National Science Foundation Workshop on the Future Power Engineering Workforce

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North American Electric Reliability Corp. (NERC)
IEEE Power and Energy Society (PES)
Power Systems Engineering Research Center (PSERC)

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Executive Summary

A serious need is emerging for more power and energy engineers to:

- replace retiring engineers so that critical expertise is maintained
- meet rising infrastructure construction needs
- modernize the grid as communications, computing and electric energy technologies converge
- help stem the tide of electric equipment manufacturing moving off-shore, and
- solve arising engineering challenges, such as in the development of advanced power electronics and energy conversion systems, new generation and storage technologies, and the integration of those technologies into the grid.

Analyses suggest that there are not enough students in the pipeline who are excited about and prepared for a post-high school education in power engineering. Through partnerships among industry, government and universities, new undergraduate and graduate power engineering education programs are being developed; however, at the same time, the university education and research infrastructure is being weakened by university decisions to not replace retiring power engineering faculty. Innovative university research is needed to address new engineering challenges while educating students. The university research support for doing so is increasingly difficult to find.

Attendees at the NSF Workshop and Executive Summit on the Future Power Engineering Workforce met to discuss engineering workforce issues and offered these recommendations:

1. Create a single, collaborative voice on solutions to engineering workforce challenges
2. Strengthen the case for extraordinary efforts to build, enhance and sustain university power engineering programs
3. Envision the future challenges in electric energy supply and demand, and develop an image that will increase interest in power engineering careers
4. Stimulate interest in power engineering careers and prepare students for a post-high school engineering education
5. Make the higher education experience relevant, stimulating and effective in creating high quality and professional power engineers
6. Encourage and support increased university research to find innovative solutions and to enhance student education.

In response to these recommendations, the IEEE Power and Energy Society will begin an initiative entitled the *Power and Energy Engineering Workforce Collaborative*, and will seek initiative partners from industry, government and universities. One of the next steps will be to form a collaborative executive council of key decision-makers in industry, government and universities to plan a comprehensive approach that gets wide support while taking actions that are necessary, timely, and feasible with the available resources. Working groups in outreach and image, education, and research will be created to support the decision-making of the executive council, and to take actions as well. This is a transitional structure with a focus on engineers for power and electric energy careers.

Working groups will scope tasks, identify where further action is needed, do what they can themselves, plan needed changes, and collaborate with others to implement actions. Existing efforts and organizations will be used to the maximum extent possible; however, planning will include the possibility of new institutions or organizations that will sustain the initiative. Other industries will be involved, not restricted to the electric power industry.

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1. Workforce Challenges Motivating the Workshop

A wave of retirements of experienced power engineers is imminent. A coordinated effort by industry, government and universities is needed now to prepare for this exodus. Without this effort, there will be a lag in replacing the lost expertise needed to maintain economic, reliable and environmentally acceptable electricity service while innovatively solving the significant technical challenges facing all industries.

Based on a survey of U.S. electric utilities, the Center for Energy Workforce Development estimates that approximately 46% of all engineering jobs could become vacant by 2012, due to retirements by the aging workforce and other forms of attrition. Although this percentage may vary across industries, it suggests that the size of the wave is so large that it must be proactively addressed through collaborative initiatives. The North American Electric Reliability Corp. (NERC), in its report entitled *2007 Long-Term Reliability Assessment*, concluded that:

> *"The loss of industry workers and their years of accumulated expertise due to retirements is a serious threat to the bulk power system reliability, exacerbated by the lack of new recruits entering the field."*

The question that all concerned parties are addressing is "are we prepared?" Unfortunately, the answer appears to be negative. In its long-term assessment, NERC states the following:

> *"Exacerbating the problem of a declining workforce is a simultaneous decline in the number of potential recruits from colleges and universities, as well as vocational schools. During the past two decades, the reduced demand for industry workers has led to a decrease in vocational training and university-sponsored electric power programs. Further to this point is the decline in the number of college professors able to teach power system engineering and related subjects."*

Aging Workforce and Engineering Faculty:
Key Concerns

Not enough students in the pipeline
Retiring power engineering faculty not being replaced

Furthermore, in a 2006 report to Congress entitled *Workforce Trends in the Electric Utility Industry*, the U.S. Department of Energy declared that:

> *"Today, the power engineering education system in the United States is at a critical decision point. 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."

A strong and concerted effort is needed by industry, government and universities to sustain university power engineering programs, attract students to the field, and increase university research support. This effort is necessary to educate for the next generation of power engineers. This is both a national crisis and a challenge that must be met to ensure that our electric energy system is able to support economic development, maintain energy security, and address major issues such as climate change.

To explore how to prepare universities for the coming large increase in demand for new power engineers, the National Science Foundation convened the *Workshop on the Future Power Engineering Workforce* on November 29-30, 2007, with approximately 75 people attending from industry, government and universities. An Executive Summit comprised of key leaders in industry, government and academia was also part of the workshop. In the discussions, workshop and summit participants identified key issues and actions on how to meet the coming increased demand for new power engineers along with possible actions to address those questions.

Key questions for preparing to meet the increasing demand for new power engineers

- How to make a strong case for action?
- How to identify ownership of the problem?
- How to build the pipeline of students into the field?
- How to communicate an exciting image of power engineers?
- How to improve teaching to motivate and prepare students?
- How to support university research for innovation and faculty hiring?

2. Recommendations from the Workshop

Create a single, collaborative voice on solutions to engineering workforce challenges

There was a broad consensus among industry, government and university workshop attendees that collaborative actions should be taken to prepare for the coming workforce challenges. Priority should be given to establishing a single voice that can speak to key concerns and solutions. The necessary steps are:

(1) create a national initiative to drive collaboration among industry, government and universities, and to facilitate communication of research and education priorities in electric energy systems;

(2) identify means for effective collaboration among industry, government and universities; and

(3) advocate for action when a strong voice is needed.

Strengthen the case for extraordinary efforts to build, enhance and sustain university power engineering programs

Studies indicate a looming shortage of power engineering graduates from U.S. universities to meet the need for new power engineers. An initiative is needed to build the student pipeline, and to sustain an essential number and mix of university power programs. A strong case for extraordinary efforts needs to be built and communicated because collective action will be motivated by a better understanding of the emerging educational challenges and what it will take to meet those challenges.

To build a stronger case, more data are needed on the future demand for power engineers; on the knowledge and skills needed by future power engineers; on trends in the number of students choosing power engineering careers; on the state of the educational infrastructure; and on metrics for describing and monitoring the state of the job market and the educational system in general. Besides making the case stronger, these studies can provide information needed to make any extraordinary efforts more efficient and effective.

Envision the future challenges in electric energy supply and demand, and develop an image that will increase interest in power engineering careers

The next generation of power engineers will face extraordinary new technical challenges. Conversations with current power engineering students suggest that they are excited about working on solutions to emerging local, regional and global challenges; however, not enough students realize that engineering offers opportunities to make a difference is solving those challenges. An image of the future power engineer should show that the future power engineer will be doing work that is exciting and important. This image needs to be communicated to prospective power engineering students in grades K-12, and in colleges. Today's engineering students are more environmentally aware, socially conscious, and globally connected. Creating a realistic image of power engineering that is appealing to this upcoming generation of engineers will be critical in the development of solutions to attract them to relevant education and research programs.

