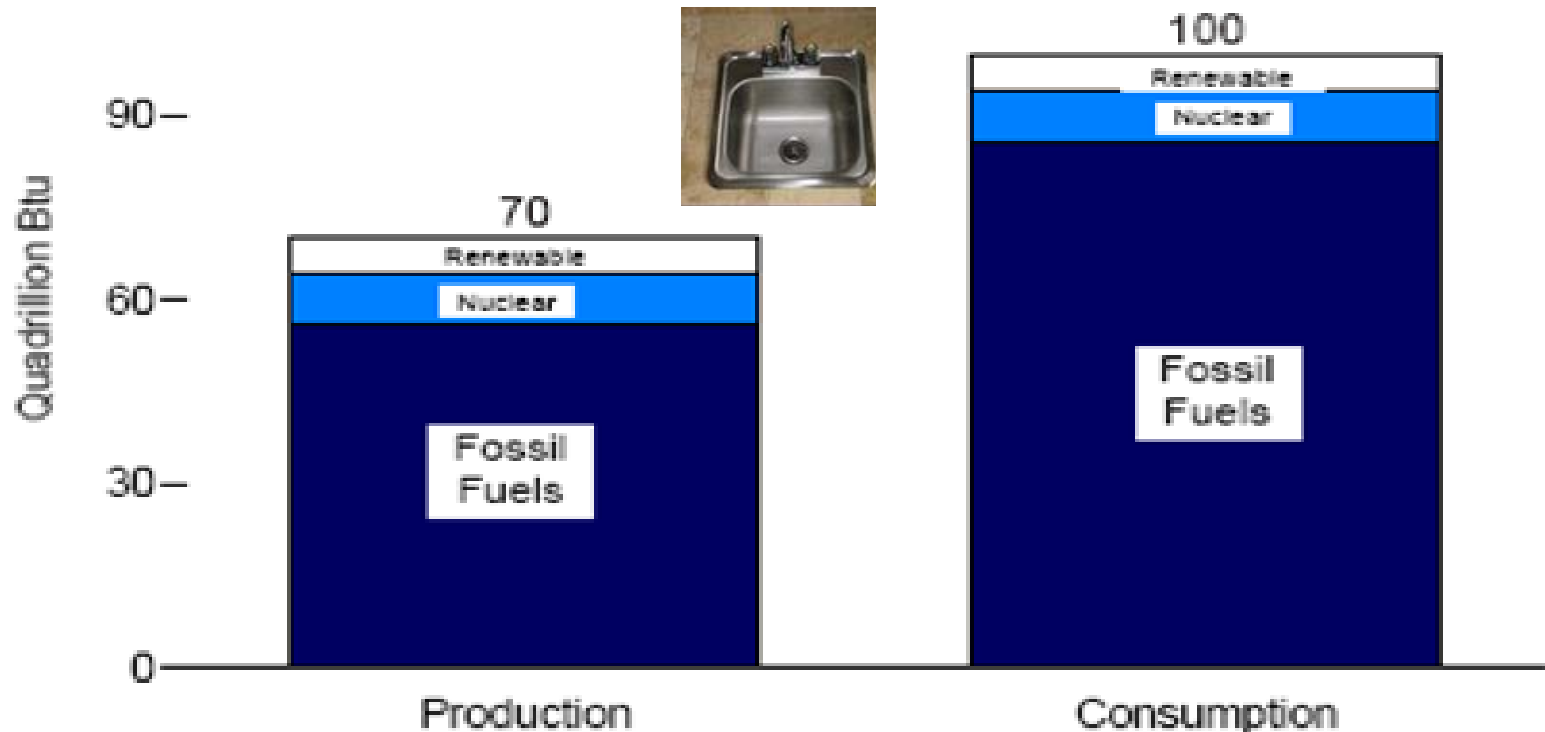
- Electric Power Sector – The Big Picture
 - Opportunities
 - Workforce Crisis and its Urgency
- Curricular Reform in Response
 - Salient Features
 - Results so far
 - Additional steps
- Workshop Agenda



Financial Crisis and Climate Change

Production and Consumption

700 B\$/yr



Climate Change



**Florida's shoreline today
(in 2005)**

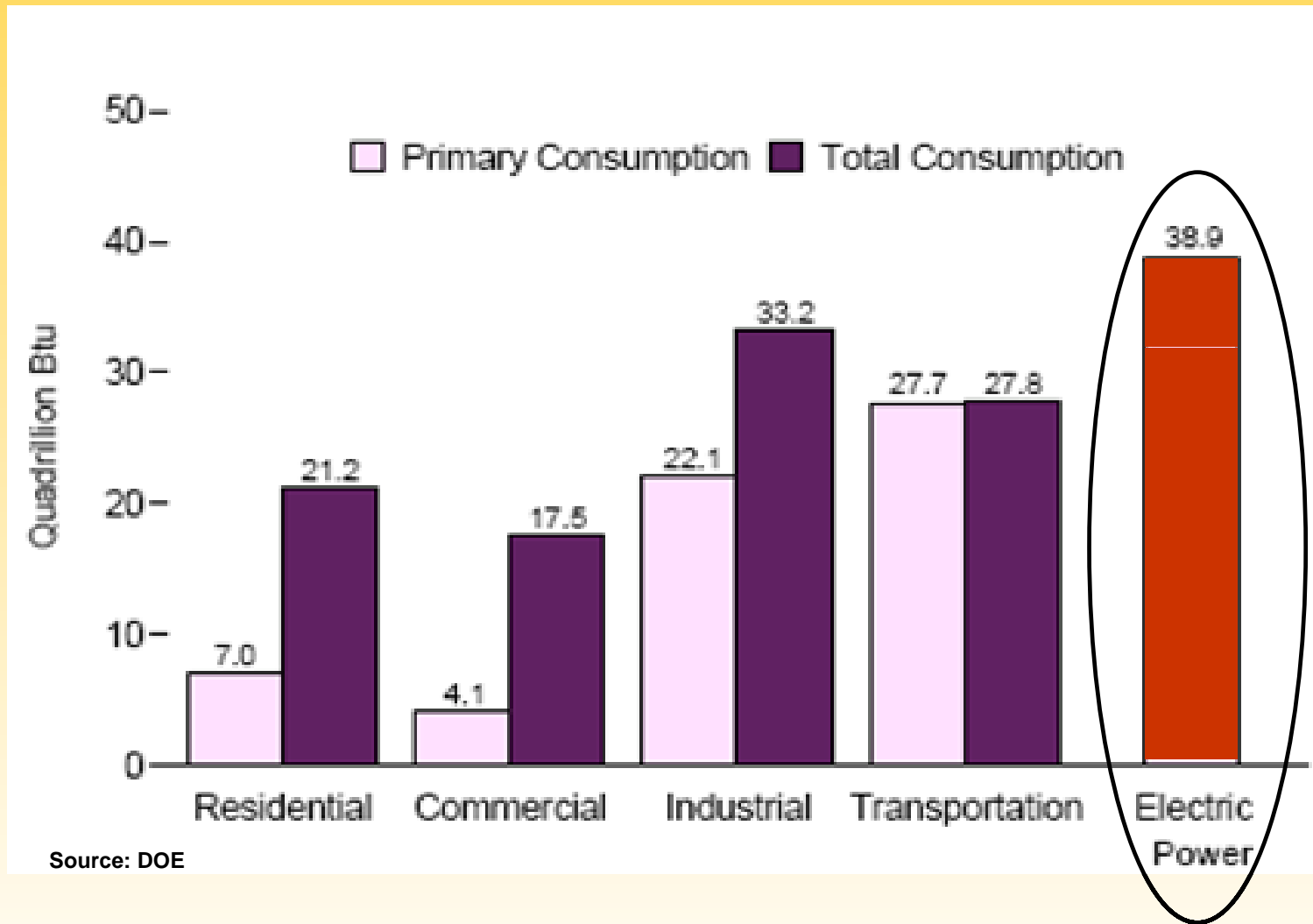


**Florida's shoreline
after about a 5 meter
rise in sea level**

Sea levels rising twice as fast.....

