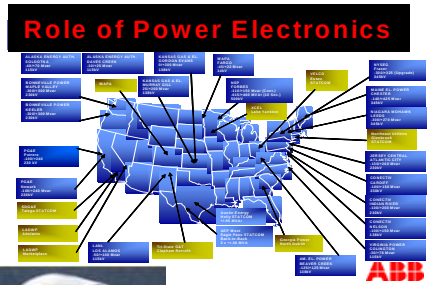
Curriculum Reform in
Electric Energy Systems
With Emphasis on
- Renewables/Storage
- Reliable Delivery
- Efficient End-Use


Wind

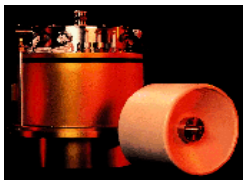

Solar




Hybrid


Fuel Cells


CFL


Flywheels for Storage

ONR-NSFEPRI-AEP Sponsored Workshop
Napa, CA 12-15, 2009

Group Effort:

- Ned Mohan
- Bill Robbins
- Bruce Wollenberg
- Paul Imbertson
- Tom Posbergh
- Dr. Narain G. Hingorani (Consultant)
- Ron Fitch (Distance Learning)
- Heather Dorr and Josette Barsness (Organization)
- Students

www.ece.umn.edu/groups/power

Center for Electric Energy

- History
  - Established in 1981 by Prof. Vern Albertson
  - Present Director - Prof. Bruce Wollenberg
  - Supported by 7 Regional Utilities
  - Budget: ~178 k$/year

Past Sponsors:

Lab Development Grants:

- NSF
- NASA
- ONR

Initial Dissemination Grant:

Present ONR Dissemination Grant:

Program Officer: Terry Ericsen

(1.23 Million Dollars over 5 years)

Supported by:

1. Electric Power Research Institute (EPRI)
   - Clark Gellings: VP-Technology
   - Rosa Yang: VP-Innovation
   - 35 k$ Honorarium to 35 Faculty/yr
2. American Electric Power (AEP):
   - Ray Hayes
   - 20 k$/yr to 10 Universities
3. NSF
   - Dagmar Niebur
   - 10 k$/yr

Perspectives on Need for Curricular Reform

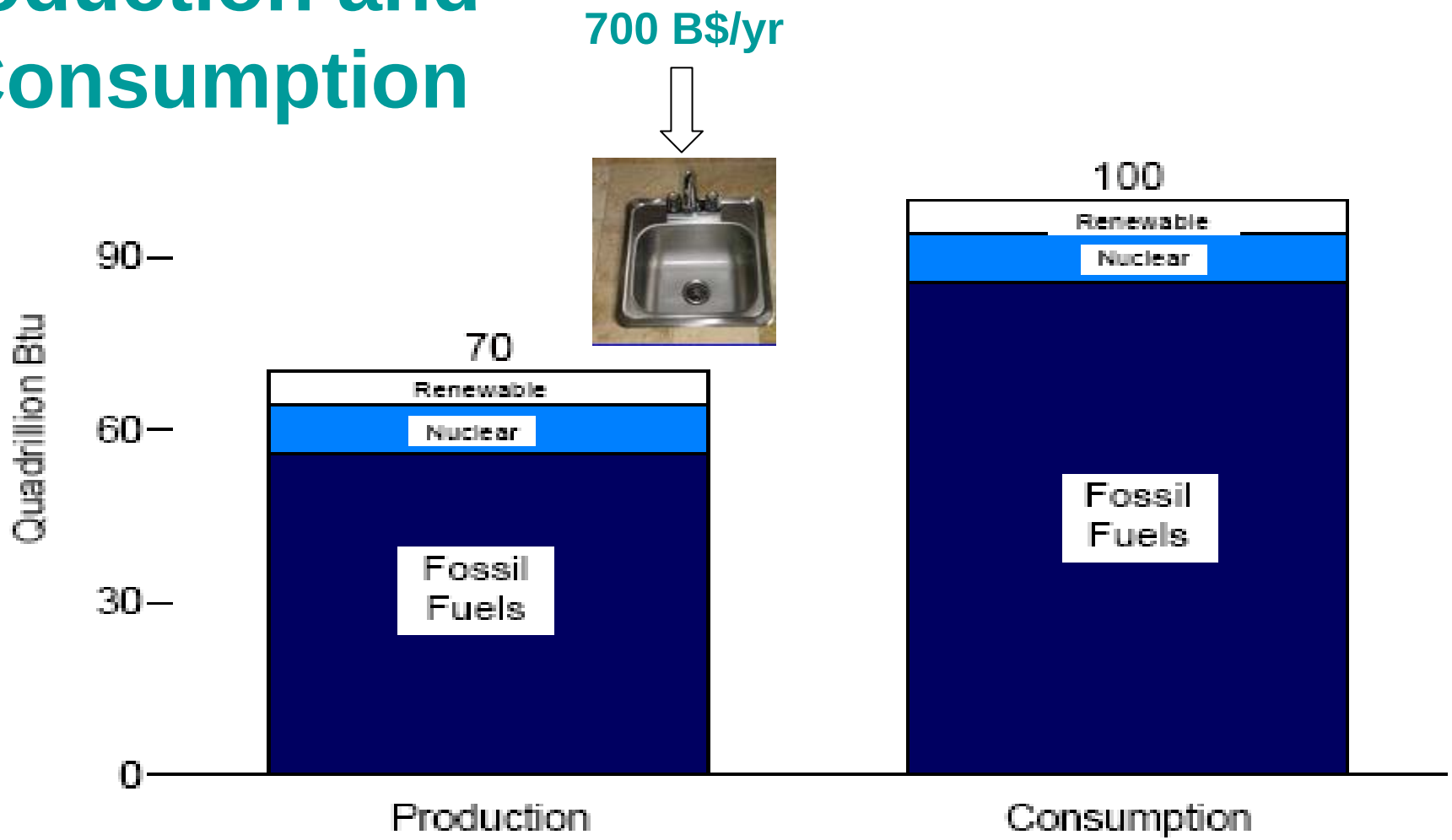
- Terry Ericsen - ONR
- NSF – Barbara Kenny
- EPRI – Clark Gellings
- AEP – Ray Hayes

Outline:

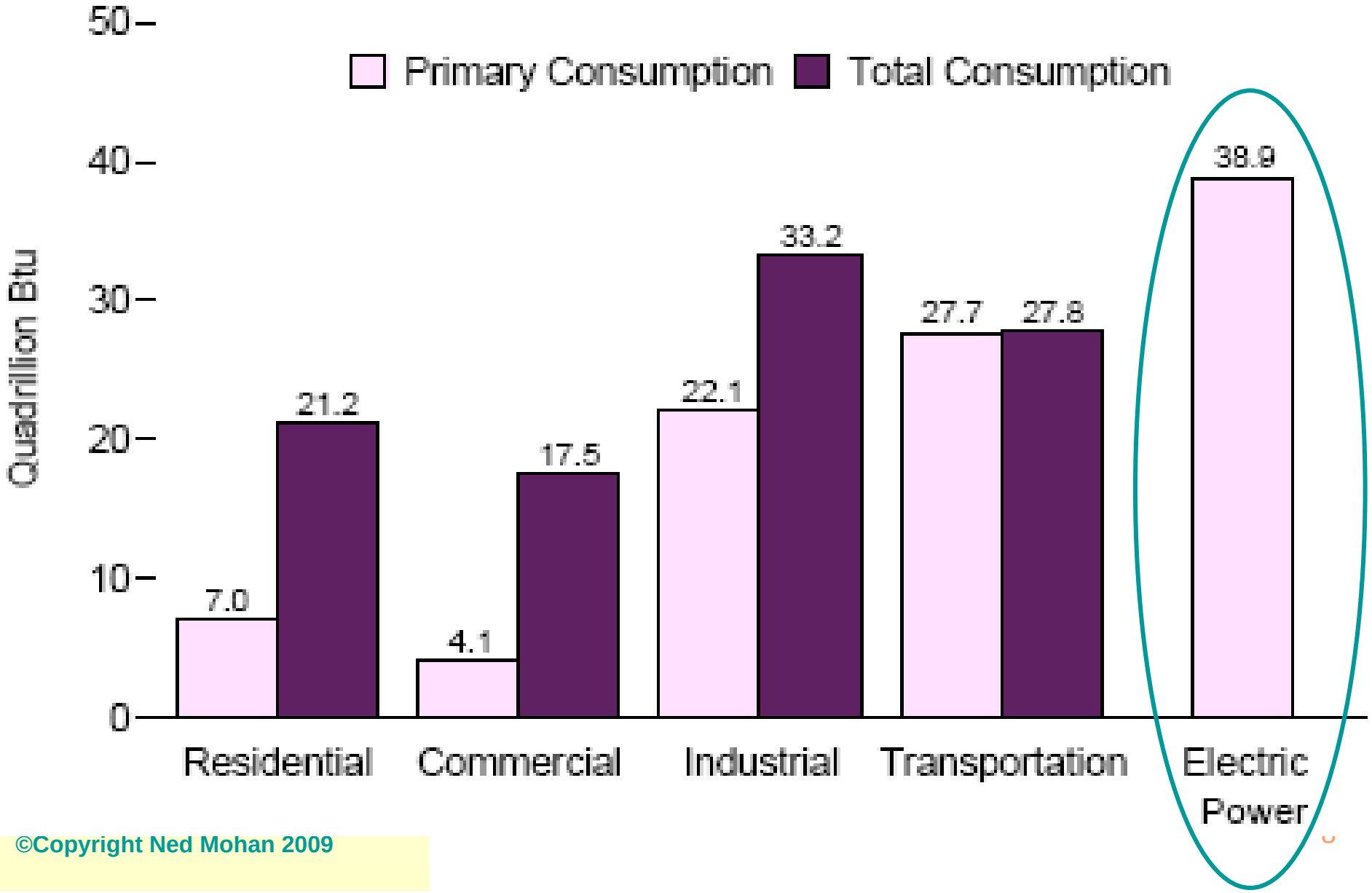
- Crisis
- Opportunities
- Approach
- Results
- Workshop Agenda

Energy Crisis and Climate Change

Production and Consumption



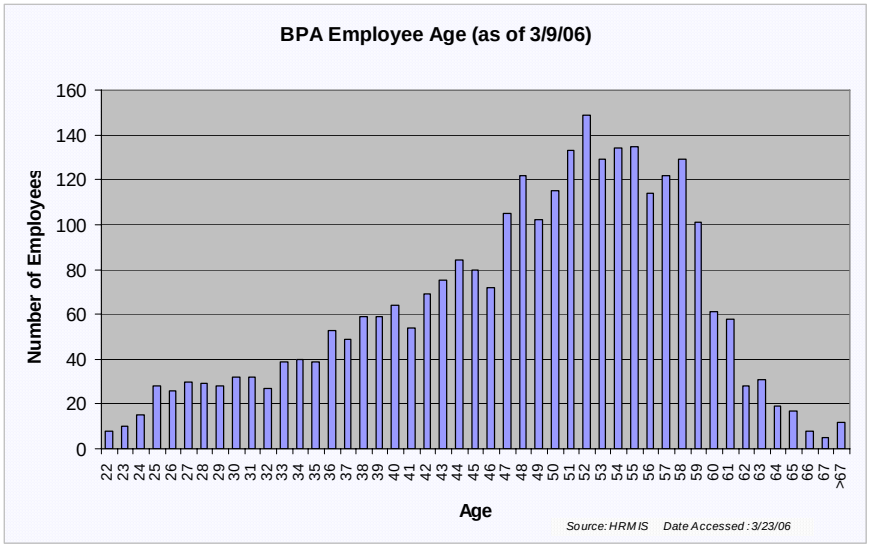
Electric Power as a Percentage



Workforce Crisis:

BPA Workforce:

- 2,944 employees
- Median age is 50
- 21% eligible to retire by 12/07
- 42% eligible to retire by 12/11