Stimulate interest in power engineering careers and prepare students for a post-high school engineering education

Concern is wide-spread regarding the decline in student interest in science, technology, engineering and math career fields. Coupled with this concern is the inadequate diversity that exists among current engineering students. Although there is a multitude of on-going industry and government initiatives to address these concerns, more participation and collaboration is needed from industry and academia to increase the effectiveness of those initiatives in obtaining larger numbers of students interested in power engineering as a career. In addition, more support is needed for teachers and school counselors who are known to be influential in stimulating interest in power engineering careers and preparing students for future education opportunities. The priorities are to increase and sustain the pipeline of power engineering students by:

(1) promoting the social importance of meeting electric energy challenges and of delivering electricity economically, reliably, securely and sustainably;

(2) making education more interesting, such as by developing hands-on group projects across course levels to stimulate teamwork environments and synergy, and

(3) leveraging government programs through collaboration, such as the National Science Foundation programs titled, “Research Experience for Teachers,” and “Grant Opportunities for Academic Liaison with Industry.”

Make the higher education experience relevant, stimulating and effective in creating high quality and professional power engineers

To excite students about power engineering careers and to better prepare them for those careers, universities need to continually evaluate and innovate in their power engineering courses with challenges facing future power engineers in mind. For example, in recent years, student interest in new courses on renewable energy systems and sustainable engineering concepts has been high. Universities and industry also need to work together to support a range of student needs and work situations, such as through mentorship, on-line courses, matriculation agreements across campuses, industry-sponsored design projects, and various industry work experiences. These actions will be enabled in part by systematic communication with industry and students, such as through surveys, focus groups, graduation interviews, and advisory boards. Priority should be given to educating students for power engineering careers by:

(1) building strong and ongoing industry relationships with universities to enhance educational programs and to support faculty in their education activities; and

(2) increasing industry and government collaboration with universities to identify education topics and implement new delivery methods that make electric power and engineering education more exciting and relevant for a new generation of students, while making it efficient and effective to control costs and improve quality.

Encourage and support increased university research to find innovative solutions and to enhance student education

Increased support of university research can lead to innovations needed to address engineering challenges in electric energy systems. The direction of university research would benefit tremendously from higher levels of collaboration among industry, government and academia to create a strategic research and development roadmap for transforming energy systems for the 21st century. Increased support of both government and industry-based research will also help graduate students to become the researchers and educators of the future, and enrich the education of undergraduates through research experiences. Industry support is needed to help advocate for increased government support and to help fund research directly. In so doing, a balance will need to be sought between research that addresses industry's short-term objectives and research on long-term issues facing industry and society at large. Finally, lessons from the various forms of research can be brought to the classroom to better prepare students for the challenges that they will face following graduation. Government, industry and universities should encourage and facilitate university research for innovation and education. Important actions are:

(1) supporting university researchers and students to better understand short- and long-term industry research needs (such as in power electronics and energy conversion, in planning and operating margins in real time, and in energy storage) so that they can make informed choices in their research directions;

(2) increasing industry, university and government research collaboration to support research and student education, to facilitate creation of innovative solutions to industry challenges, and to advance global competitiveness and leadership; and

(3) ensuring that sustained financial support is provided for university research and education efforts to maintain strong electric power and energy university programs.

3. Next Steps to Implement the Recommendations

The NSF Workshop and Executive Summit demonstrated that there are collective concerns across industry, government and universities about power engineering workforce issues. The time the attendees spent together was sufficient to generate wide-ranging ideas about how to address the issues, but not long enough to reach a consensus on what comprehensive approach should be pursued. To make progress toward finding and implementing solutions to those concerns, the IEEE Power and Energy Society will begin an initiative entitled the *Power and Energy Engineering Workforce Collaborative.* PES will seek initiative partners from industry, government and universities. One of the next steps will be to form a collaborative executive council of key decision-makers in industry, government and universities to plan a comprehensive approach that gets wide support while initiating actions that are necessary, timely, and supportable with available resources. Working groups in outreach and image, education, and research support will be created to support the decision-making of the executive council. The next steps will be:

1. Form an executive council with three working groups providing support.
2. Formulate a comprehensive approach to addressing workforce and education challenges.
   - Define the problems and the information that exists or is needed to verify and efficiently solve
   - Develop and implement the comprehensive approach with appropriate cooperation of others.
3. Initiate actions at any time that advance solutions, and that are feasible with obtainable resources.

4. Expanded Discussion of Recommendations

1) Create a single, collaborative voice on solutions to engineering workforce concerns

The shortage of the power engineering workforce is a national security issue. A national body with representatives of the stakeholders in industry, government and academia needs to be formed to speak with one voice on concerns and solutions. Awareness and contacts at key leadership levels are needed. The national body should have a regional sub-layer. The workforce problems are multi-faceted and will not be solved by any one entity; thus, strong collaboration among all concerned entities is needed. The connection between the workforce and reliability should be identified. There needs to be collaboration across government agencies at the state and federal levels, closely involving universities in the process.

There are numerous opportunities for involvement by governmental organizations or groups trying to inform governmental policy. Leaders in the power engineering community can contribute by educating Congress. IEEE-USA is a resource for the effort. The American Society of Engineering Education provides good access to engineering deans in the U.S. There is also a significant role for the regulatory agencies. Involvement is needed by federal and state regulators. The National Governors' Association is an important forum to reach the states; their focus next year is on clean energy. Regional economies can be linked to federal partners. Added value to regional economies can be achieved by leveraging work at the Environmental Protection Agency. The National Association of Regulatory Utility Commissioners would also be a valuable resource.

Human resources are as important as electrical wires and power generators. People are a critical part of the infrastructure. There needs to be a national voice for innovative power engineering education and fundamental research. People know the importance of sustaining the educational infrastructure. Actions from the government could include tax incentives (such as credits for supporting research and education), increased funding of education and university research, and assessment of policy barriers to industry support of research and education.

Collaboration among the various entities will be challenging. A literature review is needed to better understand how to build collaboration and what collaborative models work. The steps for building a successful collaboration approach should be identified. Models for effective collaboration to sustain university power engineering programs should be assessed.

Collaboration among industry, government and universities should occur in a number of areas. Collaboration could be used in establishing centers for power education and research that meet different needs than the local universities. Collaboration could also help with leveraging resources for education and research. In this regard, examination of what the nuclear engineering industry accomplished in reviving their programs would inform the development of successful collaborative models for education and research.

2) Strengthen the case for extraordinary efforts to build, enhance and sustain university power engineering programs

There is a critical need for empirical data to make a strong case for the workforce issue and the ability of universities to contribute to the solution. Although data are available on the evolution of the university power programs, there is incomplete information about the number and scope of programs, and about the outlook for faculty hiring. There is also a lack of information on the future demand for undergraduate and graduate students. To acquire information about the future, there is a need to understand where the industry will be positioned in the next decade. It is important to forecast the future of the industry to identify what the future engineers need to know and how university programs can properly educate this next generation of professionals. In response to a shortage of power engineers, salary offers should be trending upward, so more public information is needed about salary offers for graduating students.

3) Envision the future challenges in electric energy supply and demand, and develop an image that will increase interest in power engineering careers

Energy resource adequacy, environmental impact, regulatory effects, markets and pricing, and security are critically important to the global community. Power engineering is a core area of the broad energy problem that involves environmental issues. Economic growth leads to increased demand for energy. Regulatory coordination and markets are critical to establishing future industry strategies and direction. A reliable power infrastructure is highly important for the society. Blackouts have serious consequences. As noted above, NERC has declared that the power engineering workforce is a critical issue for the reliability of the power grid in the future. Climate change is a concern shared by countries around the world. Students are attracted to the "green energy" field; saving the planet is a great motivator for many students in today's universities. Ways should be found to capitalize on their motivation and global awareness, and provide research and educational opportunities for students to exercise their creativity.