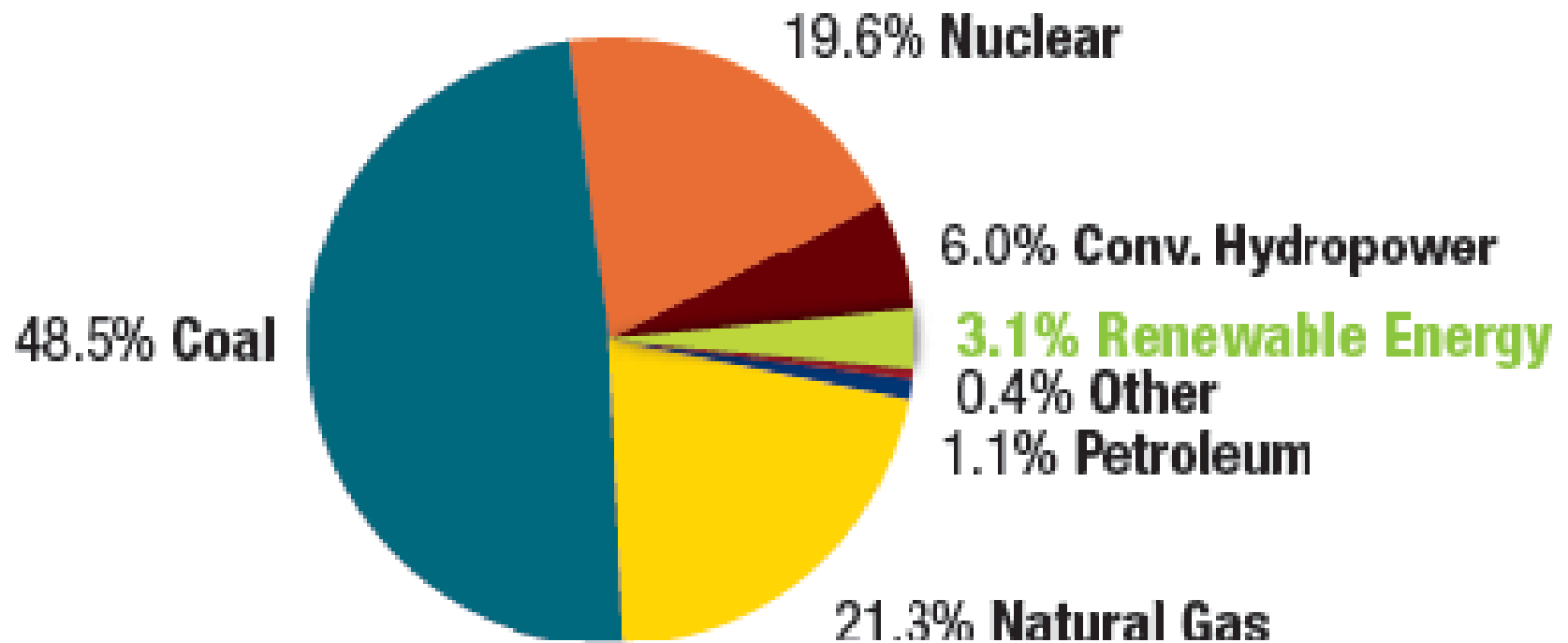


Electric Power



Electric Power Generation by Fuel Type:

U.S. Electric Net Generation (2008): 4,112 billion kWh

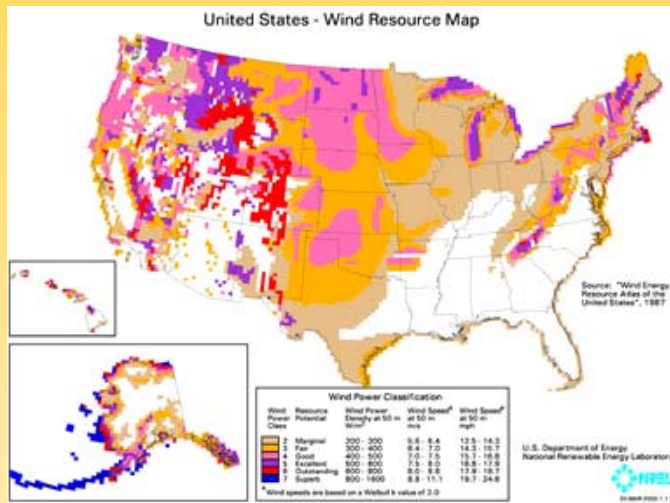


Electricity from Renewables

- Wind
 - On-land
 - Offshore
- Solar
 - Concentrated Solar Power (CSP)
 - Photovoltaic (PV)
- Wave
- Geothermal



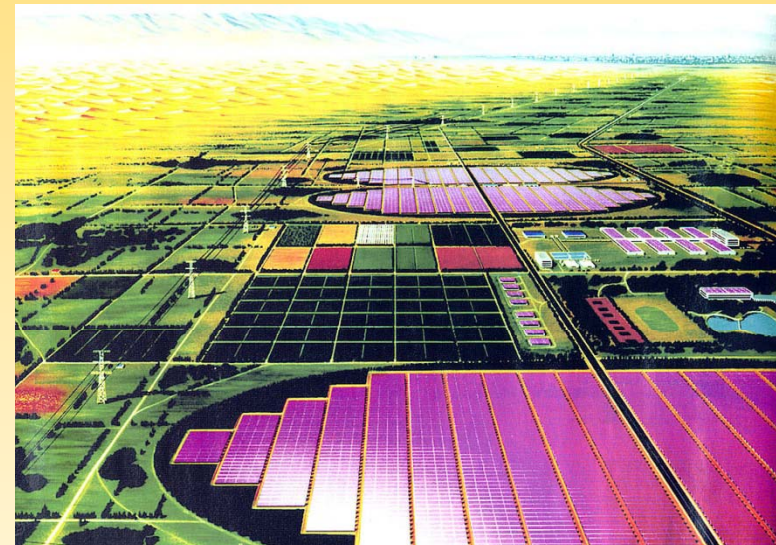
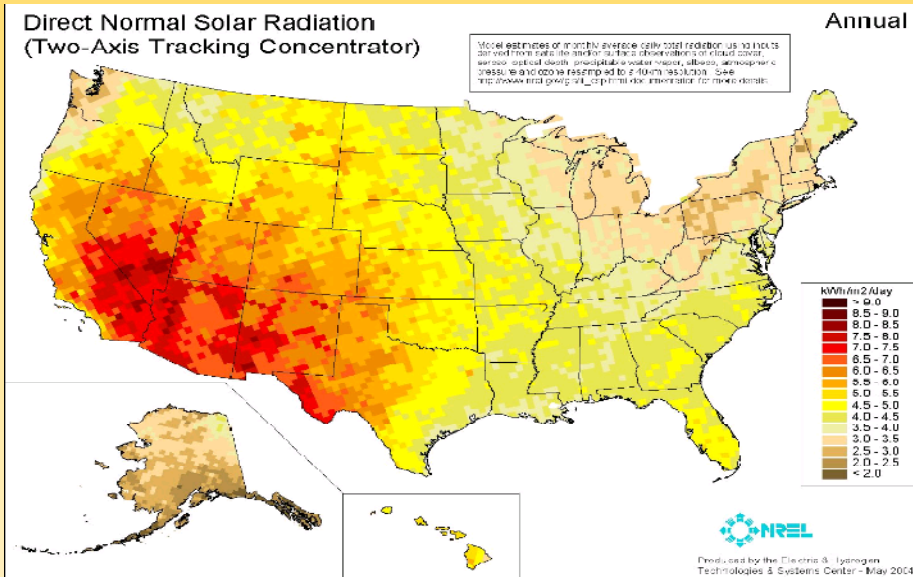
Wind



DOE estimates offshore resources to be 900,000 MW.