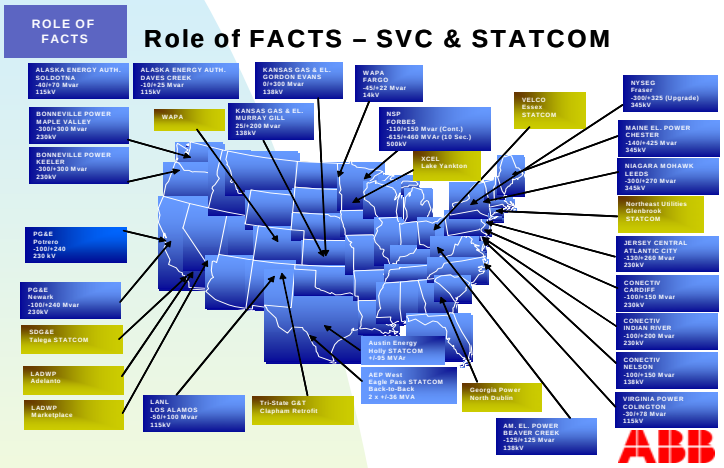


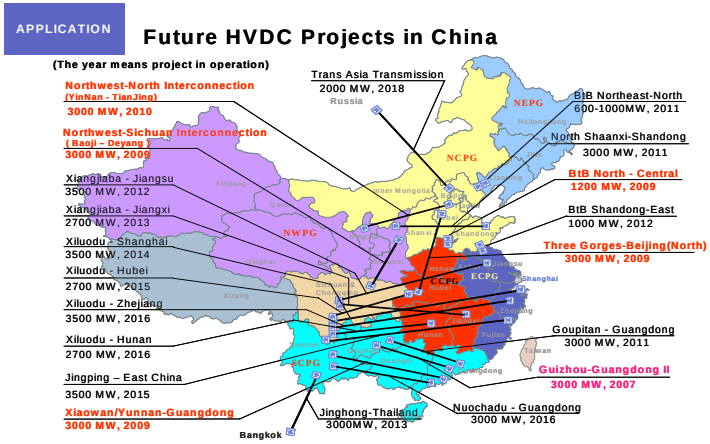
Data Source: HRMIS as of 2/9/06

Source: Clark Gellings, EPRI

Crisis in Undergraduate Education

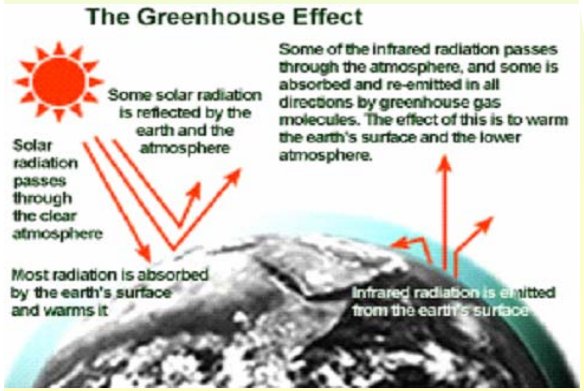
- Courses have not kept pace with Industrial Practices





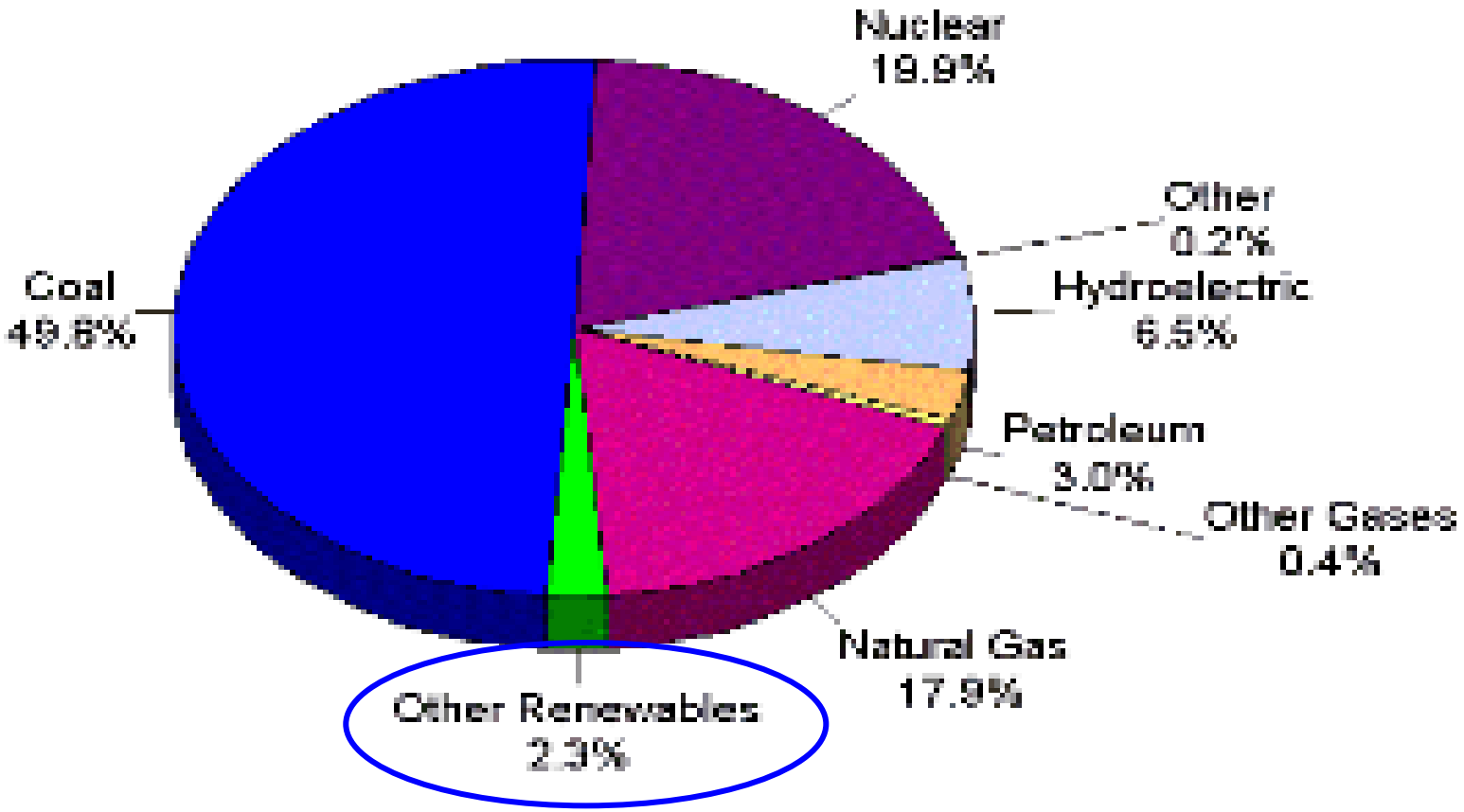
- Power Programs are Stagnating

OPPORTUNITY: Young People are Concerned about the Environment -



We can tap into their enthusiasm to make a difference and provide them a career path.

Electric Power - Generation by Fuel Type:



Electricity from Renewables:

- Wind
  - On-land
  - Offshore
- Photovoltaic
- Wave Energy
- Geothermal

Nuclear (?)