4) Stimulate interest in power engineering careers and prepare students for a post-high school engineering education

Outreach is an important aspect of the workforce issue. Communicating the image of power engineers should **s**tart at the K-12 level. There needs to be an effective way to attract students into power engineering. Outreach efforts are important to reach the young population and understand clearly what motivates and excites them. These efforts will help to create an image that engineering is "flashy, dynamic, and cool." Nuclear engineering survived the image problems; the image of a nuclear engineer and the nature of their outreach programs should be studied.

There is a perception that children of blue collar workers tend to be more interested in engineering careers; however, tuition costs are often a barrier for them. The lack of diversity in engineering means that there are untapped opportunities for increasing student interest in engineering. Availability of scholarships may be a great boost to student interest in engineering. Internships and cooperative programs for university students can also support a student's education, and have been highly successful at many universities.

Students and their parents today are concerned about outsourcing of engineering jobs to other countries, thereby increasing job security worries about engineering careers. Whether outsourcing is a realistic option for the industry needs to be assessed and communicated.

A better job needs to be done explaining the importance of engineering to the public. Young people need opportunities to talk with young engineers. The power engineering community needs to work with high school teachers and school counselors to help them understand what power engineers do and how they can make a true difference in the world and contribute to the overall good of society based on their work. Universities could help by hosting teachers under the National Science Foundation program "Research Experience for Teachers." Companies should hire students as interns and co-ops. To help inform and excite students, national competitions could be held. For example, the FIRST Robotics Competition has the goal "to create a world where science and technology are celebrated… where young people dream of becoming science and technology heroes."

Outreach efforts need to emphasize that it is critical to maintain a strong infrastructure for power engineering education and research; increasing the number of students in power engineering classes will be helpful in sustaining and growing these programs. As part of the outreach efforts, the general public, as well as policy-makers in Congress and the regulatory agencies, needs to be informed about the negative impact on the reliability of electric energy supply and national security posed by a diminishing power engineering workforce.

Initiatives should take advantage of the outreach and education programs available through the U.S. Department of Labor, the National Academy of Engineering and the National Science Foundation. It would be useful to take an inventory of those programs, assess their effectiveness in increasing interest in power engineers and determine how targeted industry assistance could increase effectiveness. There may also be leveraging opportunities with the U.S. Department of Energy (including the National Labs), and state programs.

5) Make the higher education experience relevant, stimulating and effective in creating high quality and professional power engineers

Universities should continue reassessing their power curricula to enhance or develop courses that deliver knowledge and values to attract top-level students. Opportunities for undergraduate and graduate students to work on industry projects should be pursued. Bringing industry speakers to the classroom as guest lecturers or as adjunct faculty would show the practicality of the education that the students are receiving. Curriculum innovations should be recognized and rewarded in the universities and by professional societies. To increase coverage of contemporary topics, course modules could be created. Universities should collaborate to share courses and resources through various forms of distance learning and web-based methodologies. Since areas of faculty expertise vary across universities, cross-university matriculation agreements could be made. On-line instruction could be achieved through maintenance and development for power courseware websites. Special funding for new courses, such as a “green energy curricula,” could be sought from industry or government. College students could be involved in focus groups to better understand their motivation, topics of interest, and attraction to engineering. Industry and student participation in mentoring programs could be encouraged. Finally, research studies on how to improve engineering education should be encouraged.

Besides education for a university engineering degree, there is also a need for continuing education opportunities. Special short courses can be created either in residence, on-site or on-line. These courses can meet important short-term needs, but they do not substitute for the comprehensive education found in a university degree program, nor do they support the research missions that are critical for sustaining university programs over the long term.

6) Encourage and support increased university research to find innovative solutions and to enhance student education

A critical element in sustaining a university power program is the availability of ample research funding opportunities. In a research university, faculty members must be productive in research to become tenured. Research and educational programs without fundamental research support may be eliminated. Adding faculty is difficult to justify if the opportunities for research in power engineering are limited. Today, universities are driven by rankings of the colleges or departments that often involve their level of research funding. One of the most important criteria for faculty promotion and tenure decisions at universities is research program success. A long-term agenda for research and education is needed. Engineering deans and department chairs need to be convinced that they should replace retiring power faculty.

University research funding has predominantly come from government, such as the National Science Foundation, the U.S. Department of Energy, and the Office of Naval Research. However, government funding has been declining in general. A better job needs to be done demonstrating the value of university research to industry. Alternative models of research collaboration among industry and universities should be explored to achieve better cooperation across universities, industry, and government. Industry can also support university programs by visiting engineering deans and department chairs at the universities, as well as helping with educating Congress and government agencies about the value of research. Complementing fundamental research with practical applications is a possible model for increased overall research program funding within the universities. This will require effective outreach activities and collaboration among academia and industry.

Collaboration between industry and academia on a strategic roadmap for university education would be helpful in stimulating ideas for innovative research by faculty and graduate students. Areas for expanded research could include:

- research on new equipment for the power industry
- identification of challenges for independent system operators and regional transmission organization
- developing new green energy generation technologies
- integration of renewable energy generation sources
- demand-side resources, energy efficiency, and distributed generation
- storage, such as battery and flywheel technologies
- power electronics and energy conversion technologies
- nanotechnology applications to energy.

Universities could provide the research and transfer the results on to hardware and software vendors for commercialization. Issues on intellectual property management need to be addressed in a collaborative manner.

In summary, sustaining university programs requires recruitment and retention of students, and solid research support. The path to achieving sustainable programs is through collaboration among industry, government and universities, and through the establishment of a single, collaborative voice regarding how to meet the coming engineering workforce challenges and the need for innovative solutions to regional, national and global energy problems.

Appendix A
Summaries and Notes of Workshop Sessions and the Executive Summit

A.1 Background

Exiting engineering expertise and talent shortages in the power industry could soon start constraining industry's ability to innovate and efficiently meet technical challenges in the years to come. Estimates put the loss in technical talent through retirements at around 50 percent in the next 5 to 8 years. To provide the industry with a sufficient supply of well-trained engineers, there is a critical need to sustain electric power engineering programs at U.S. universities. Just like industry, the power faculty members are "graying," and there is no guarantee that when they retire, their positions will be filled by new faculty in the power area. This is evidenced by the steady decline of many power programs in the U.S. As a result, there is a need for a critical assessment of the need for university-educated power engineers that industries will be hiring. It is important to understand the educational requirements of those industries and the factors that will attract students into the power field. There is also a need to look into the capability of university power programs at large research universities and at smaller universities to meet the expectations of the industries that will be hiring engineering program graduates.

The importance of the workforce issue has been recognized by the U.S. Government. As required by the Energy Policy Act of 2005, the U.S. Department of Energy (DOE) submitted to Congress the report entitled "Workforce Trends in the Electric Utility Industry." This report (along with referenced studies) pointed out a number of significant trends and found that: "*Today, the power engineering education system in the United States is at a critical decision point. 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.*"

We are highly concerned about the deterioration of our capacity to educate power engineers at U.S. universities. The concern is for all industries employing power engineers. To address this issue, one of the fundamental requirements that the universities have to meet is to ensure that our undergraduate power engineering programs are attractive to the new generations of students. The environment of power engineering has changed drastically in the last decade due to the unprecedented regulatory reforms and technological breakthroughs. However, our undergraduate power engineering curriculum has not kept pace with its fast changing environment. In order to attract the best and brightest students to power engineering, we must take a holistic look at the undergraduate power engineering education and develop a national strategy.