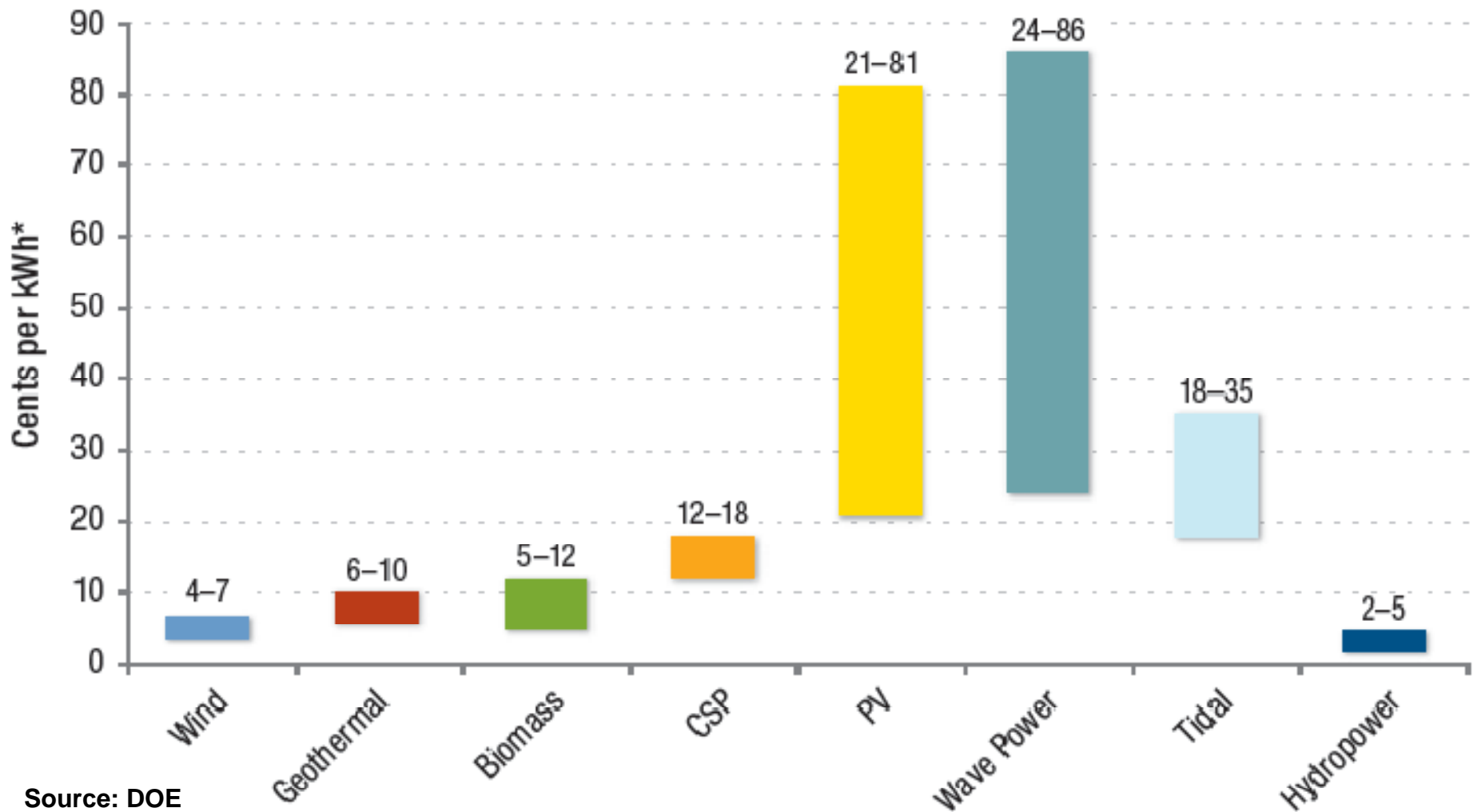
- 20% by 2030

Solar



Solar is today where wind was 5-8 years ago.

Price Range of Renewable Electricity by Technology (2008)



Source: DOE





Nuclear

Jan 30, 2010

Obama moves quickly to promote nuclear power

Jan 29, 2010

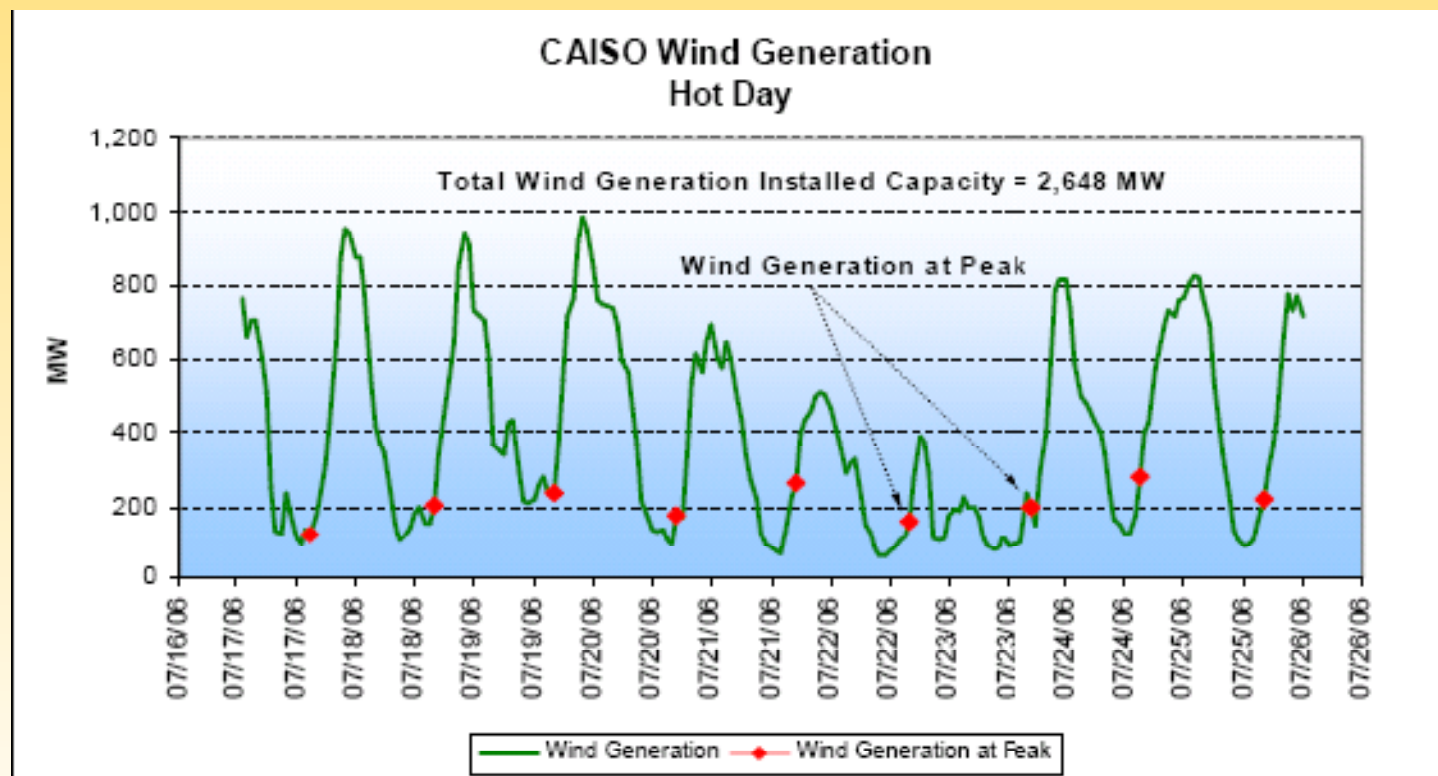
Obama's call for nuclear power plants angers supporters





Storage

You have to go a very long distance to get diversity!



Storage Options

- Compressed Air
- Fuel Cells
- Flywheels
- Superconducting Magnetic
- Ultra-Capacitors
- Batteries
 - Lead Acid, Li-ion, NiMH, Flow, Sodium Sulfur



