Working to Build the Future Workforce in Electric Power and Energy

Dennis Ray
Deputy Director
Power Systems Engineering Research Center

Prepared for the National Research Council’s Energy and Mining Workforce Committee
August 22, 2011
Objectives

• Provide an overview of the work that is being done to prepare the future electric power and energy workforce

• Suggest workforce questions, issues and opportunities, with a particular emphasis on the grid as requested by the Committee

• Identify sources of recommendations for addressing energy workforce challenges
Overview

• National concerns
  • effects on grid reliability and capability of losing knowledge and expertise due to retirements
  • filling the pipeline of students
  • improving employability and retention
  • achieving effective education

• As a nation, is the scale, scope and effectiveness of how we are responding to these concerns sufficient to build the workforce of the future?
Drivers of Workforce Requirements in the Electric Energy Sector

• Electric demand growing via electrification.
• Infrastructure is aging (already old).
• Retirements are increasing while younger, less experienced, culturally different workers, are entering the workforce.
• Grid modernization has become a priority.
• Societal needs are changing (e.g., goals for high penetration of renewable generation, more customer engagement)
Electrification Trend

- ~1% annual growth to 2035 (EIA 2011 Annual Energy Outlook)
- Broadening portfolio of ways to meet the need

Major Investments Needed

• $1.5 to $2.0 Trillion by 2030 with $880 B for transmission and distribution (Brattle Group 2008)

• $338 to $476 Billion for Smart Grid investments until 2020 (EPRI 2011)

• Examples
  • Transportation electrification
  • Transmission integrating renewable generation
  • Replacing aging infrastructure
  • Climate change: adaptation and mitigation
Storage, Sensors, Self-Healing… in the Grid

Communication Media: BPL, Wi-Max, Satellite, Fiber, DSL, Wi-Fi, RF Mesh, etc.

Smart Grid Infrastructure: Software/database, network communication and monitoring, and control architecture

Renewables Integration

Substation/Feeder Integration

Self Healing

Residential Customer Demand Response Integration

Smart Grid: System Functions vs. Customer Functions
Smart Grid Brings New Challenges

- Interoperability
- Cybersecurity
- Grid reliability
- System monitoring, control and protection
- Communications
- Decentralized vs. centralized control
- Customer engagement
- Capital investment (utility, users)
- Access to information vs. privacy
Electric Energy Jobs

- Electric generation, transmission, distribution (400,000 est.)
- 1/3 lineworkers, plant/field operators, technicians, pipefitters/field operators. 6% engineers. May 2009 BLS estimate of utility electrical engineers in generation, transmission and distribution: 13,530.
- Manufacturing, services (engineering, design, etc.), industrial energy users, other industries (aerospace, ship-building, etc.)

<table>
<thead>
<tr>
<th>Utility Energy Field</th>
<th>2009 National Jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Distribution</td>
<td>149,375</td>
</tr>
<tr>
<td>Fossil</td>
<td>141,229</td>
</tr>
<tr>
<td>Nuclear</td>
<td>56,410</td>
</tr>
<tr>
<td>Natural Gas Distribution</td>
<td>112,883</td>
</tr>
<tr>
<td>Bulk Transmission</td>
<td>28,877</td>
</tr>
<tr>
<td>Other</td>
<td>10,370</td>
</tr>
<tr>
<td>Total</td>
<td>535,085</td>
</tr>
</tbody>
</table>

Center for Energy Workforce Development (2009)
More Information Needed

• Extent to which contracted labor and outsourcing is substituting for in-house labor.
  • Effects on building the future workforce?
  • Effects on workforce need estimates?
• Current and future role of non-US citizens
  • Limits on hiring non-US citizens without a green card (i.e., security, cost of processing visas, etc.)
Examples of New Workforce Needs

• 2022: 150,000 professional and skilled craft for construction
• By 2030: 60,000 to operate and maintain electric generation systems
• 10,000-15,000 to construct transmission facilities
• 90,000 for smart grid (while 25,000 will be redeployed)
• 11,000 for energy efficiency