We strongly believe that critical shortages in the power engineering workforce are inevitable without strong and concerted efforts to sustain university power programs. This is a national challenge that must be met to ensure that the nation will continue to enjoy reliable and cost-effective energy in the 21 century.

The DOE report is an excellent beginning point for discussions on engineering workforce issues and recommendations for addressing the critical challenges in assuring an ample supply of new power engineers. The warning calls are being heard not only from government, but also from utilities, vendors, and consultants. Yet a consensus on the positive steps that need to be taken has not yet been reached. We believe that the reason for this lack of consensus is due, in part, to (1) lack of agreement on how serious the gap between the need for new engineers and the ability of universities to graduate them will be, and when it will begin to manifest itself and (2) lack of understanding of the integral relationship between university education and university research infrastructure.

This NSF-sponsored workshop addressed critical issues related to the national challenge on the future power engineering workforce. The objectives of the workshop were:

- *To assess the current state of knowledge of the future demand for and supply of university-educated power engineers, thereby reducing the extent to which there will be a gap between the need for new engineers and the ability of universities to meet that need.*
- *To develop an understanding of what it takes to sustain university power programs, and the role of research infrastructure in educating undergraduate and graduate power engineers.*

The workshop was held during November 29-30, 2007, at Holiday Inn, Arlington, Virginia. The agenda of the workshop is included as Appendix B. The following appendices provide information about the participants:

- Appendix C: List of NSF Participants
- Appendix D: List of all Participants
- Appendix E: List of the Executive Summit Participants

The first day of the workshop had a number of presentations followed by a breakout discussion session. An Executive Summit was held on the morning of the second day. After the Executive Summit concluded, workshop participants discussed ideas that were shared over the workshop and summit, and possible action items. The following sections were written by the indicated discussion editors to provide a record of the comments by speakers and attendees. Their notes include ideas from different perspectives, and that fall in a range of emphasis or priority. There is also no attribution of comments to particular people.

A.2 Workshop Presentations

On the first day, speakers provided different perspectives on the workforce issues and solutions. Workshop attendees then discussed the presentations. This section of the report summarizes the presentations and subsequent discussions. The presentations are available on an Iowa State University website, http://ecpe.ece.iastate.edu/nsfws/

A.2.1 Situation Analysis: Morning Session Presentations and Discussion, November 29

The following presentations were given in two morning sessions:

Morning session 1:

- ***DOE Perspective***
  Patricia Hoffman, U.S. Department of Energy
- ***Power Engineers and the Electric Utility Industry***
  Mary Miller, Edison Electric Institute
- ***Maintaining a Skilled Workforce***
  Richard Lordan, Electric Power Research Institute

Morning session 2

- ***Canadian Perspective on Workforce Issues***
  Catherine Cottingham, Canadian Electricity Association
- ***The Future Power Engineering Work Force***
  Carol Berrigan, Nuclear Energy Institute
- ***Overview of the Status of U.S. University Power Programs***
  Dennis Ray, Power Systems Engineering Research Center
- ***University Training and Research in Canada***
  Géza Joés, McGill Univ., Canada

Presentation and Discussion Notes

Discussion Editors:
Alex Flueck, Illinois Institute of Technology
Patrick Ryan, IEEE Power and Energy Society

Power production growth rate forecast is 1.8% annually. This is much lower than the growth rate in the 50s, 60s, 70s and 80s. Therefore, the power delivery segment will not need the number of engineers that were required in the high growth decades of the past.

In the past, electric utilities supported local university power programs. This is no longer the case. The exceptions, such as Tennessee Valley Authority (TVA), are few. TVA recently created three chaired professorships at local universities. The other example of industry support, but no utility support, was reported at a university that had no power program and recently launched a new program in power and energy with a focus on coal and nuclear.

There is significant downward pressure on electricity rates. Therefore, constrained revenue streams make it very difficult to support universities. While we all appreciate the near-term benefits of reduced rates, the future costs could be large, as the lack of investment further narrows the gap between declining capital investment and steadily growing demand for electricity.

One suggestion was to include research and development (R&D) expenses in electricity rates. However, regulators and interveners (such as consumer groups) tend to oppose any increase in rates. In Canada, some utilities say that they need to add employees and increase rates, but provincial regulators traditionally have viewed employees as a variable cost rather than necessary infrastructure. Canadian rates are the 3rd lowest among the developed countries, but consumer groups still complain that rates are too high.

Clearly, education on the complex issues related to rates will be necessary. This is related to the need for leadership with a strong background in engineering. Several attendees felt that senior leaders with advanced business degrees, but no engineering degrees, may not understand sufficiently the complex technical issues of electricity delivery.

Another complicating factor is that the industry's problems are evolving constantly. New technology may be able to sidestep historically difficult problems. Technology innovations are necessary.

Several attendees pointed out the decrease in industry funding for universities. According to the U.S. Department of Energy August 2006 report on "Workforce Trends in the Electric Utility Industry", the Electric Power Research Institute (EPRI) R&D funding has decreased over 10 years from a peak in 1994 of $595 million to $272 million in 2004.

In addition to the total decrease in R&D funding, the balance between strategic R&D (i.e., long-term research typically done by universities) and applied R&D (i.e., short-term research typically done by companies) has shifted dramatically toward applied R&D. From 1994 to 2004, EPRI strategic R&D decreased roughly 90% from $150 to $15 million. The long-term effects on university research programs of moving away from strategic R&D that tends to be the research strength of universities may be nearly impossible to reverse as retiring power professors are replaced by other sub-disciplines within electrical and computer engineering.

As a result of the decreased research funds, it is more difficult for graduate students to pursue power engineering degrees, and relationships between the power industry and the university power programs have declined. Many attendees stressed that research relationships between industry and academia are critical to the future success of the industry.

Some industry representatives mentioned that intellectual property (IP) has become a major obstacle to increasing R&D funding for universities. Companies find it difficult to sponsor projects if the company does not have ownership of the IP.

At the National Science Foundation (NSF), the number of proposals has increased, while the budget has remained constant or has shrunk due to other priorities within the federal government. It is expected that the NSF budget will increase under the America Competes Act of 2007 which proposes to double federal funding over ten years in basic research in physical sciences and engineering.

Proposal costs have increased over time. Some industry proposals to the Department of Defense have cost $100,000 for the company to prepare. NSF and others have addressed this issue by requiring pre-proposals or short concept papers which are then evaluated by the sponsor. Then, only a small group of pre-proposals are invited to submit full proposals and compete for the program funds.

Many academics believe that a crisis in power engineering research funding at universities will translate into a crisis in new technology development. With globalization, this will mean that more innovation will be done outside the United States. The long-term effect will be a weaker power industry in the U.S., although the effects may not be felt by utilities for some time.

Based on EPRI studies of R&D expenditures as a percentage of sales, the U.S. electric power services industry, combined with gas services and sanitation services, spends less than the hotel industry and less than the restaurant industry on R&D. (See Massoud Amin, "Modeling and Control of Complex Interactive Networks", IEEE Control Systems Magazine, Feb 2002.)

The nuclear power industry has come together successfully to create a unified R&D roadmap. The electric power industry should adopt a similar strategy. This sentiment was shared by both the U.S. representatives and the Canadian representatives. Without a technical roadmap, it is difficult to predict skill requirements for the future. New technologies could have a significant impact on the types of personnel and skills needed in the future. Appendix G summarizes factors leading the renaissance of university nuclear energy programs.