Nuclear Power in Minnesota and the Nuclear Power Renaissance:

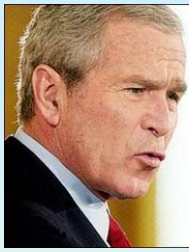
Terry Pickens Director, Nuclear Regulatory Policy, Xcel Energy

www.ece.umn.edu/groups/power

Internet-based Monthly seminars (seminar 14, June 27, 2009)

Renewable Portfolio Standards (RPS)

"Wind can supply up to 20% of U.S. electricity"
President Bush, February 21, 2006

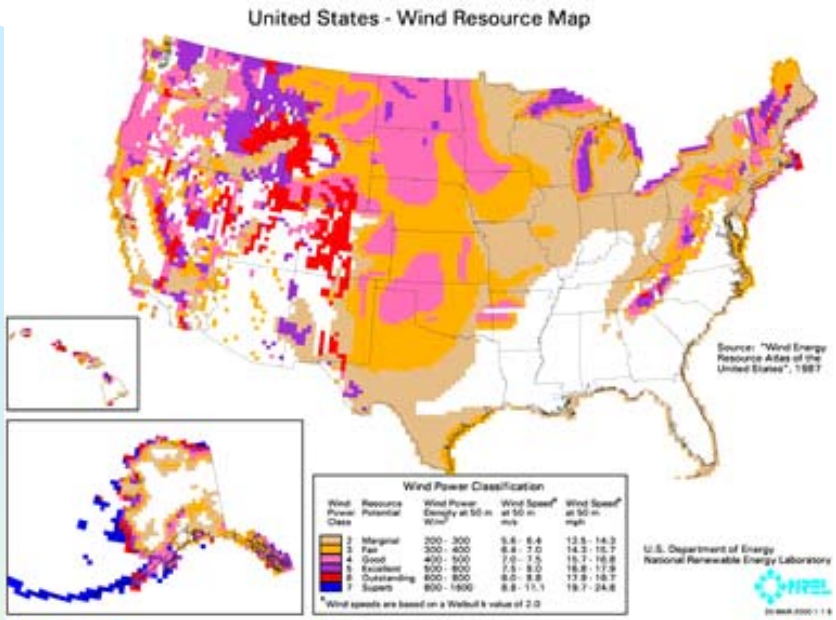


Governor Pawlenty signs renewable energy law

Al Gore's Call for 100% Renewable Energy Within 10 Years

WIND

DOE estimates offshore resources to be 900,000 MW.

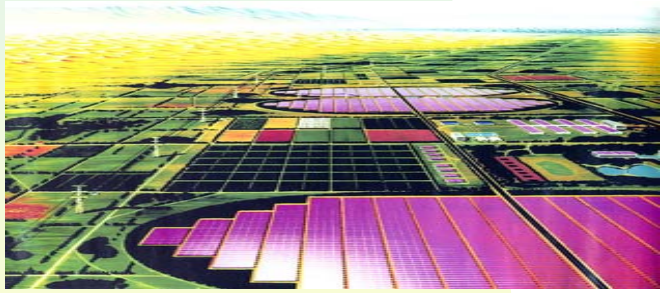


Cost of Electricity

- Coal-Fired: 5.0- 6.0 ¢/kWh
- Single-Cycle Gas-Fired: 20 ¢/kWh
- Combined-Cycle Gas-Fired: 8.0-10.0 ¢/kWh
- Wind Turbines:
  - 6.0 ¢/kWh with PTC*
  - 8.0 ¢/kWh w/o PTC*

*PTC – 1.9 ¢/kWh

“ The new wind projects account for about 30% of the entire new power-producing capacity added nationally in 2007 ….”



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

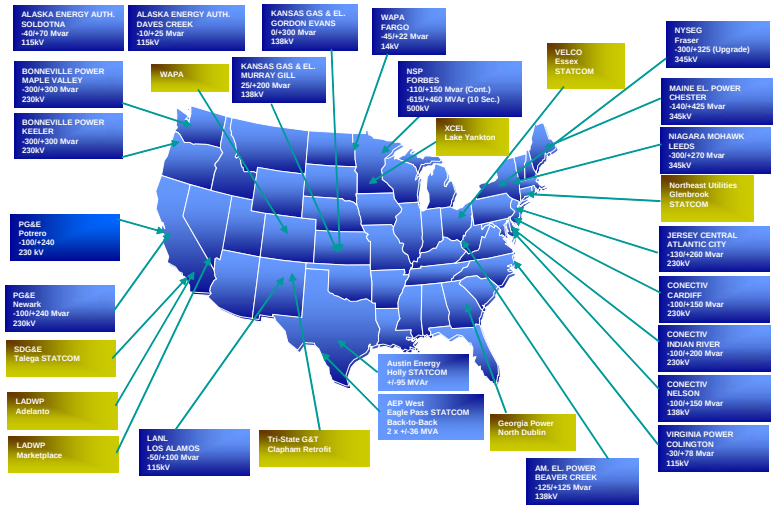
Sodium Sulfur Battery Energy Storage and its Potential to Enable Further Integration of Wind

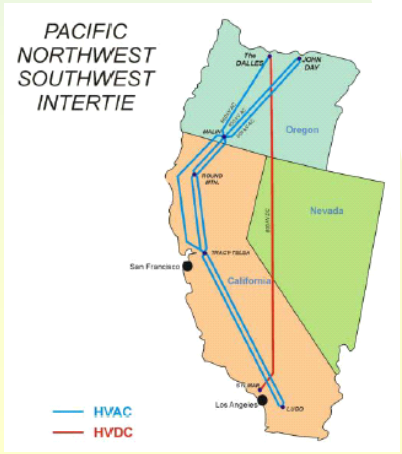
By Xcel Energy

Reliable and Efficient Delivery:

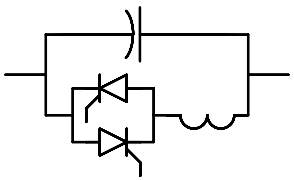
HVDC Projects in North America

Role of FACTS – SVC & STATCOM

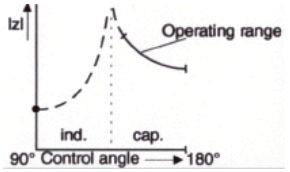




TCSC



(a)