A Projection for a Smart Grid

• Short-term: 280,000 new positions from smart grid projects
• Long-term: 140,000 “high value” jobs
• Also loss of jobs due to new technology
• Big boost for equipment suppliers, suppliers of enabled services of distribution smart grid services

The US Smart Grid Revolution:
KEMA's Perspectives for Job Creation. 2009.
• Analysis of lineworker and T&D engineers supply and demand (BLS, DOL)
  • Shortage of lineworkers (>45,000) – most acute in 2010. (Note: CEWD 2009 estimate = 69,000)
  • No forecasted shortage in power engineers (11,000) (Note: jobs estimate only includes utilities)

• Recommendations to Congress
  • Foster math and science education
  • Build interest in energy-related careers
  • Note: viewed as long-term solution

# CEWD 2009 Survey: Employee Losses through 2015

<table>
<thead>
<tr>
<th>Job Category</th>
<th>Percentage of Potential Attrition &amp; Retirements</th>
<th>Estimated Number of Replacements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technicians</td>
<td>50.7</td>
<td>27,800</td>
</tr>
<tr>
<td>Non-Nuclear Plant Operators</td>
<td>49.2</td>
<td>12,300</td>
</tr>
<tr>
<td>Engineers</td>
<td>51.1</td>
<td>16,400</td>
</tr>
<tr>
<td>Pipefitters / Pipelayers</td>
<td>46.1</td>
<td>8,900</td>
</tr>
<tr>
<td>Lineworkers</td>
<td>42.1</td>
<td>30,800</td>
</tr>
</tbody>
</table>

**Gaps in the Energy Workforce Pipeline: 2009 CEWD Survey Results**. Center for Energy Workforce Development. Based on 535,000 est. of employees in electric utilities and integrated electric and gas utilities. Due to delayed retirement plans, the Task Force on America’s Energy Jobs postulated a “silver tsunami” may occur when retirements actually occur.
Characterizing the Cumulative Workforce Needs Over Time

Recently  Future →

Existing Workforce  New Hires

Note: More data needed to add substance to this chart.
The reliability of the North American electric utility grid is dependent on the accumulated experience and technical expertise of those who design and operate the system. As the rapidly aging workforce leaves the industry over the next five to ten years, the challenge to the electric utility industry will be to fill this void…

2006 Long-Term Reliability Assessment
North American Electric Reliability Corp.
See also the 2007 Long-Term Reliability Assessment.
Hiring

- Hiring experienced engineers is a critical need (relatively low number mid-career engineers).
- Hiring slow now in utilities, but not as much so for other companies.
- Utilities more likely to hire BS grads than MS/PhD grads.
- Hiring of international students not done or limited in many companies.
  - More likely to be done in manufacturing, engineering services, consultants, research organizations.
- Median salaries for power engineers lowest among major EE fields
Conventional Education Pathways

- High School
- Engineering Technology Schools
- Universities (undergrad and grad)
- Community Colleges
- Apprenticeship Programs
- Jobs
Additional Training Opportunities

- Utilities are finding that fewer new applicants can pass the background checks, drug screening and pre-employment tests.
- Pass rates on pre-employment tests:<50%
- Company-sponsored training
- Courses before pre-employment testing
- Boot camps (e.g., low-income initiative targeting 16-26 year olds by Center for Energy Workforce Development)
  - Industry fundamentals
  - Lineworker, line construction
- Professional development
- Retraining engineers for an energy career
Challenges

• Getting students interested and prepared for energy jobs or post-high school education
• Improving diversity in the workforce and reaching targeted segments
• Providing support for students to get and keep them committed to energy careers
• Advancing education value, quality and cost efficiency
Career-Choice Decision Factors

• What made you decide on your career path?
  • Interesting career (67%)
  • Opportunity to help solve significant societal challenges (38%)
  • Make the world a better place to live (33%)
  • Good pay opportunities (30%)
  • High likelihood of getting a job (20%)

IEEE PES International Survey of Power Engineering Students
June 2007
Influential People in Career Choices

• Who influenced your career choice?
  • Guidance counselor/mentor/teacher (26%)
  • Talking with people in the industry (22%)
  • Parent’s suggestions (12%)
  • Friend’s suggestions (6%)
  • Media (2%)

IEEE PES International Survey of Power Engineering Students
June 2007
Making Face to Face Contacts

FPL is committed to education

Whether it's energy conservation discussions in grade school classrooms or nuclear science training at universities, FPL is passionately committed to education. Through FPL's continued support, employees and their communities are able to engage in numerous educational opportunities.