With respect to the technical talent shortage or "gap" analysis, it is not clear that the fundamental data are reliable. For example, there have been many studies that have counted employees that are eligible for retirement, but the experience level of those people has not been captured in the raw data. If employees were represented by their "experience-years," then statistics might tell a more compelling story. Simply counting experienced employees as equivalent to inexperienced employees could be misleading. This type of detailed labor market information would lead to a more sophisticated econometric model, but there are costs of creating such a model.

Looking at the demographics of the electric power industry, it is clear that we need to broaden participation, especially among women and underrepresented minorities, to reach the entire pool of talented professionals. One way to broaden participation is to broaden the scope of traditional power engineering courses. One university has reported significant increases in the percentage of women in their "power" courses, from 8% several years ago, to 16% today. The increase is attributed to the inclusion of renewables and a broader energy focus.

From a student's perspective, the critical issue is whether job opportunities will continue to be available throughout the student's entire career. If jobs are not available, then there is no point in studying the associated subject. Furthermore, if jobs are available, will they continue to be available in the U.S.? China will graduate about ten engineers for every one in the U.S.; India will graduate about five engineers for every one in the U.S. Will the explosion in the number of engineers in Asia mean that U.S. power engineering jobs will move overseas?

In the near-term of the next 5-7 years, there appears to be a need for engineers and engineering managers in the U.S. For example, the Independent System Operators in the U.S. have turnover rates of roughly 12% of their engineering staff. Senior engineer salaries hover around $105,000. Director-level position salaries rose 11% in the last year. However, the industry has long-term needs that will be met with new engineers that are currently in grade schools. There should be a coordinated effort to reach into the K-12 pipeline.

We began the second discussion session with the topic of survey data. There was some concern about the validity of the data. For instance, many terms are not defined clearly within the Power and Energy Society (PES) survey conducted by the Power Engineering Education Committee (PEEC). Different universities may interpret the questions differently. The most reliable data are gathered from the question regarding the number of power faculty at each university, which is easily verifiable.

PEEC survey provides much valuable information; however, the weakness of the PEEC survey instrument is the lack of data on future demand for engineers. The recently launched PES careers web site (pes-careers.org) is an attempt to collect demand numbers from companies that post their job opportunities on line.

As mentioned in the first morning session, broadening the traditional power courses to include renewables, energy and power electronics has increased course enrollments at a number of universities. Rather than talk about transmission and distribution, it was suggested that power courses focus on more general energy topics, as well as communication and control applications in electric power delivery systems.

Also repeated from the first session was the need for companies in the electric power industry to support their local universities that have power programs. In fact, some faculty mentioned an undesirable practice in which companies hire students that have not had a single power course. As a consequence, the message to students is that there is no need to take any power course to gain a job in the power industry.

An additional anecdote was delivered by a faculty member whose university recently hosted a career fair on campus. A large utility sent a recruiter to the career fair. However, the recruiter was not interested in engineering students with a power background – too costly. Instead, the recruiter was interested in engineering technology graduates.

Another example of the uncertainty in the future demand for power engineers comes from a brief informal poll conducted by a faculty member during a recent advisory board meeting. The industry representatives were asked how many power engineering students they were planning to hire. The responses were varied but seemed to average around 2-3 new hires for every 5 retirements. In addition, some of the new hires were expected to be technology graduates.

Compared to the nuclear power industry, the electric power industry is roughly a decade or two behind. The nuclear industry has strong collaborations with university nuclear engineering programs. The industry mainly supports test reactors, but the infrastructure support is vital to the survival of the university programs. The nuclear industry has professional organizations that focus on young engineers (www.na-ygn.org) and women engineers (www.win-global.org). The university nuclear engineering programs have grown over the past decade as seen in the four-fold increase in undergraduate enrollment and the five-fold increase in graduate enrollment. Again, Appendix G summarizes factors leading to the renaissance of university nuclear energy programs.

Based on "back-of-the-envelope" calculations derived from the Center for Energy Workforce Development (cewd.org) data, the demand for power engineering graduates may be on the order of 3,500 total over the next 5 years. If there will be a sudden surge in demand for power engineering graduates, then there are several initiatives that should be started today, otherwise there could be a significant mismatch between supply and demand in the future.

First, we must recognize the intense competition for faculty slots within engineering, especially electrical and computer engineering. If research funding in electric power is far below research funding in other areas, such as bioengineering, semiconductors, electronics, digital systems, signal processing and communication, then it will be extremely difficult to persuade engineering deans that new and replacement faculty positions should be allocated to electric power. Increased research funding brings many benefits including faculty positions, long-term R&D innovation, new undergraduate courses that incorporate state-of-the-art techniques and tools, as well as graduates that are prepared for the future.

Second, we must recognize that there is already intense competition for electrical engineering graduates. To attract students to the electric power industry, new internship and co-operative education programs will be necessary. Similarly, undergraduate research projects funded by industry will expose students to the exciting challenges in electric power.

Third, we must recognize the intense competition for K-12 students. To attract students to engineering, particularly power engineering, we need to work with K-12 teachers to help them practice engineering design and understand engineering innovation. Then, the K-12 teachers will be comfortable enough to teach engineering design and innovation in their classrooms. Another avenue for recruiting K-12 students would be to create summer programs at universities funded by local industry.

A.2.2 Problem Assessment and Development of Solutions: Afternoon Session

The following presentations were given:

- ***What Industry Needs***
  Terry Boston, Tennessee Valley Authority
- ***Overview of NSF's Program in Power, Controls and Adaptive Networks***
  Dagmar Niebur, National Science Foundation
- ***Workforce Issues***
  Anjan Bose, Washington State University

Presentation and Discussion Notes

Discussion Editors:
J. Mitra New Mexico State University
G. T. Heydt Arizona State University

Notes on Terry Boston's Presentation

It is important to understand the industry's needs. The technical issues are storage, controllability, and wide area visibility. The U.S. workforce in power is declining. TVA is facing a declining work force. The need for welders is mentioned as an example.

Loads have worse (lower) load factors with high peaks so we need a controllable grid. There is a promise of HVDC in controllability. Materials science advances are important. Commercialization may be a limiting issue, included in the limitation is handling intellectual properties. For monitoring and control purpose, the power grid visibility is lacking, but PMU deployment has a promising present and future.

Storage is a critical area to make the system 'more efficient' to serve peak demand. Compressed air may be a solution and seems to be better than pumped storage. Utilization of renewables requires advances and use of storage. Battery technology may have a place in this. CO_2 recovery may be the most costly item in the careers of present power engineers. Additional needs are technologies to manage growth, and CO_2 related technologies.

Notes on Dagmar Niebur's Presentation

An overview of the NSF power and energy thrust as part of the Power, Controls and Adaptive networks program was given. The program is part of the Division on Electrical Communications and Cyber Systems (ECCS) at the National Science Foundation Subject to full appropriation of the American Competes Act, it is projected that NSF's budget will double over the next ten years. In this case the funding for ECCS is expected to increase significantly over the next decade. A research theme for 2007–08 on complex engineered and natural systems was announced by the Engineering Directorate in 2007 and ECCS as well as PCAN are aligning their priorities.

The NSF funding is highly competitive. The funding rates NSF-wide decreased from above 30% to about 25% over the last 15 years. The engineering funding rate at NSF is also down from 24% to approximately 14% in last eight years. ECCS division funding rate is at about 17% for the fiscal year 2007. For the power and energy thrust, the funding rate was about 22% range at the expense of an on average smaller budget size. NSF-wide competitive awards are generally in the $100K range for about 2.5 years. For the power and energy thrust the award funding size is about $80K for about 2.7 years. The number of CAREER proposals received for the power and energy thrust is close to the single digit level. Unsolicited proposals are less than 10% of proposals submitted to ECCS as a whole. The present power and energy thrust budget is close to $4M per year.