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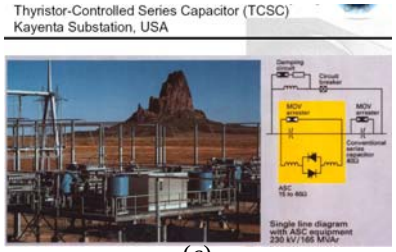
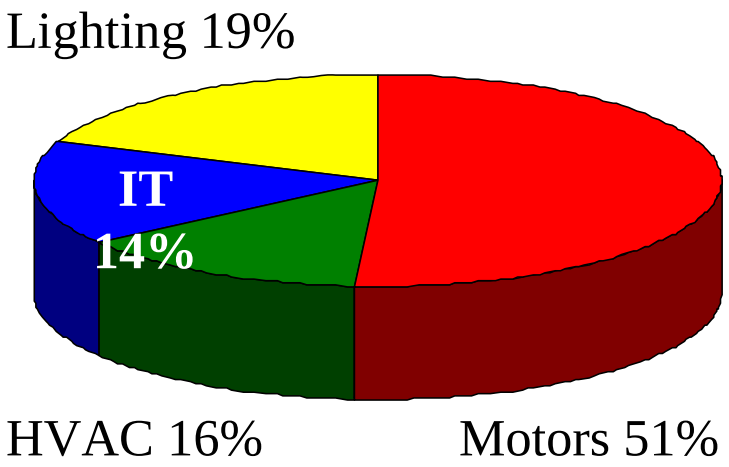
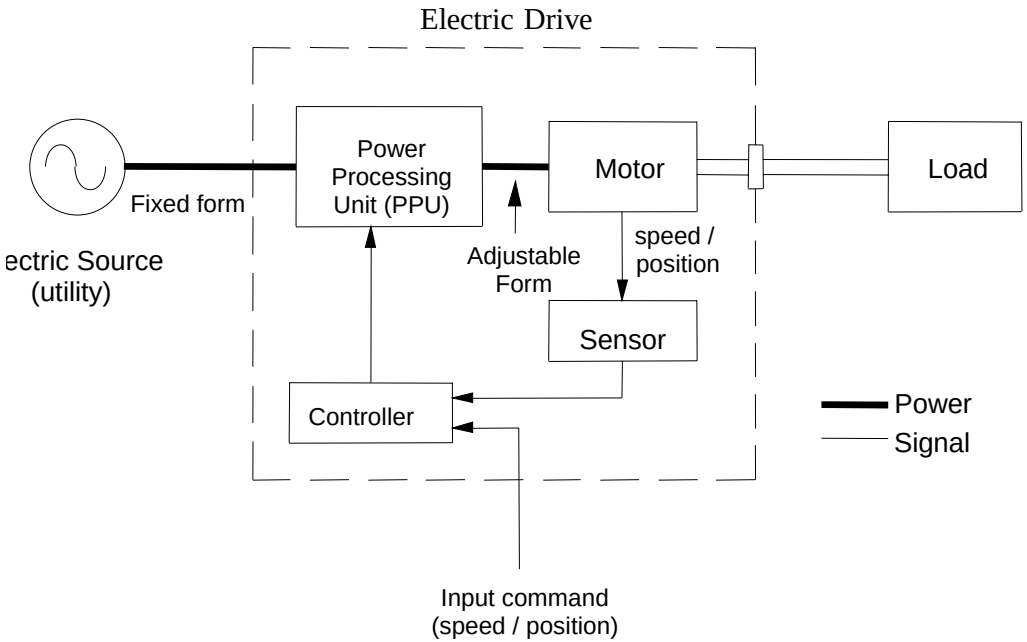


(c)

Efficient End-Use:

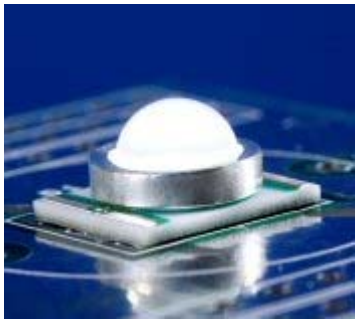




Adjustable Speed Drives

Plug-in Hybrid?

CFL

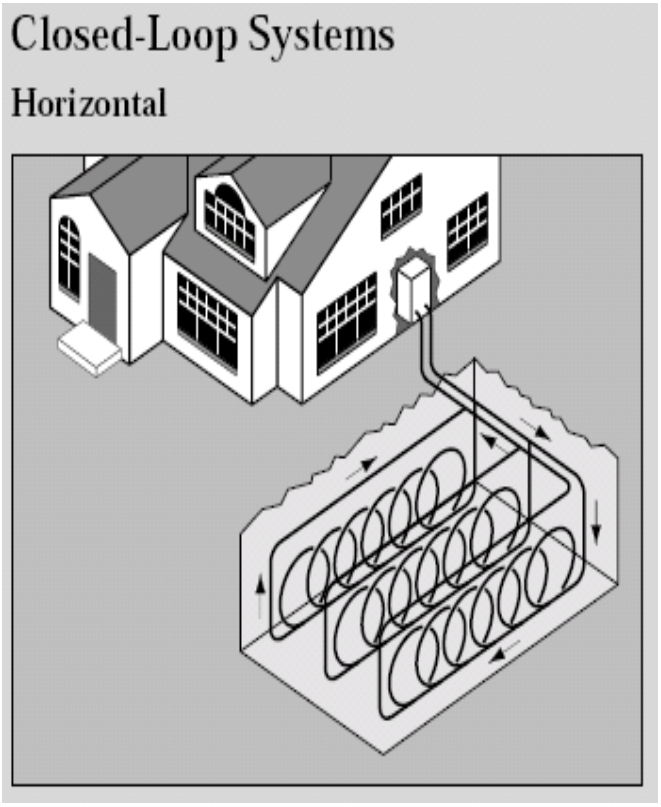


LED Lighting

Geothermal Heat Pumps

Warren Gretz, NREL/PIX06534

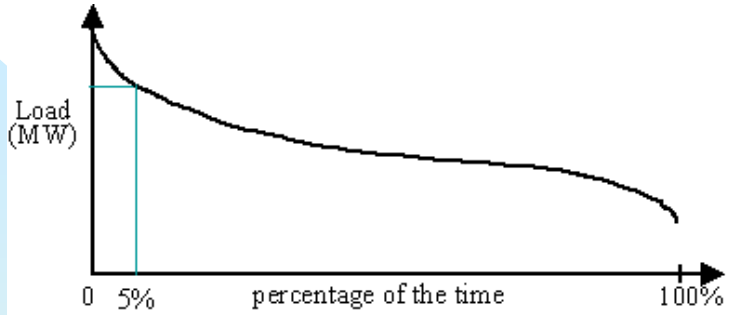
For a home of 1,500 square feet with a good building envelope and a geothermal heat pump, energy costs are about one dollar a day.