Professor Whys
This interactive show teaches kids in public schools the science behind electricity

Captain Conservation
FPL's energy conservation superhero offers an educational program for public schools

Solar Stations
This program promotes solar education in schools and offers grants that teach about energy

Workplace Partnerships
FPL has created job-training programs with local communities and state colleges

Energy Encounter
Visit over 30 interactive displays on energy, electricity, nuclear power and the environment

FPL for Kids
Educational games, experiments and information for kids, parents and teachers
Developing Effective Websites

There are many reasons to consider a career in the energy industry. With the right education and training, you can begin a rewarding, well-paying career that benefits millions of people every day.
Stimulating Competitions

IEEE PES Smart Grid Competition, DOE’s National Science Bowl, FIRST Family of Programs, …
Creating Motivational Videos

IEEE Power & Energy Society, 2010
Reaching Out to Targeted Sectors

Helmets to Hardhats is the fastest way for Military, Reservists, & Guardsmen to transition from active duty to a career in the construction industry.

1. We’ll help you build your profile
2. Guide you through searching, & applying for careers
3. Connect you with other Veterans
4. Provide you with advice from our staff of construction industry and military professionals

GET STARTED >>

FEATURED CAREER

>> Intl. Brotherhood of Boilermakers & Iron Ship...
Boilermakers and boilermaker mechanics make, install, and repair boilers, closed vats...

FEATURED OPPORTUNITY

>> Want to be a Boilermaker?
It’s more than just the construction and repair of boilers.

Your Life Under Construction.
Supporting Teachers

Lesson plans, materials, applets, guest speakers, targeted learning programs, academies, field trips, NSF research experiences, etc.
Two Efforts to Help Teachers

• National Energy Education Development Project: a comprehensive energy education project

• National Energy Foundation: Promotes, and provides resources for, education related primarily to energy, water, natural resources, science and math, technology, conservation…
Questions

• Will the future political environment support continuation or growth of the outreach efforts?
  • Outreach to K-12 requires resources and time
• What is the scale, scope and effectiveness of the efforts at schools nationwide? Is it sufficient?
• How can entrepreneurial development of curricular support (e.g., lesson plans, applets) be made more effective?
  • No guidelines. Need to help “developers” produce and market good products.
Creating Systematic Career Pathways Programs

CEWD Get Intro Energy Career Pathway Model

• Provide outreach and support to students and potential applicants (e.g., career awareness, mentoring)

• Provide an education framework for career preparation (e.g., stackable credentials, uniform curriculum, education network)

• Encourage partnerships, building on the Energy Workforce Consortia model (28 state consortia in operation)
Educating within a Framework

Industry-based, Energy Competency Model. CEWD
Supporting Students – University Example

IEEE Power & Energy Society’s Scholarship Plus Initiative™ to encourage university students to pursue power and energy engineering careers

- Now selecting first scholarship awardees
- Funding
  - PES provided $1,000,000 seed funding
  - Target goal of $10M in philanthropic donations over 2 years
- Offering
  - Providing scholarship support: $2,000, $2,000 and $3,000 in years 1, 2 and 3. Likely to raise scholarship level next year.
  - Facilitating mentoring and career experiences for the awardees
  - Targeting U.S. citizens or permanent residents
University Power Engineering Programs

• Universities with power engineering courses and graduate students: over 100
  • Faculty sizes, number of courses, number of students vary considerably
  • Number of substantial programs: perhaps 20-30

• The Numbers
  • 200 (est.) full-time equivalent faculty / instructors in power engineering
  • 40% (est.) of university power engineering faculty eligible for retirement by 2013. Perhaps one-half will do so.
  • 1,500 (est.) graduating undergrads, 550 enrolled Masters, 550 enrolled Ph.D.’s
Challenge: Getting the Data

• Undergrads usually don’t declare concentrations
• Detailed faculty data on power engineering not regularly available
• Course offerings, faculty retirement data, etc. generally not available from typical sources
• Coming soon: IEEE PES Power & Energy Education Committee Survey of Higher Education
University Power Engineering Program Trends to Mid-2000’s

• Declining student enrollments except at the doctoral level
• Untenured faculty declined from 20% in early 90s to 12% of total (takes 5-6 years to get tenure)
• Approximately 3 faculty members hired for every 4 that left
• Reported total research funding per institution declined.