Notes on Anjan Bose's Presentation

A question is raised concerning whether it is a fact that there is a dire crisis in the workforce. This has been ongoing for a while. The Bureau of Labor Statistics (BLS) takes a contrary point of view. In a recent meeting of BLS and NSF data gatherers, different interpretations of the basic data arose. Also, there has been no dramatic increase in engineers' salaries at the entry level. In addition, there have been no CEOs of power companies stating the case for the existence of a dire crisis in the power industry.

We need jobs for students and research for faculty to sustain the power engineering educational programs. The power industry is recruiting mainly BS level students, but also more mechanical than electrical engineers.

There is a question: do we need the top research universities to supply industry needs? The question relates to the need for research to foster innovation (rather than straight industry needs for bachelor degree graduates). Recall that companies like American Electric Power (AEP) had top research programs (e.g., in EHV transmission) and had a 1000 kV design ready to go – but the fact is that the first 1000 kV AC system is likely to be in China in 2008. This illustrates that innovation in industry has largely been dropped.

A myth is "the research done at universities is not useful." The reality is that universities do produce research results that make a great impact on industry practices. Some examples are state estimation, fast decoupled power flow, dynamic security assessment, and phasor measurement units; the fundamental development of these technologies was done at universities. Companies like PowerWorld basically evolved as start-ups from universities.

We need to continue the outreach efforts, even if hiring is not so eminent. We need to maintain the presence of power programs at the universities. This is the motivation for endowed professorships in the power area. They are needed to maintain the power engineering presence on campus.

Workshop Participant Comments

It was stated that Shanghai Jiao Tong, University in China, has 80 faculty members in the power area alone, and a total of 300 faculty members in electrical engineering. The shortage of power engineers is not a problem in all countries.

Concerning the health of power programs, it was emphasized that students need to know that there are jobs out there that are challenging and interesting. Also, university administration needs to know there is long-term availability of research funding. The idea of supporting coursework and nothing else does not make sense; it produces no innovation through research. It is important to support research. The business case is that students are the product of a program that can be sustained through research support; without the support there will be no program.

It was pointed out that the electric power industry is diverse and that there is considerable need for innovation. Correspondingly, students need a broad and diverse education and should not be over-specialized. Academia cannot wait for industry to drive innovation. Engagement between industry and academia is required at the highest levels of the organizations.

Utilities have a business to run and it takes a business case to attract funds to support chairs. Utilities need to be able to make a solid business case using data. Someone needs to build a marketing case that utilities can take to their stakeholders.

Over the years, innovation and students have been viewed as a single product. Now they are separate. Academia wants research money while industry only wants to invest in the production of qualified engineers. Return on investment in research is much lower than that in education programs that produce more engineers.

For several universities, the Office of Naval Research put up much of the research funding. The Navy is perceived as being behind technologically, yet they realize the importance of investing in power engineering. The funding levels from industry are appalling. How can one expect a return on investment on such low levels of funding? On research funding, it was mentioned that Google has just published an RFP in the power area.

Material science and Nanotechnology are other areas that need energy-related research. Much revolutionary work comes out of universities. There is going to be an NSF workshop in fall 2008 on the role of nanotechnology for energy.

Idaho National Labs is a Department of Energy multipurpose lab which provides a large research facility of which the research community can take advantage.

At one time, Iowa State University was one of the largest power programs in the U.S., with seven faculty members. Now they're down to four, but the department chair points to faulty in other departments who are working on solar energy, Locational Marginal Prices, mechanical energy conversion, etc., and states they are all "energy" faculty.

Universities also invest significantly in power programs. For instance, at RPI, the teaching load has dropped from four courses/faculty/year to 2.25 courses/faculty/year. This constitutes a significant investment. Universities also similarly invest in research programs.

Other general comments were as follows:

- Only industry can provide interesting jobs.
- There is a need to make a long term (e.g., 30 year) commitment to faculty members – this is a basis of the need for research.
- We need a national research agenda in energy.
- Partnerships are needed with industry making the business case for support of power engineering education. "Students" may make our best business case – without students, support from industry could be even more unlikely.
- The total research and investment funding in power engineering is so low as to beg the question of critical mass.

- Investment in course work may not foster innovation. Without investment in research, technology change stagnates.
- There is a need to expand the traditional concept of a power engineer: there are mechanical engineers, solar engineers, materials engineers, and others who are also power engineers.

A.3 Searching for Solutions: Brainstorming Breakout Sessions

Following the presentations in the afternoon session on November 29, all the workshop attendees went to separate breakout sessions for the purpose of brainstorming for solutions to the challenges of educating the future power engineering workforce. Breakout session chairs facilitated brainstorming on specified questions. The attendees were invited to prioritize the solutions using a voting scheme. Appendix F gives the instructions for the breakout groups.

This section of the report summarizes the results of the breakout sessions. For use in the Executive Summit, a one page summary of the breakout session conclusions was prepared. It was distributed at the beginning of the Executive Summit that began on Friday morning, November 30. The one-page summary is in Appendix G.

A.3.1 R&D and Technology Innovation Breakout Session

Chair: Vijay Vittal, Arizona State University.
Co-Chair: Gregory Reed, KEMA

Discussion Questions:

- What are the critical future R&D needs in addressing challenges in electric energy systems?
- What is the role of university research in meeting those needs?
- What are the ways that we can move forward to build a sustainable education system?

Breakout Session Notes

1) Research Needs:

The group discussed various and wide-ranging areas of research needs to be considered, including large-scale simulation; distributed and renewable resource technologies and integration; advanced control systems and automation; superconductivity, power electronics and conversion systems; energy storage; phasor measurements; advanced materials; semiconductors; micro-grid systems and technologies; and aspects of nano-technology development. As a result of the research needs discussions, three primary areas were established as the most important and critical areas of necessary sponsored funding, as follows:

A) Planning & Operating Margins in Real-Time

B) Power Electronics Technologies

C) Storage – Distributed, Independent, Residential

In relation to planning and operating margins in real-time, it was conferred that with the changing market structures, pricing mechanisms, access to information, and other factors, the need for real-time planning and operating capabilities is essential in establishing accurate response to system needs and events with state-of-the-art speed of response capabilities. The real-time aspect of system operations will continue to be increasingly important in a market-driven environment, for planners and operators of the electric power system. With the increased implementation of phasor measurements and increased reliability program measures, the need for real-time operation methods is also important. Given the enhanced requirements of a competitive market environment and the dwindling operating margins due to the lack of transmission enhancements, the need to develop such tools is critical. An added capability of such tools would include the ability to reflect the impact of market mechanisms on the analysis. A primary requirement of such a tool would include accuracy and speed. Such tools would also have to take into account the uncertainties imposed by renewable energy resources such as wind and solar power. The tool would have to incorporate complex models and have the ability to handle large system sizes to facilitate their use by ISOs and RTOs.

Power electronics continues to experience an expansive build-out at all levels of the power system – transmission, distribution, and demand-side. From FACTS and HVDC, to power quality systems, to DC/AC conversion technologies for renewable and distributed generation integrations, more and more power electronics is present on the system. Continued advanced research on semiconductor technologies, system designs and efficiencies, and operating capabilities of power electronics systems will be essential for the proper and improved integration of so much advanced control methodologies being placed on the networks.