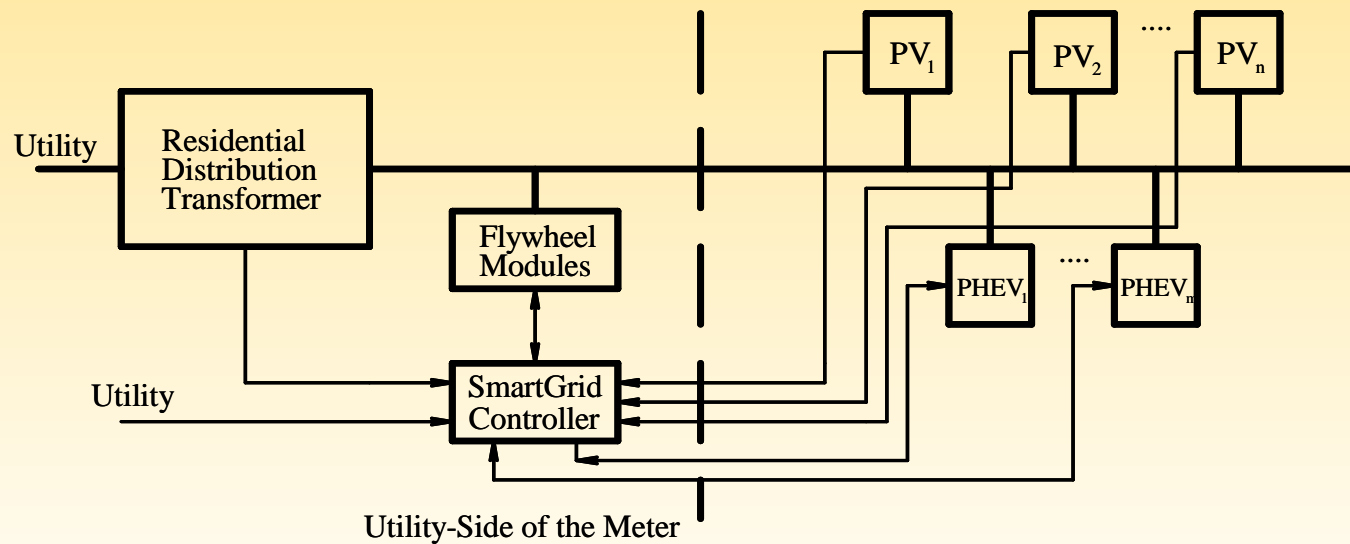
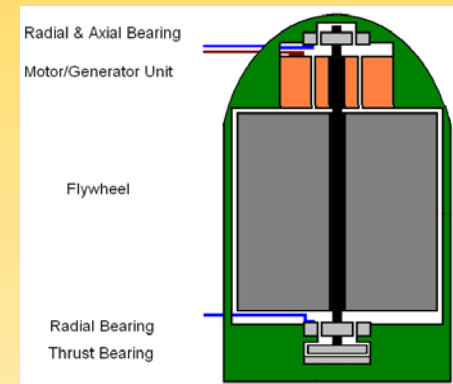
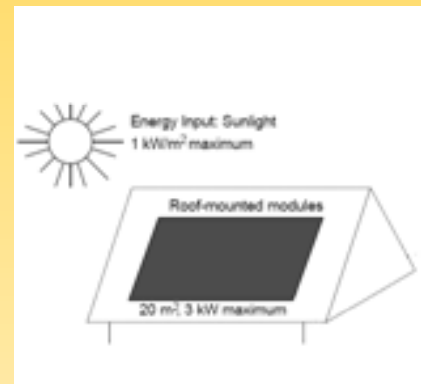
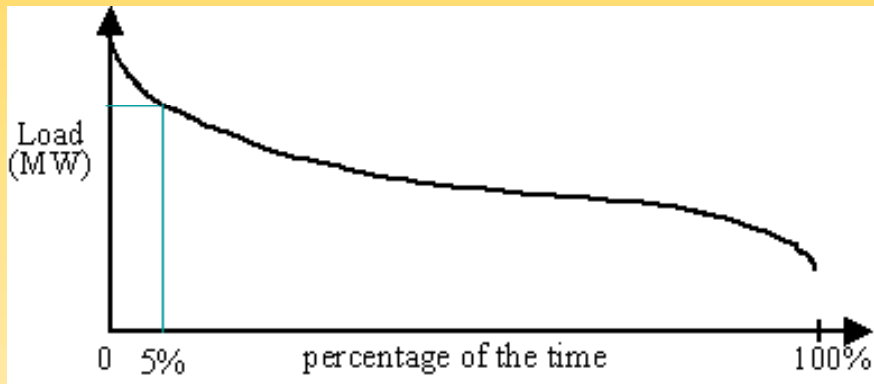
Sodium-Sulfur Batteries

Project Description

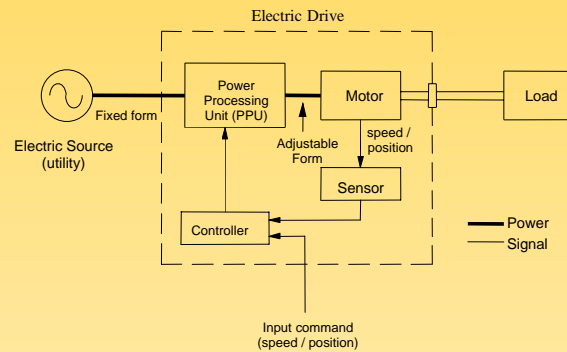
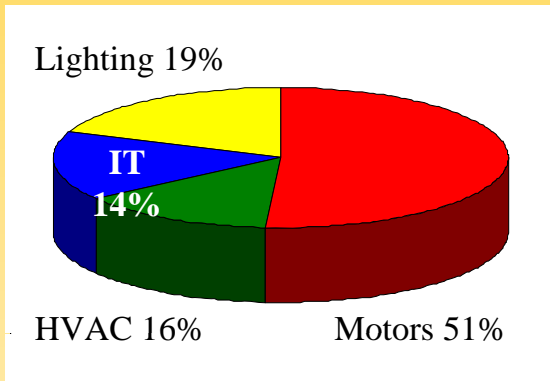
- **1 MW NaS Battery System**
- Can deliver 1 MW for 7 hrs
- Power Conditioning Equipment
- 175 kW backup power
- Wind farm/grid interconnection
- Local and remote data and communication equipment
- **Two Phases of Study**
- Understand how system could optimize wind farm economies
- Understand how system could optimize utility integration of wind resources