IEEE PES Power Energy Education Committee Survey Results for Various Academic Years. Informal surveys. See also “Professional Resources to Implement the Smart Grid.” Heydt, et.al. 2009.
Recent Trends

• Course enrollments rising
• New focus on energy engineering rather than just electric power – often multidisciplinary
• New or rejuvenated programs, some with smart grid theme. Advice for new programs funded by NSF and Office of Naval Research.
• Increasing variety in delivery methods (On-line, on-site, etc.)
• Faculty hiring: temporarily jumped following ARRA funding for smart grid deployment
• Losses in historically strong research universities not being corrected due to lack of research support
Growth In Undergrad Engineering Enrollments: 2007-2010

<table>
<thead>
<tr>
<th>Engineering Field</th>
<th>Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Engineering</td>
<td>16.9%</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>16.9%</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>13.2%</td>
</tr>
<tr>
<td>Electrical/Computer Engineering</td>
<td>6.8%</td>
</tr>
</tbody>
</table>

2007 Future Power Engineer Workforce
NSF Workshop Recommendations

• Create a single, collaborative voice for workforce solutions
• Paint future challenges to enhance the image and increase interest in related careers
• Stimulate interest and prepare students for a post-high school engineering education
• Make the higher education experience relevant, stimulating and effective
• Strengthen the case to build, enhance and sustain university programs
• Increase university research funding to find innovative solutions and enhance student education
PES Workforce Collaborative Goals

1. Double the number of power graduates
2. Provide $4 million undergraduate power engineering scholarships
3. Create 2,000 internship opportunities
4. Hire 80 new power faculty members in the US over the next five years
5. Raise annual university research funding to $50 million per year
6. Create five University Centers of Excellence to conduct power research and education

In easy-to-reference lists, the report outlines specific steps for industry, government and educators to meet these goals.
Without strong support for strategic research in power systems engineering and without qualified replacements for retiring faculty, the strength of our Nation’s university-based power engineering programs will wane, and along with them, the foundation for innovation in the power sector to meet our energy challenges in the 21st century.

Without a sizable research portfolio, it is not possible for a disciplinary area such as electric power to get new faculty positions or resources.

Professor Vijay Vittal, Director, Power Systems Engineering Research Center in filed comments to FERC in RM06-16, July 2006.
University administrations need to know there is a long term commitment to university research in the area. The students need to know there are high paying, interesting jobs.

Traditional Power Engineering Topics

Electric Machinery
Energy Conversion
Energy Development and Power Generation
Energy Management Systems
Energy System Design
High Voltage AC/DC, FACTS
Industrial and Commercial Power Systems
Motor Drives and Controls
Power Electronic Applications

Power Quality
Power System Relaying and Protection
Power System Stability and Control
Power System Transients
Power Systems Instrumentation and Measurement
Power Systems Operations, Planning
“Professional Resources to Implement the ‘Smart Grid’”. 
Gerald T. Heydt and others. North American Power 
Symposium, 2009.
Curriculum Enhancements

- Direct digital control
- Power system dynamics and stability
- Power quality and signal analysis
- “Middleware” migration
- Environmental and policy aspects
- Reliability and risk assessment
- Economic analysis, energy markets
- New concepts for power system monitoring, protection and control
- Communications, IT

Smart Grid Education Recommendations

• Design retraining programs that speak directly to the training gaps of existing electric energy industry workers;

• Design engineering and technical curricula for future employees that resonate with the needs of the smart grid workforce, such as broad analytical skills, strong engineering fundamentals, and strong business acumen.