With the increased penetration of renewable sources of energy and the uncertainty of renewable sources. research related to storage ranging from large scale to small scale is of paramount importance with regard to enhancing the ability to serve load from an uncertain source. Specific efforts would have to be directed toward increasing efficiency and making sure that the energy delivery capability of the storage is substantial. Energy storage is seen by the industry as a driving solution to many of the issues that are experienced in electric power system operations. From the obvious value of storage to provide improved efficiency in operations and energy scheduling, to the importance of storage in effectively integrating large penetrations of certain renewable energy resources, energy storage on a larger and more economical scale is critical. Further research toward greater commercial viability in the types of energy storage technologies deployed, improved subsystems and designs, and the enabling technologies themselves are all important in establishing energy storage efficiencies in the early stages of larger scale implementations.

In the discussions around all of the research areas identified, the common theme was that nearly all technology areas have experienced significant under-investment over the past two and half decades in order to maintain pace with present-day application needs. The result has often been that many new technology deployments are being installed with expectations of 'commercial grade' operation. In order to truly establish proper methods and time-lines for research and development of new technologies, before demonstration and deployment, much of the basic research in the early stages of technology innovation must first take place. Thus, there is a critical need to perform basic funded research and establish innovation well in advance of commercial application requirements. Of the three critical areas of research identified, as well as in other emerging new technology developments, it was strongly recommended that increased funding from all appropriate sources not only be increased, but focused on the need to establish more basic research avenues, as well as applied research opportunities.

2) Role of University Research:

The role of university based research is viewed as highly critical toward moving the industry forward. The group identified the need for university research as not only important for new and innovative technology advancements, discussed to some extent in the preceding section, but also for the growth and enhancement of electric power university programs in general. The group identified three main areas of high importance with respect to the evolving role of university research, as follows:

A) Ensuring Vibrant Power Programs and Students via Sustained Research Support

B) Enhanced University / Industry Interaction

C) Industry Centers at Universities

The obvious need to ensure vibrant electric power programs and to continue to attract students was not only one of the main themes of the workshop overall, but is necessary for the continued viability of electric power programs in the U.S. By establishing avenues and funding for sustained research programs and support, the proper financing mechanisms and future stream of students and research professors needed to meet future needs can be adequately established. It was clear from the group discussions that support and funding will be needed from various sources, not just government, but also from other sources including greater levels of industry collaboration.

Enhancing university / industry interaction and collaboration was viewed as a very important aspect of needed growth and expansion in the role of university research. Greater collaboration between industry and academia to define a strategic roadmap for stimulating ideas for innovative research for faculty and graduate students, as well as for funding and supporting such research, is greatly needed. Industry participation is not only critical for provide new and sustainable avenues for great research funding, but also in developing innovative and modern education programs that appeal to a new generation of potential students and that provide research opportunities that are both relevant to industry needs and dynamically attractive to students and faculty alike. In cases where this has been successful, the interaction of all levels of industry organization participants, from executives to engineers, has been a key component of commitment and sustained support with industry partners. In many examples, universities can provide the research of identified needs, and transfer the results on to hardware and software vendors for commercialization. One main area that needs considerable improvement from all parties involved is the issue of intellectual property management, which needs to be addressed in a collaborative manner. By carefully selecting research projects that limit intellectual property issues, higher levels of successful university / industry collaboration can be achieved. However, with continued evolution of relationships and understanding, universities can participate in not only translation and applied research for industry needs, but also in some areas of basic research. The key aspect of enhancing interactions is to first create the opportunity for university power research faculty to engage proactively with regional industry partners to develop relationships and understanding.

By establishing industry centers at universities, the ability to more efficiently develop collaboration can be better achieved. This also aides in dealing with some aspects of where certain types of research can be conducted in relation to some issues of intellectual property terms. In any event, the physical location of industry centers at or near university campuses and research facilities, is viewed as a major advantage in facilitating the enhanced levels of university / industry interaction that is sought. In addition, this also creates an environment for longer-term levels of commitment from industry partners, leading to the sustainability needs for power research programs as identified.

3) Sustainable Education:

In the group discussion regarding aspects of sustainable education, a roadmap of developing infrastructure through personnel and resources was identified as an important component, along with participation from industry in various ways including student mentoring and cooperative and internship opportunities. The three key areas of focus for sustainable education were developed as follows:

A) Infrastructure – People and Resources
   Students → Metrics → Public/Private Partnerships

B) Student Mentoring by Industry Employees

C) 1. Coop and Intern Opportunity in Freshman Years
   2. Means of Reliable Student Support

The roadmap of infrastructure to people and resources is achieved through various levels of student population increases, identification of metrics for measuring successful education program results, and participation of public/private partnerships to enhance the educational experience. Innovation in education program and curriculum development is also an important component of establishing sustainable education programs in power. Appealing to the new generation of student interests, including aspects of new and emerging issues that have greater levels of global awareness and societal impacts of power and energy markets, are important aspects of outreaching to students. The development of the proper infrastructure for housing modern educational facilities with state-of-the-art learning tools and technologies and laboratories is viewed as a necessary initiative in sustaining power education programs. The facilities and infrastructure itself must be functional and appealing to create attractive learning environments for the most effective recruiting of new and increased numbers of students in the power area. Students themselves are becoming more and more aware of the emerging importance of energy sustainability as a defining issue of this century, and the ability to attract students to the power area is not only necessary for sustainable education programs, but also for the evolution of power programs moving forward. Establishing the proper metrics for measuring the success of student increases in both numbers and interest in power will be important to anticipate the various future needs, from infrastructure all the way to needed faculty.

Another issue to be dealt with is the need to increase the number of power engineering faculty at universities, both for education and research focuses – the current power engineering faculty demographic itself is not immune to the aging workforce issues. Metrics that establish means for achieving successful classroom environments and results, in addition to advancing educational methodologies will be important for attracting high quality students and faculty alike. Such metrics must take into consideration the need for investment in current facilities and education programs in order to bring them to state-of-the-art levels. By establishing public/private partnerships in this arena, it is viewed that both greater interest and investment in the sustainable education area can be achieved. There is a workforce development issue that is paramount and closely linked to sustainable education programs in the power and energy area, and that impacts economic development both regionally and nationally. Both private and public institutions, from local to state to national levels, will need to play a role in the development and continuation of the proper educational infrastructure and program developments of the future.

Greater university / industry collaboration was identified as a key component to university research programs. It is only logical that the university / industry relations develop beyond just research programs and to a deeper level involving industry mentorship of power engineering students. This provides a large number of benefits for both the industry personnel and organizations, as well as for the students. Initiatives from informal mentoring relationships through concepts of "career shadowing" help to not only engage industry personnel in the advancement of student development, but allow students to understand the workforce environment at an early stage and to begin to apply their learning within workforce situations to bring about practical enhancements to their coursework and classroom studies.

Early year cooperative and internship programs have proven to be extremely effective for both students and industry participants. Enhancing such programs and increasing the developmental aspects of career experiences for students will continue to be important in addressing future workforce needs. Placing students in the engineering workforce environment at an early stage provides a means to increasing their levels of contribution later on as eventual full-time employees at earlier career stages, as well. There is an impending need for not just engineering talent within the workforce development arena, but also for the future leadership development. Successful cooperative and internship programs aid tremendously in propelling student's understanding of industry and market environments, and thus enhance their ability to develop both technical and leadership skills from an early stage.

The other main aspect of sustainable educations is realized through the link to research. Both are needed to improve and grow the power and energy programs nationwide, and through the proper infrastructure and programs for education, we can improve the environment, interest, dynamics, and sustainability for research areas as discussed in the previous sections.