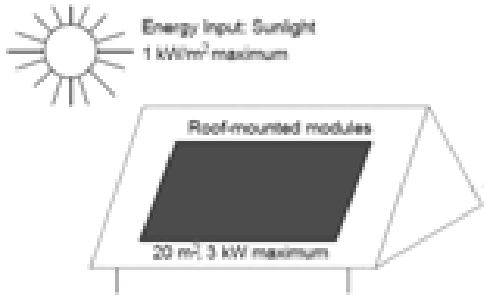


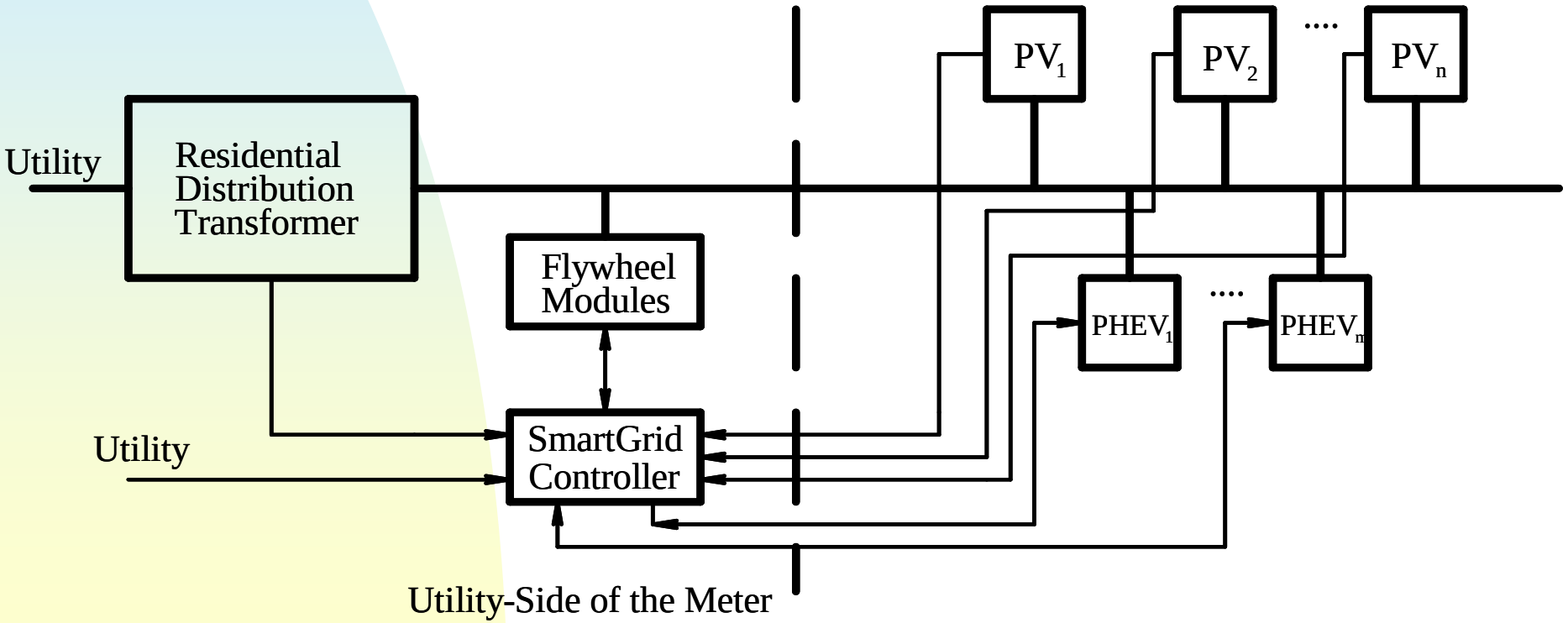
Role of Adjustable-Speed Drives

Plug-In Hybrid Electric Vehicles

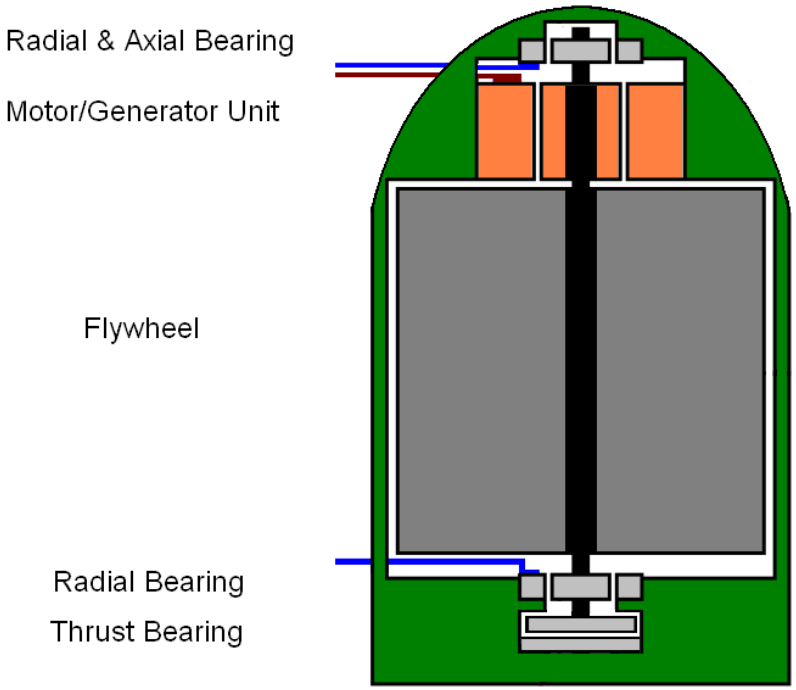
Flywheel Energy Storage







Flywheel Energy Storage

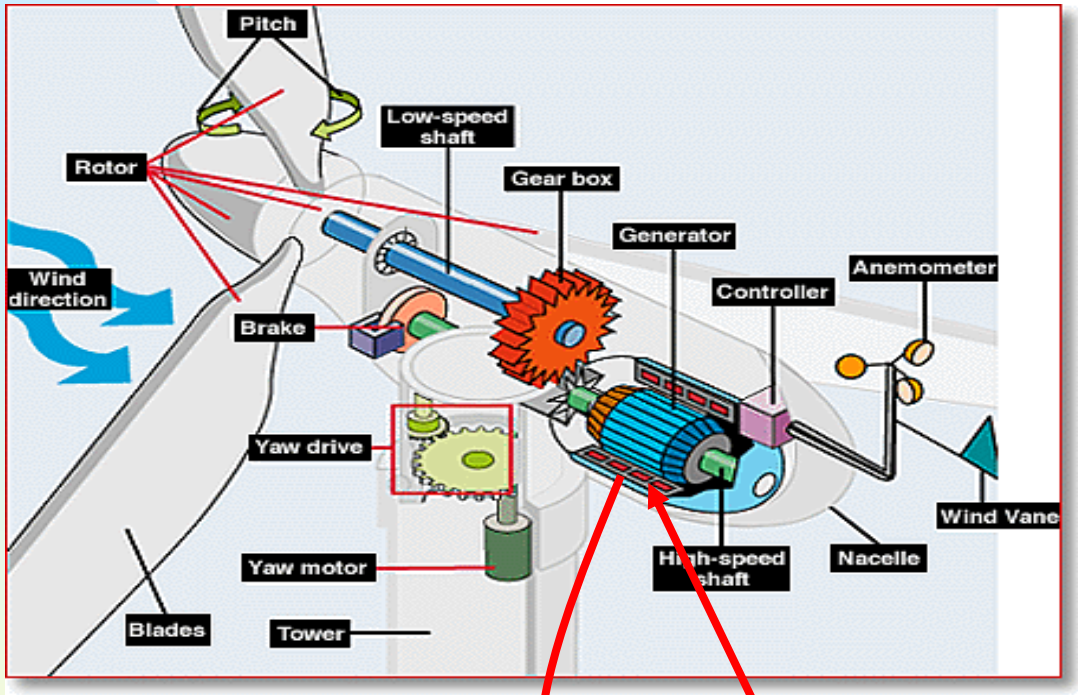


Our Response:

Design an **Integrated** Curriculum

- **Benefits Students**
  - Meets Breadth and Depth Requirements
  - Independent of Workforce Shortages
  - Emphasizes Renewables

Wind Generation: Example of an **Integrated** System



$161kV$

V

0

$Time$

Low-Voltage Ride-Through

$0-690V$
$10-60\,Hz$

Generator

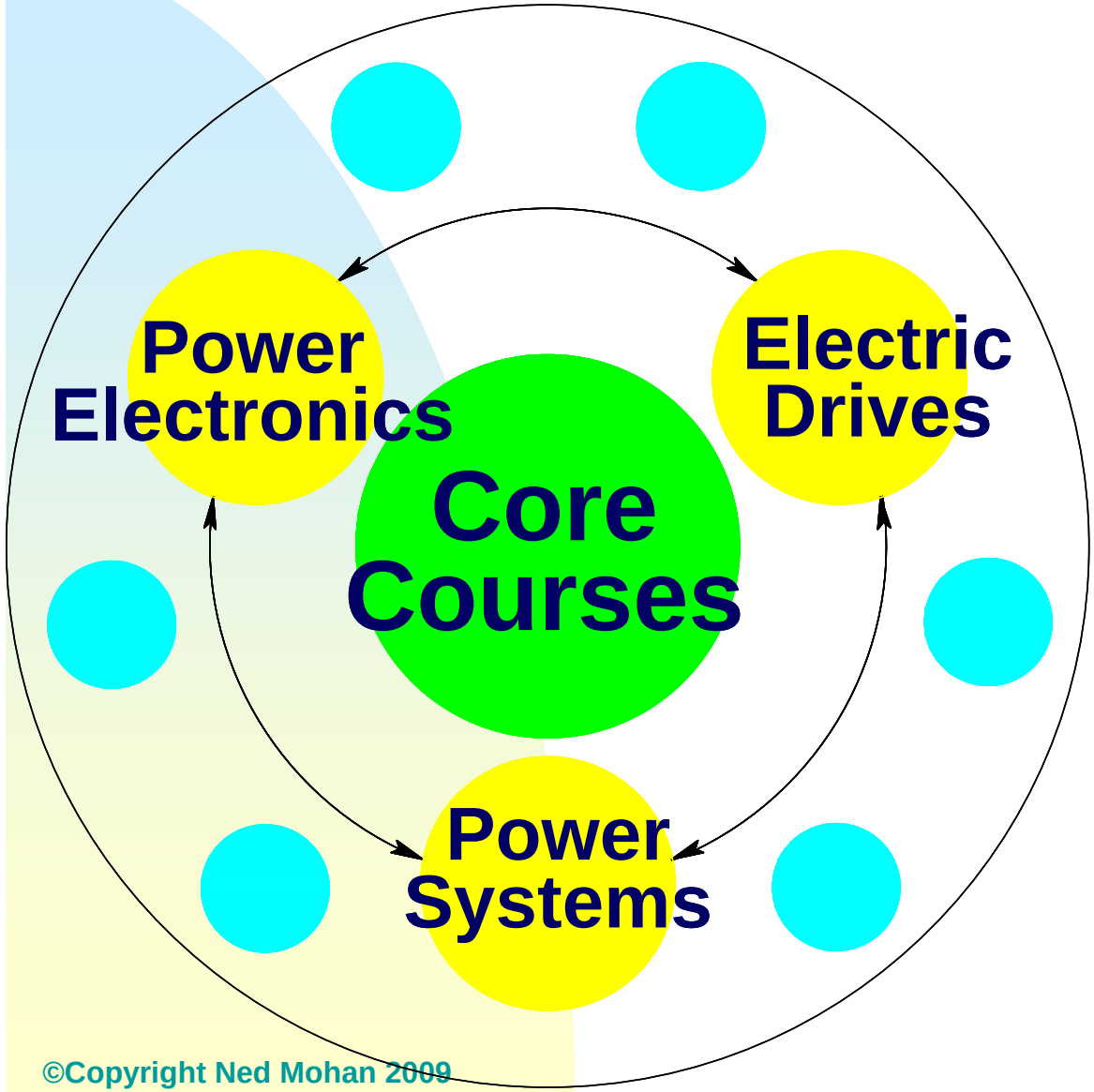
$690V$

$34.5kV$

$60\,Hz$

Power Electronics Converter

Electric Energy Systems Focus Area: Only 3 Senior Technical-Elective Courses



≡ Complementary Course

Core Courses
(First 3 Years; common to all focus areas)

- Physics
- Chemistry
- Math
- Liberal Arts Requirements
- Basic Electric Engineering Courses
  - Circuits and Systems: dc, step-response, steady state ac, Laplace Transform, Fourier Transform, Phasor Analysis
  - Electronic Circuits
  - Electro-Magnetic Fields

Students can choose one of these Focus Areas in the 4th Year:

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

Breadth and Depth Requirements in Senior Electives at UMN:

- Breadth Requirement
  - At least one course each in four areas
- Depth Requirement
  - At least two courses in one area
- Similar at Numerous Other Universities

Suggested Complementary (5 to 6) Senior Technical-Elective 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

Continuing Education:

- As a Graduate Student – MS or PhD
- Internet-based Distance Education
  - as a Graduate Student
  - as a Non-Degree Student
- Short Courses for CEUs or PDH

Benefits of Our Approach:

- Broader range of topics in each course
- More in-depth coverage!
- Students are broadly trained
- Domestic Graduate Students (?)