• Design retraining efforts to familiarize workers with smart grid technology and systems.

• Educate current students who will be the smart grid workforce of tomorrow.

Smart Grid Competencies

The competencies required by lineworkers, power plant operators, relay and substation technicians, and other skilled craft positions in the electric energy industry will not change. New training will be required to understand the new technology and new procedures or protocols.

*The Smart Grid Evolution: Impact on Skilled Utility Technician Positions*. Center for Energy Workforce Development.
Smart Grid Education and Training Growing

- ARRA Funding: $100 million for 54 smart grid workforce training programs (universities, community colleges, utilities, vendors, etc.)
- Professional development: universities, EPRI, vendors, consultants, professional societies, associations, national labs, unions, etc.
- PSERC Future Grid Initiative – creating courses, materials and reference videos
IEEE Power & Energy Society

• The PES Plain Talk Courses For Non-Engineering Power Professionals
  – Power System Basics: Electric Utility Operation Inside and Out
  – Distribution System: Delivering Power to the Customer
  – Transmission System: The Interconnected Bulk Electric System

• IEEE eLearning Smart Grid 101 Series
• Distribution Automation – an Enabling Technology for Smart Grid
• Cyber Security for the Smart Grid
• NIST Smart Grid Conceptual Model
• Smart Devices for the Smart Grid
• Smart Grid Integration
• Standards for the Smart Grid
• The “Smarter” Grid – What is it?
• Smart Grid: From Concept to Reality
Smart Grid Education Challenges

• Education and training needs evolving
  • Body of knowledge still growing
  • Applications using the data are still being developed.
  • Programs, practices and standards still in-progress.
• Number of employees actually needing the information growing as deployment continues – but not every engineer and technician today
• Technical knowledge needs often are company-specific.
• Need for sound smart grid curricula and materials
• People still need the basic competencies.
Future Grid Education Challenges

• Understanding and quantifying uncertainty
• Decision-making under risk
• New analytical tools for operations and planning (still a work in progress)
• Multi-disciplinary balance (engineering, business, economics, public policy, etc.)
• Engineering curricula balance: power system fundamentals vs. energy systems, power electronics, communications, IT, etc.
Education: Value, Quality, and Sustainability

• Describe and track use of the nation’s energy education systems

• Develop an effective, portable national credentialing system (positive value proposition may drive this)

• Conduct evaluations to see what is working, what is not, and why
  • Look for big impact opportunities (having many diffuse, uncoordinated, “one-off”, activities may not be enough)
Education: Value, Quality, and Sustainability

• Systematically collect and openly disseminate foundational competency expectations for employment. Share methods for identifying those expectations.

• Explore ways to promote sharing of training and education materials.
  • Look where common curricula could be developed or education modules shared.
Education: Value, Quality, and Sustainability

• Establish business models for sustainable education and training programs
  • Develop and get institutional support for a transparent process for creating effective education and training materials that can be used by K-12 teachers

• Encourage collaboration and dialog on effective education and training practices
  • Share lessons learned
  • Expand the body of knowledge, such as National Academies report “Successful STEM Education: A Workshop Summary”. Make reports accessible to a broad audience.
Recommendations from Task Force on American’s Jobs

• Establish regional, multi-stakeholder workforce consortia
• Improve data collection
• Best practices and training standards for energy sector jobs
• Support for individuals
• Education and career counseling

Task Force on America’s Future Energy Jobs.
Recommendations from the 100 Day Energy Action Plan

• Direct the Secretary of Labor to create a $300 million “Clean Energy Workforce Readiness Program,” augmented by state and private sector funding, to foster partnerships between the energy industry, universities, community colleges, workforce boards, technical schools, labor unions and the U.S. military to attract, train and retain the full range of skilled workers for America’s clean energy industries.

• Require all federal agencies to commit 1 percent of their R&D budgets to competitive, portable undergraduate and graduate fellowships in energy-related disciplines for American students.

• Direct the Secretary of Labor to assess, classify and widely publicize the demand-driven needs for energy-related occupations and align federal workforce investment programs and state-directed resources to support skills training and career path development in energy fields for American citizens.