Flywheel Energy Storage



Efficient End-Use

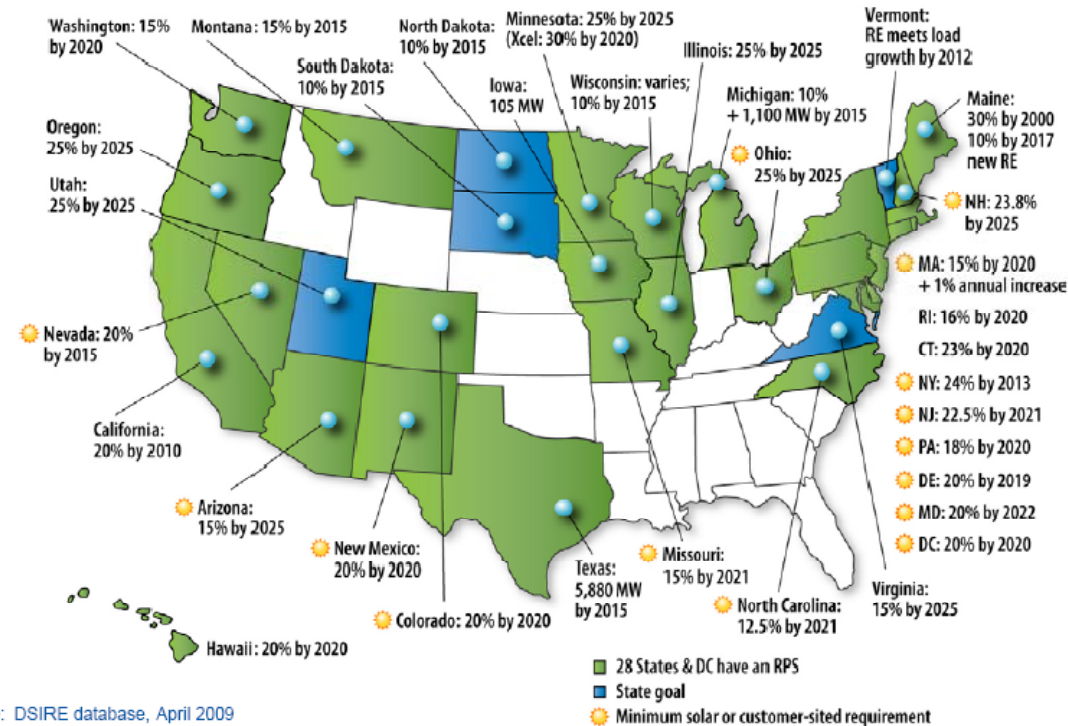


Adjustable Speed Drives



Renewable Portfolio Standards

State Policy Framework Renewable Portfolio Standards

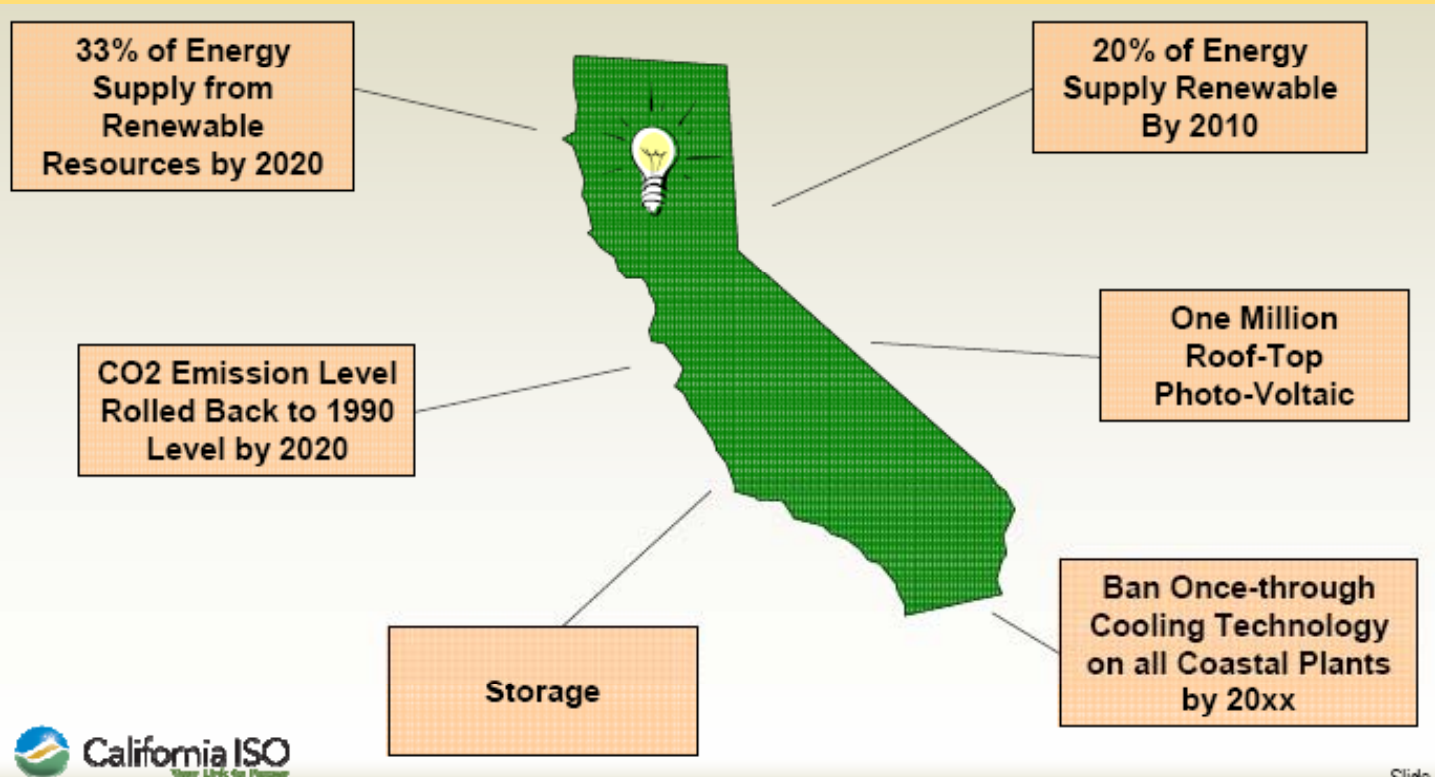


National Renewable Energy Laboratory

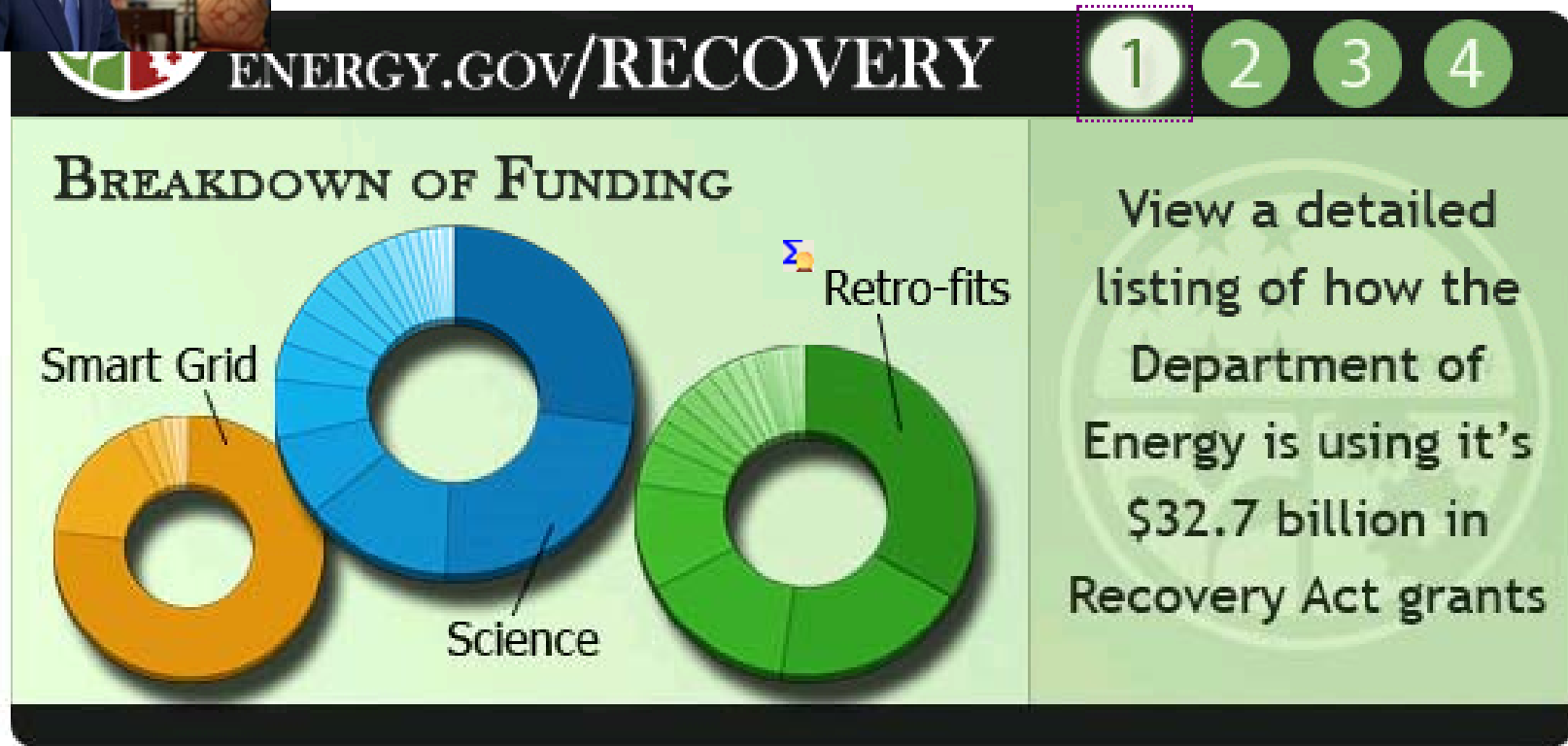
Innovation for Our Energy Future



California RPS



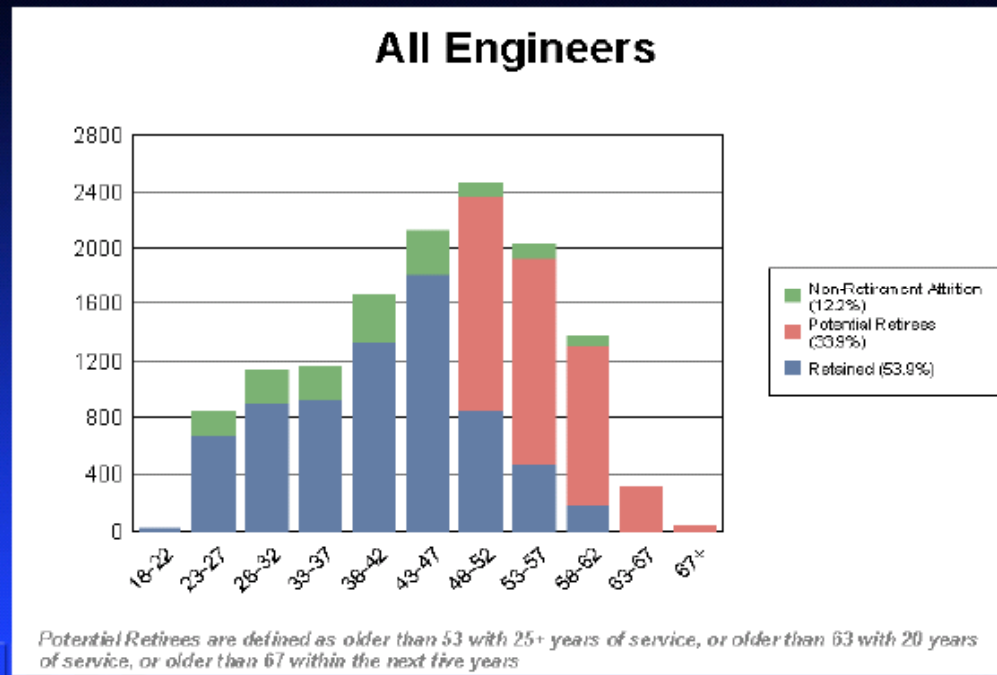
The American Recovery and Reinvestment Act of 2009