Audience Response:

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

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

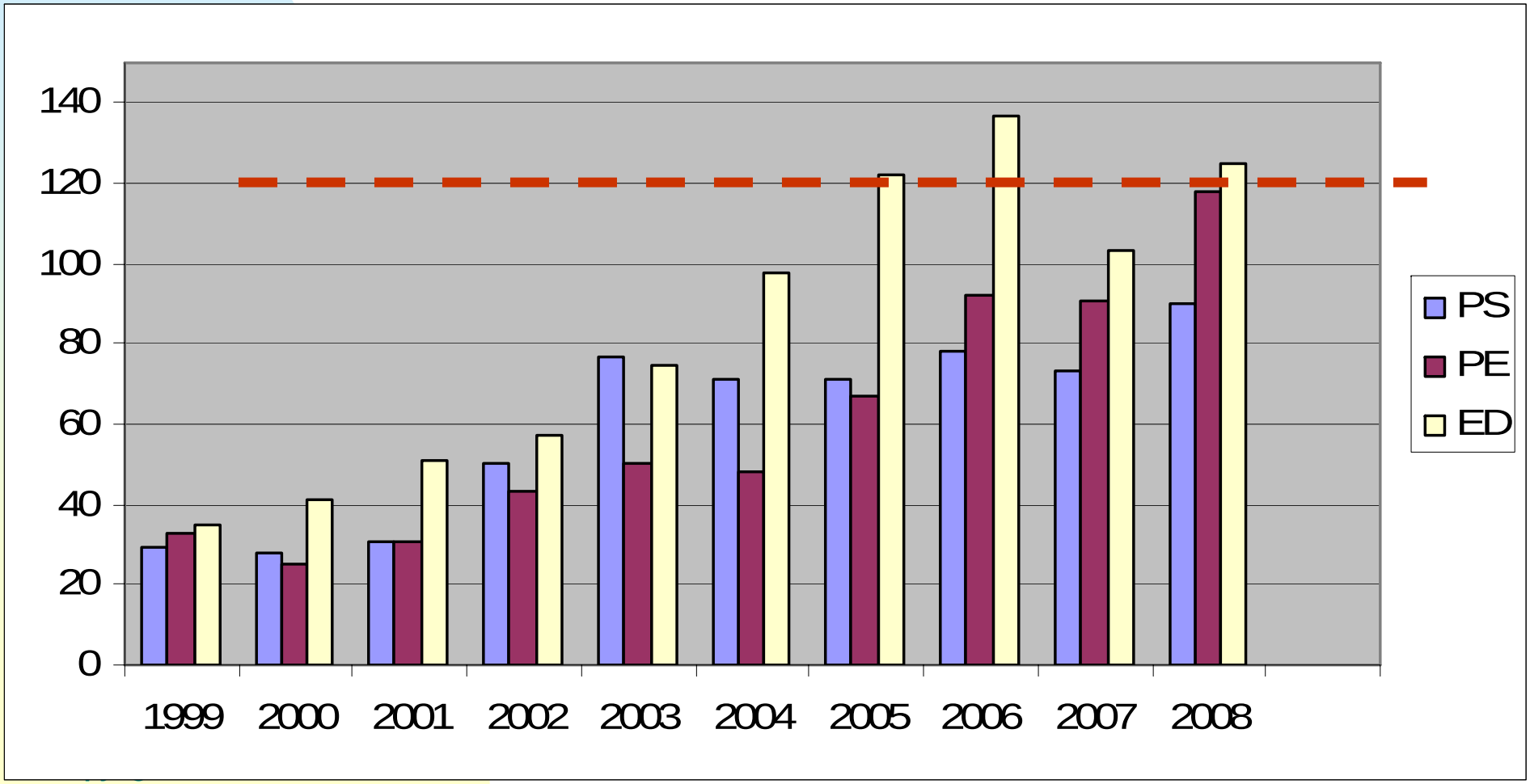
Pedagogy:

- Online Homework Problems
  - TA as a co-Teacher
- Student Response System
- Field Trips

Gender Equality: A Goal

Increasing Student Enrollments –

2008-2009 at UMN: **Power Systems (PS): 90**
Power Electronics (PE): 118
Electric Drives (ED): 125



Mission:

- Affect Curricular Change in at least **175** Schools Nationwide
  - Adapted already in various combinations at ~**100** schools

Distance Education:

- **For Practicing Engineers**
- **University Education (?)**

- Ron Fitch and Heather Dorr – 1:45-2:00 PM

Available Resources:

- All Necessary Materials
  - Course Learning Objectives
  - Textbooks (Presentation Slides, Solutions Manuals)
  - Labs
  - Online Assessment Problems
- Annual Faculty Workshops to Exchange ideas
  - Join the Community of Teaching Scholars
- Weeklong Summer Immersion Workshops
  - Travel Expenses paid plus honorarium

Workshop Agenda

10:30-12:00 p.m.

Details of the Proposed Curriculum and UMN Developed Laboratories

- **Power Electronics – Bill Robbins**
- **Power Systems – Bruce Wollenberg**
- **Electric Drives – Paul Imbertson**

1:30-1:45 PM

Description of Corvallis, OR: Site of 2009 Summer Faculty Workshop – Ted Brekken

1:45-2:00 PM

Distance Education – Ron Fitch, Heather Dorr

3:00-3:30 PM

Open Discussion of UMN-Proposed Curriculum and Online Courses: Chaired by Julie Ellis

3:30-5:00 PM

Invited Poster Session (Coffee + Cash Bar)

6:00-7:00 PM

- **Curriculum Advisory Board Meeting** – Chaired by Nari Hingorani
- **ECE Dept Heads Working Group Meeting** – Chaired by Marc Bodson

7:00-8:30 PM **Banquet (spouses invited)**:

Presentation by Dr. Terje Gjengedal, VP-Statkraft, Norway on "Energy for the Future- Possibilities and Challenges"

Saturday

7:00-8:00AM Continental Breakfast

8:00-10:00 AM **Reports of the Working Groups**

10:30-12:00
Presentations from Industry on Educational Needs

- Yakout Mansour – President and CEO – California ISO
- Danny Spear – General Dynamics Electric Boat
- Waleed Said – Hamilton Sundstrand
- Noel Schultz – IEEE Power Engineering Society

1:30-3:30 PM

Designing 2nd Courses (Entry-Level Graduate Courses) - Chaired by Noel Schultz

3:30-5:00 **Summation and Action Plan**

5:00-5:30 **Certificates of Appreciation**