Managing the Workforce Transition to Reduce Loss of Knowledge

- Workforce planning: identification and evaluation of knowledge and skills at risk and strategies to address the risk.
- Automating: applying technology to complete tasks.
- Recording: putting knowledge into accessible records.
- Educating: transferring knowledge to the next generation of engineers and technicians.
- Hiring retirees to help.

Work “place” Challenges

• Understanding and responding to the differences between younger and older generations

• Getting flexibility for succession planning when the pressure is to keep employment low (and to minimize energy price increases)

• Maintaining morale and career excitement while providing quality training when the pressure is for rapid organizational change (e.g., wind energy integration)

• Retention challenging when cost-control is a priority.
Researchable Questions

• What is the current state of the energy education system? What are the implications of state and federal funding cut-backs?

• What knowledge and skills need to be learned? What are effective education/training frameworks and methods? Why?

• What will the long-term demand be for workers? What are the options for meeting the demand and how should those options be evaluated?
For the National Academies

• National Academies have been helping!
  • Successful STEM Education: A Workshop Summary
  • Engineer Girl: http://www.engineergirl.org
  • Engineer Your Life: http://www.engineeryourlife.org
  • Changing the Conversation: http://engineeringmessages.org
  • Rising Above the Gathering Storm
  • And more…

• What more could the National Academies do?
  • Present work to reach broader audiences,
  • Coordinate with related efforts
  • Engage the various communities in fruitful discussions
Will we have the workforce we need in the coming years?

- Do we have a plan or coordinated plans?
- Are the programs working? Are they sustainable?
- Do we see the needed number of students in the pipeline?
- Are we collaborating better?
- Are we less stressed about the workforce outlook?
Who’s Responsible for Solutions

• Universities
• Community Colleges
• K-12 teachers, counselors, admin.
• Parents
• K-12 service organizations
• Research organizations
• Professional societies
• Industry associations
• Employers
• North American Electric Reliability Corp.
• CEWD

• State regulators
• Federal regulators
• National regulatory associations
• Congress
• State legislatures
• State workforce agencies
• Department of Labor
• Department of Energy
• National Science Foundation
• State and national consortia
• National Academies
• And many more
References by Slide Number


The US smart grid revolution: KEMA's perspectives for job creation. KEMA. 2009. (Slide 12)


Gaps in the Energy Workforce Pipeline: 2009 CEWD Survey Results. Center for Energy Workforce Development. (Slide 14)

2006 Long-Term Reliability Assessment and 2007 Long-Term Reliability Assessment. North American Electric Reliability Corp. (Slide 16)

FPL is Committed to Education Website (Slide 23)

Get into Energy Website (Slide 24)

FIRST Website (Slide 25)


Helmets to Hardhats Website. See also Troops to Energy Jobs. Center for Energy Workforce Development. (Slide 27)

The Power Grid Tutorial. Trustworthy Cyber Infrastructure for the Power Grid. University of Illinois at Urbana/Champaign (Slide 28)

National Energy Education Development Project (Slide 29)

National Energy Foundation Website (Slide 29)
References by Slide Number


IEEE Power & Energy Society’s Scholarship Plus Initiative™ Website (Slide 33)

Gerald T. Heydt, et.al. Professional Resources to Implement the Smart Grid. Presented at the North American Power Symposium. 2009. (Slide 34, 36, 45, 46)

Electric Power Engineering Education Resources 2005-06. IEEE Power Engineering Society Committee Report. (Slide 34, 36)

Profiles of Engineering & Engineering Technology Colleges. 2010 Edition. American Society for Engineering Education. (Slide 38)


The Smart Grid Evolution: Impact on Skilled Utility Technician Positions. Center for Energy Workforce Development. (Slide 48)
DOE-Sponsored Workforce Training Programs. Smart Grid Information Clearinghouse. See also Recovery Act Workforce Training. Office of Electricity Delivery & Energy Reliability. U.S. DOE. (Slide 49)

The Future Grid to Enable Sustainable Energy Systems. Power Systems Engineering Research Center. (Slide 49)