Aging Workforce

Engineering Workforce Employees Exiting

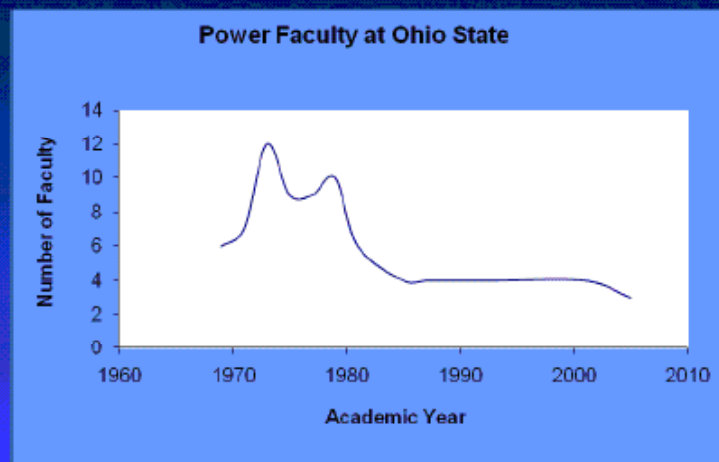
46% of electric utility engineering jobs could be vacated by 2012 *



Faculty Retirements

University Power Systems Engineering Programs

- Weakening programs: Of 48 university programs surveyed in 1987/8 and 2005/6, 50% declined and 15% grew in number of major faculty members.
- Former strong programs declining or ending



Power Engineering Faculty

Carnegie Mellon University:

1975: 8 faculty; 2007: 1

Cornell University:

1975: 7 faculty; 2007: 1

University of Michigan*:

1971: 5 faculty; 2007: 0

UC Berkeley:

1971: 4 faculty; 2007: 1

Univ. of Missouri-Columbia:

1975: 8 faculty; 2007: 0

* Recent decision to rebuild program



Source: IEEE Power Engineering Education Committee Survey
Results for Various Academic Years.



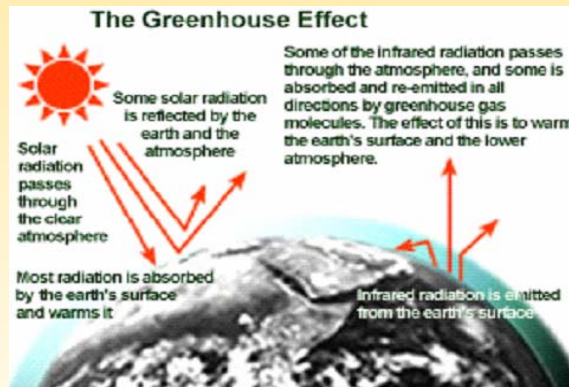
Crisis in Undergraduate Education

- Courses have not kept pace with industrial practices
- Fail to address present and future opportunities
- Power Programs have stagnated



But we can fix it.....

- Young people are concerned about the environment
 - We can tap into their enthusiasm
 - Provide them a clear career path



Choice of Focus Areas

1. **Electric Energy Systems**
2. Control
3. Computer Engineering
4. Optics
5. VLSI
6. Digital Signal Processing
7. Magnetics
8. Micro-Electronics
9. MEMS, Nano
10. Solid-State Devices

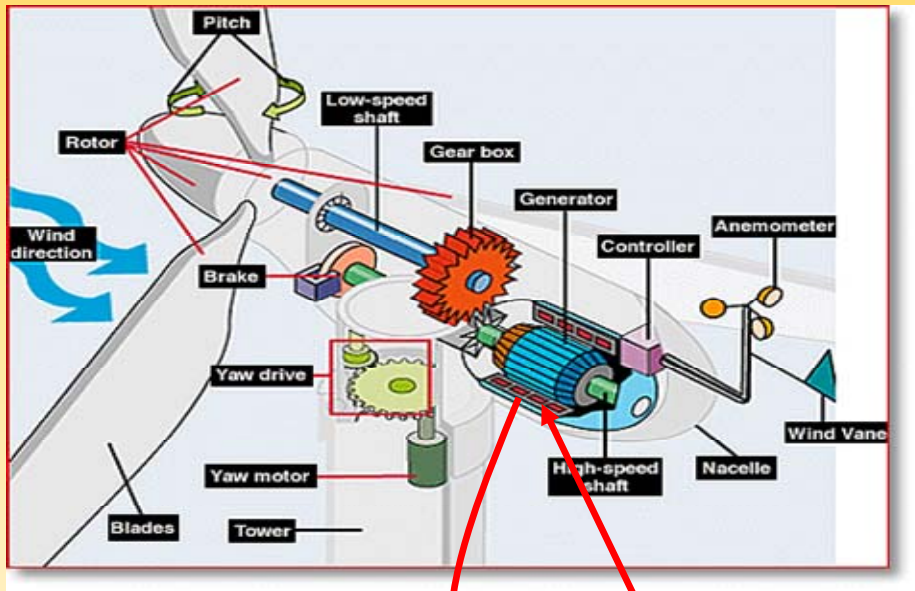


Basis for Curricular Reform

- Integrated Curriculum
- Benefits Students
 - Fundamentals based
 - Students are flexible in their employment



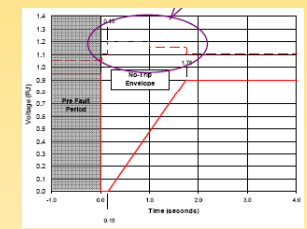
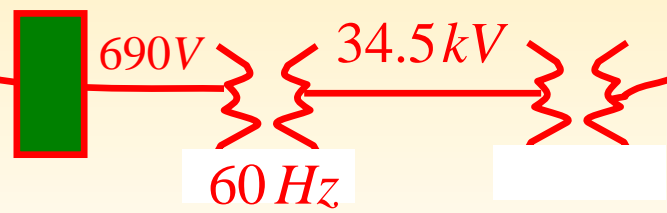
Example of an Integrated System



0 – 690V
10 – 60 Hz

Generator

Power Electronics Converter

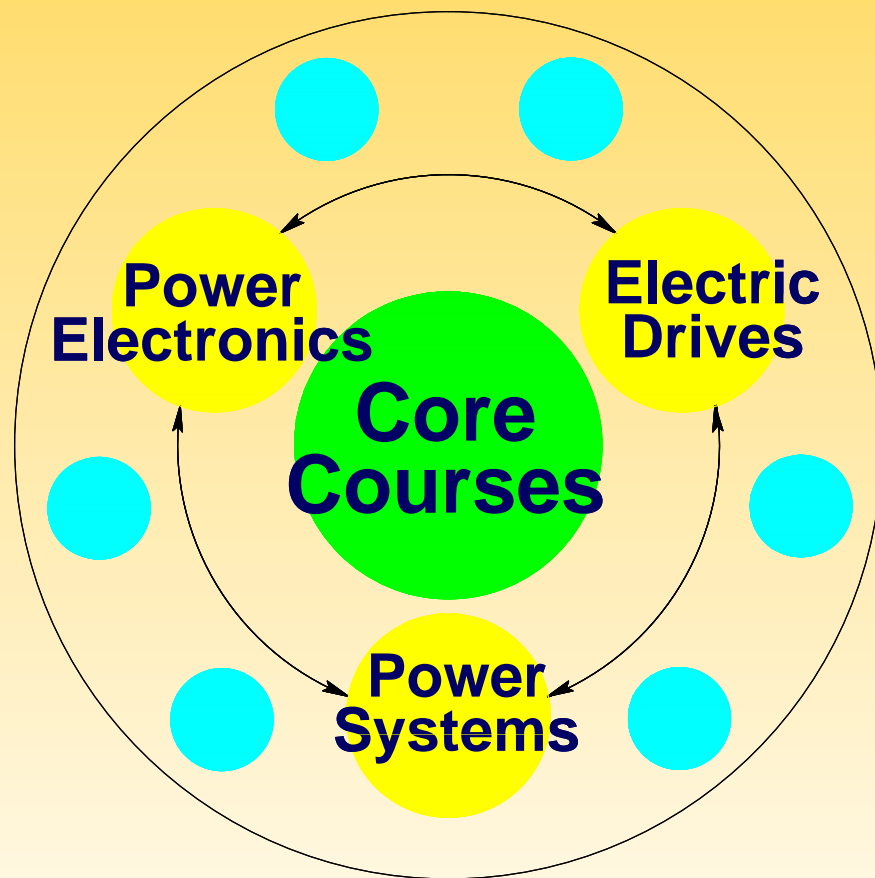


Voltage Ride-Through

161kV



Only 3 Senior Electives



● ≡ Complementary Course

Complementary Courses

- **Analog and Digital Control courses**
- **Embedded Controllers: DSP and FPGAs courses**
- **Course on Analog Circuit Design**
- **Programming Language courses**
- **Course on Heat Transfer**
- **Course on Thermodynamics**

A Senior-Design Project Required



Curriculum Developed

Power Electronics

Features:

- Switching Power-Pole as the Building-Block
- Includes dc-dc Converters and dc-ac Inverters
- Feedback control of Converters

Textbook

- Slides
- Solutions manual



Hardware Lab



- Course Learning Objectives
- Online Homework Problems

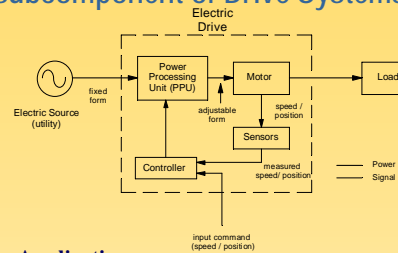
Vendor:



HiRel Systems
Duluth, Minnesota
Phone: 218-727-3115

Electric Drives

Teaching Machines as a subcomponent of Drive Systems



Applications:

- Harnessing of Wind Energy
- Electric and Hybrid-Electric Vehicles

Textbook

- Slides
- Solutions manual

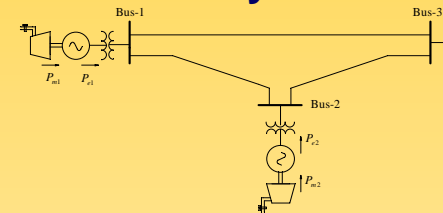


DSP-Controlled Lab



- Course Learning Objectives
- Online Homework Problems

Power Systems



Includes Topics such as

- Renewables/Storage
- HVDC, FACTS
- Voltage Stability

Textbook

- Slides
- Solutions manual



Software-based Lab:

- MATLAB/Simulink, PowerWorld, EMTDC
- Complete Lab on CD
- 18 Short Video Clips

- Course Learning Objectives
- Online Homework Problems

Lab Manuals can be downloaded from:
www.ece.umn.edu/groups/power

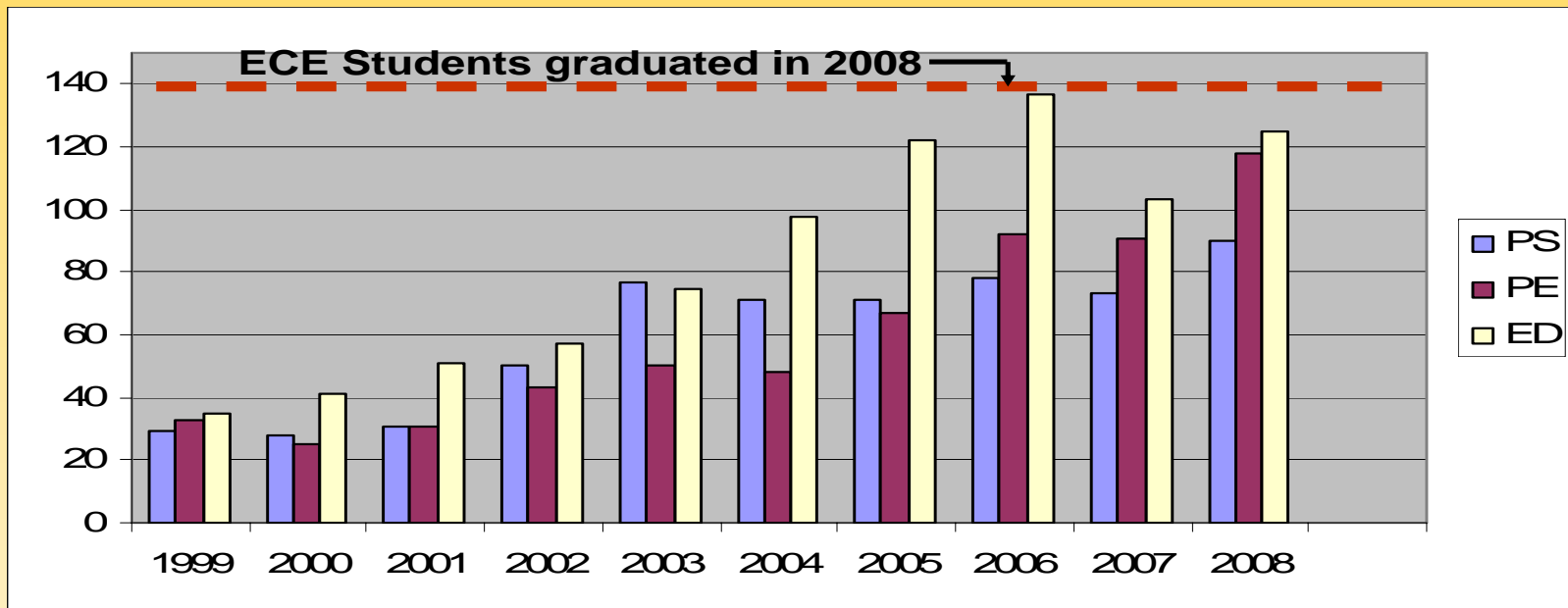


Curriculum – What is Unique?

- Only 3 Courses
- Room for Complementary Courses
- Courses are Carefully Designed
 - Fundamentals based (not overview-type)
 - More Topics in Greater Depth
 - Supported by Textbooks
 - State-of-the-Art Laboratories
 - Prepare Students for Lifelong Learning



Increasing Student Enrollments



Academic Year 2008-2009:

Power Systems – 90

Power Electronics – 118

Electric Drives - 124





Dissemination Success and Goals

- Over 100 schools using it in various combinations
- Hardware Laboratories in 97 University Courses
- Goal is to reach 175 schools by the end of the ONR Grant



Available Resources

All Necessary Materials

- Course Learning Objectives
- Textbooks (Presentation Slides, Solutions Manuals)
- Labs
- Online Assessment Problems

Annual Faculty Workshops to Exchange ideas

Weeklong Summer Training Workshops



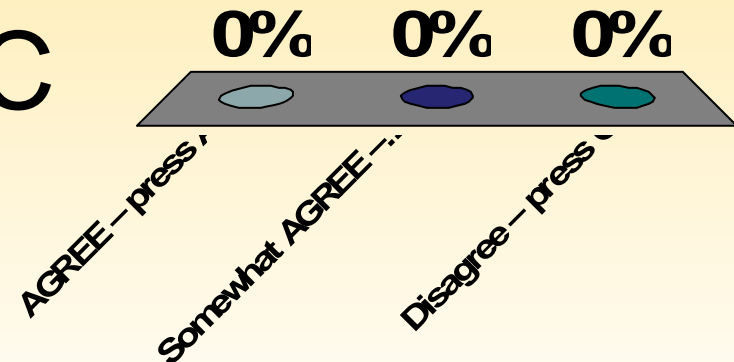
Question

- Undergraduates will benefit if broadly trained (i.e., the graduate school is the place to specialize)
 - Agree: Press A
 - Somewhat Agree: Press B
 - Disagree: Press C



Undergraduates will Benefit if Broadly Trained (i.e., Graduate School is the place to Specialize):

- AGREE – press A
- Somewhat AGREE – press B
- Disagree – press C



Undergraduates will Benefit if Broadly Trained (i.e., Graduate School is the place to Specialize):



Attention to Pedagogy

NSF CCLI Type-1 Proposal with Prof.
Allison Kipple of NAU and Prof. Tamara
Moore of UMN (1/1/2010-12/31/2012)

“Collaborative Research: An Innovative
Instructional Strategy for Widespread
Implementation of Electric Energy Systems
Curriculum, as a Model in STEM Education”



Preparing the Workforce on a National Scale

- CI-EESE (Center for Innovation in Electric Energy Systems)
 - Members: Midwest ISO, NY ISO, ISO-NE, Air Force Research Lab, Hamilton Sundstrand
- Creating Internet-Based Course Modules
 - Useful to Practicing Engineers
 - License to Universities
 - to Offer a Minor or a Certificate
- Online Short Courses
 - Power Systems Protection in 2009
 - Over 300 registrants



Curriculum on Wind Power

October 15, 2009

Secretary Chu Announces New Investments in Cutting-Edge Wind Energy Research Facilities

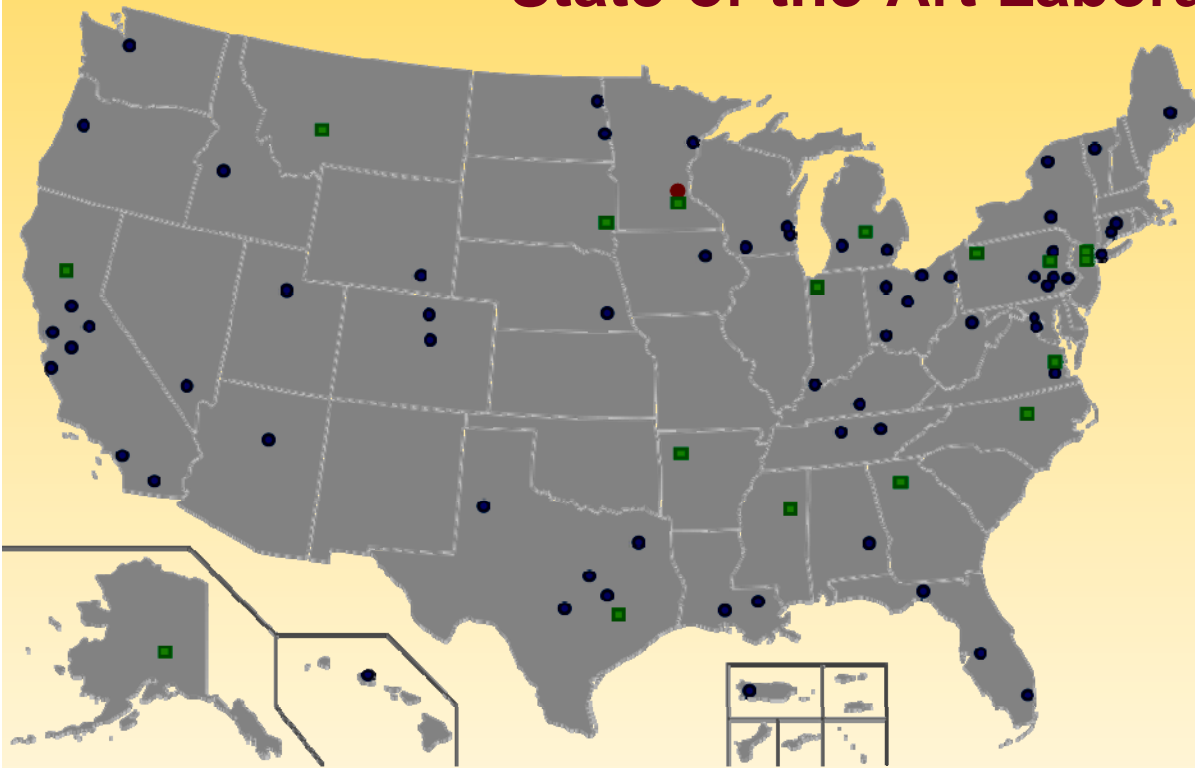
Recovery Act funding to support wind energy technology research, development, and career education opportunities at three U.S. universities

- **University of Minnesota (Minneapolis, Minn.) – up to \$8 million**

The University plans to install a new Siemens 2.3 MW turbine research facility at the University of Minnesota Outreach Research and Education (UMore) Park in Rosemount, Minnesota to study novel mechanical power transmission and electric generator systems. The University consortium's research and development plan includes active and passive flow control strategies to increase energy capture, broaden the operational envelope of the turbine, and reduce structural loads and fatigue. The University of Minnesota's turbine will be in close proximity to an existing wind farm, providing an opportunity to further validate and reinforce research findings regarding turbine wake interaction, wind farm interaction, and wind energy efficiencies. The educational initiatives include new graduate and undergraduate web-based course modules, programs specifically focused on wind power technologies and integration with other renewables, and student internships with industrial partners at consortium field sites.



**Applied to DOE-FOA-152:
“A Nationwide Consortium of Universities to
Revitalize Electric Power Engineering Education by
State-of-the-Art Laboratories”**



82 Universities

“These 82 schools represented about 25% of all the graduates in electrical engineering in 2008.” – William P. Robbins



Workshop Agenda

Friday 10:15-12:00 p.m.

- **Details of the Proposed Curriculum**
 - Power Electronics: *Bill Robbins*
 - Power Systems: *Bruce Wollenberg*
 - Electric Drives: *Paul Imbertson*

12:00-1:30 Lunch (on your own)



Friday Afternoon

1:30-2:15 p.m.

- **Pedagogy**
 - Allison Kipple, NAU
- **Online Courses**
 - Heather Dorr, UMN

2:15-3:30 p.m.

- ***Open Discussion of UMN-Proposed Curriculum***



Friday Evening

3:30-5:30 p.m.

- **Poster Session**

6:00-7:00 p.m.

- **Working Group Meetings**

- Curriculum Advisory Board – Nari Hingorani
- Dept Heads/Deans Working Group – Issa Batarseh

7:00-8:30 p.m.

- **Banquet**

- Speaker: Candace Thille



Saturday Morning

7:30-8:00 a.m. Continental Breakfast

8:00-9:45 a.m.

- **Need for Educational Reform and Discussion**
 - Leah Jamieson
 - Dejan Sobajic
 - Terje Gjengedal

10:15-12:00 p.m.

- **Reports of the Working Groups and Discussion**
 - Curriculum Advisory Board: *Nari Hingorani*
 - ECE Dept Heads/Engineering Deans Working Group: *Issa Batarseh*



Saturday Afternoon

12:00-1:30 Lunch (on your own)

1:30-3:30

- **Designing 2nd Courses (Entry-Level Graduate Courses)**
 - Power Systems – Bruce Wollenberg
 - Power Electronics – Hari Krishnaswami
 - Electric Drives- Ted Brekken

3:30-5:00

Summation and Action Plan to reach the ONR-Grant Goal of at least 175 Schools

5:00-5:30

Certificates of Appreciation



President Obama, January 27, 2010



January 27, 2010

...The nation that leads the clean energy economy will be the nation that leads the global economy. And America must be that nation.

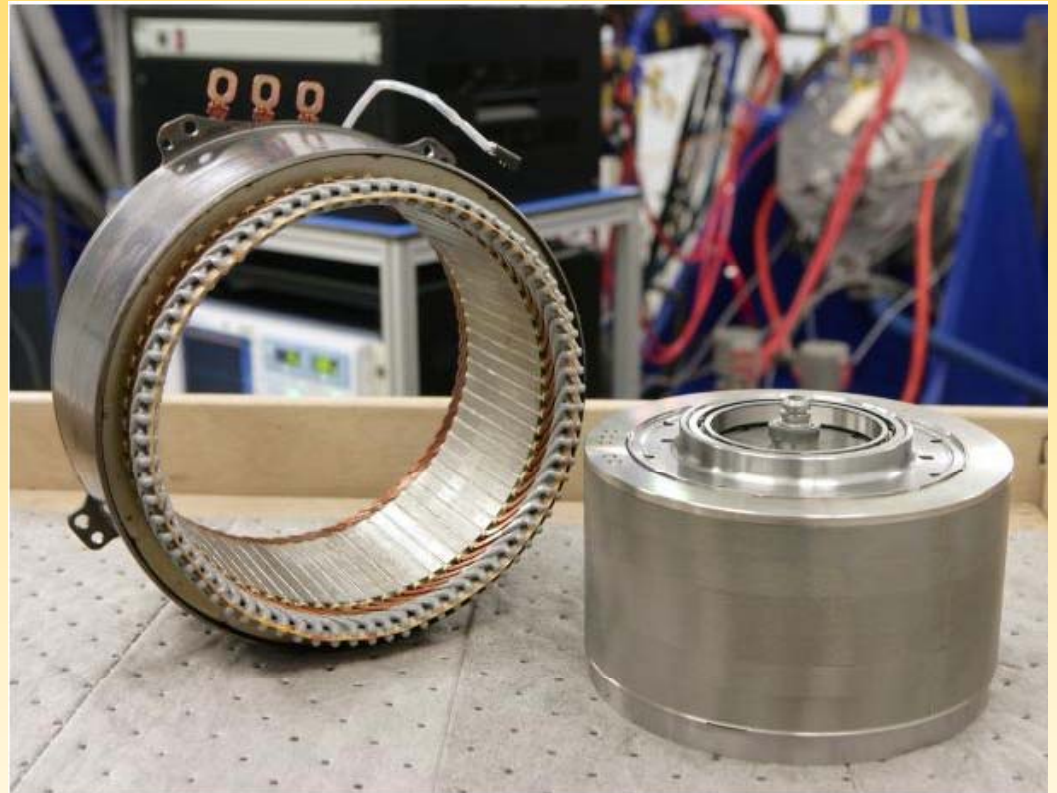


GM to make electric motors in U.S.



COURTESY: GENERAL MOTORS

GM's first new electric motors would be used on vehicles like the next generation of the Chevrolet Tahoe Hybrid



Key to GM's future for hybrids and electric cars: an electric traction motor (right) and stator at GM's Powertrain Engineering Development Center in Pontiac, Mich.

(Credit: General Motors)

“Anything, everything is possible...”