Conclusions. We should encourage and facilitate university research for innovation and education by:

- *Helping university researchers and students to better understand industry research need priorities so that they can make informed choices in their research directions (such as power electronics and energy conversion, planning and operating margins in real time, and storage).*
- *Increasing industry, university and government research collaboration to support research and student education, to facilitate creation of innovative solutions to industry challenges, and to establish global competitiveness and leadership.*
- *Ensuring that sustained support is provided for university research and education efforts to maintain strong electric power and energy university programs.*

A.3.2 Innovations in Education Breakout Session

Chair: Hamid Elahi, GE Energy
Co-Chair: Noel Schulz, Mississippi State University

Discussion Questions:

- What are the most effective and innovative strategies for educating the future power engineering workforce? Strategies could curriculum, programs, educational institutions, and collaboration methods.
- What are the ways that we can move forward to build a sustainable education system?

Breakout Session Notes:

Question #1: What are the most effective and innovative strategies for educating the future power engineering workforce?

There are alternative paths for power engineers using established power programs. The utility industry recruited electrical engineers and placed them in training to become power engineers. There are utility programs to retrain and diversify the knowledge of engineers, such as one from National Grid and WPI. The program includes three power systems classes, and three MBA classes. Students receive a certificate with a Masters in Power Systems Management that is half technical and half management. The program has graduated 80 people. Classes are scheduled every three weeks with a full day on Friday and Saturday. Students pay fees and purchase books. Most of the students are within 90 minutes' drive. The program is also offered through telecommuting.

We should promote collaboration between universities by having modular classes on the web to allow small programs to access power classes. We can use the technical society to set the standards and have vendors to deliver the curriculum. There could be an alternative program for students with Bachelors degree to work for a Master's or Ph.D. degree through an on-line program to attract more people. There should be opportunities for module e-learning so that students can do course work on the job. We need better opportunities for two-way traffic between industry and academics. Sabbaticals should include the national laboratories.

We need to take a careful look at the power engineering curriculum to identify the necessary changes and updates. Universities need to design the curriculum to benefit students instead of industry. Students should receive broad training so that they can go wherever they want to go. There is an issue of training versus educating people. It is desirable to have a curriculum with the overall fundamentals of electrical engineering with three courses in the power area. It may be too much to have more than three classes, but the power curriculum would not be strong enough with fewer than three courses. It is not desirable for undergraduate engineering students to overspecialize too early. The example of the University of Minnesota was mentioned; at U of M, the number of power courses was reduced to three so students can take other classes.

It is an interesting idea to view a Master level degree as the first professional degree in engineering. There is also a need to partner with utilities to use their models and technology so students have more industrial knowledge. It is desirable to integrate the curriculum with industry practices. Innovative teaching tools, such as modeling and simulation, E-learning, and virtual laboratories, should be utilized.

Opportunities for current students should be expanded. Students can gain work experience through co-ops and internships within the curriculum, including graduate co-ops and internships. Undergraduate research opportunities are excellent mechanisms to expose students to challenging problems. Projects should be available with design and build challenges. The educational experience includes activities like leadership, entrepreneurship, communications, and business. We should encourage professionalism, e.g., joining IEEE PES, and encourage students and faculty to actively participate in professional societies.

An emerging generation of naval ships is requiring knowledge of power systems. The use of shipboard electrical systems requires people with new knowledge and experience. This is a good example of the need to retool people for today's new challenges.

We need to recruit the next generation of power engineers. There is a view that engineering helps move people from the lower economic class to the middle economic, but cannot help them move to higher class without business, law and medical degrees. After one receives an MBA, one should not forget the engineering roots. We need to impress upon the students the value of the profession (thus providing a professional identity) and partner with the industry to do that. It will be necessary to instill the idea that engineering is about helping people.

Question #2: What are the ways that we can move forward to build a sustainable education system?

We need to develop strong partnerships in the power engineering community. Effective partnerships between academics, community and industry should be built. Universities can approach local/regional power-related industries to create power affiliates centers. The career opportunities should be expanded beyond utilities. This is important for recruitment and marketing.

On the issue of education, we need to define what we are educating today and define our target audience. It is important to identify the constituencies and recognize that the power industry is diverse; it is not one-for-one. The areas of continuing education and lifelong learning should be promoted. There is also a need to educate the guidance counselors and other programs. We need to develop a research agenda for power engineering.

Among the universities, we have different types of education institutions. Some have active research programs and others are focused on education. Both are needed. For the vitality of power programs, we need to ensure a pipeline of power engineering faculty.

Universities need to develop curriculum to excite a new generation of students, and use pedagogical tools preferred them, such as blogs and podcasts. It is important to identify the core common elements that are needed within the curriculum. Up-to-date textbooks need to be developed. It is critical to look at system issues within the curriculum. We need a system engineering class – power systems. We also need to put "integrated system engineering" into the curriculum.

Priority Solutions that are Implementable

#1 – Modular E-learning
#2 – a) Work experience through co-op and internships (undergrad and graduate)
b) Develop curriculum to excite new generation of students
#3 – Industrial Partnerships
#4 – Design curriculum to benefit students – don't over specialize

A compilation of the ideas that were discussed and the subsequent voting is given in the following tables.

Flip Chart Results

(R= Priorities, G=Implementable, and the number of votes received)

What are the most effective and innovative strategies for educating the future power engineering workforce?

1. Retrain/ expand; educate "non-power" EE		2R
2. Modular e-learning		8R ; 7G
3. Design Curriculum to benefit students…Don't "over-specialize"		4R ; 2G
4. Set Standards and get a vendor to deliver curriculum		
5. Impress the value of Eng. on students		1R
6. Industry Partnership		6R ; 4G
7. MS as 1st professional degree		
8. Integrate curriculum with industry practice		1R
9. Innovative teaching tools (digital labs, videos, etc)		4R ; 2G
10. Work experience through loop and internship (under-grad and grad)		7R ; 6G
11. Undergrad research		1R
12. Communication, leadership, and entrepreneurial programs		4R
13. Design and build competition		3R
14. Encourage active participation in Prof. Societies		1R
15. Eng. is all about helping people		1R
16. Two-way industry- University sabbatical exchange		3R
What are the ways that we can move forward to build a sustainable education system?		
1. Identify the constituents need		2R
2. Active research at selected schools		2R
3. Ensure a pipeline of PE faculty		1R
4. Streamline the EE undergrad curriculum		2R
5. Bldg partnership between schools, industry, and community		3R
6. Develop a research agenda for P.E.		2R
7. Raise visibility of P.E.		1R
8. Put integrated systems engineering in the curriculum		4R ; 1G
9. Approach local utility industry for affiliate programs		2R ; 1G
10. Expand marketing of future job opportunities		1R
11. Develop up to date text books		2R
12. Develop curriculum to "excite" new generation of students		7R ; 7G

Conclusion. Educate students for power engineering careers by:

- *Building strong and on-going industry relationships with universities to enhance the educational program and to support faculty in their education activities.*
- *Increasing industry and government collaboration with universities to identify education topics and implement new delivery methods that make electric power and engineering education more exciting, relevant, and efficient for a new generation of students.*

A.3.3 Outreach Programs Breakout Session

Chair: Chris DeMarco, Univ. of Wisconsin - Madison
Co-Chair: Robert Teichman, American Electric Power

Discussion Questions

- What are the most effective and innovative strategies for increasing the pipeline of power engineering students? Strategies could include best outreach practices, leveraging existing programs, and roles of industry, government and universities.
- What are the ways that we can move forward to increase the pipeline of new students?

Breakout Session Notes

This breakout session was concerned with educational outreach, primarily in those contexts that impact the pipeline of potential future power engineers; that is, outreach to K-12 students in the nation's school system, to the adults who influence the decision-making of such students (e.g., parents, guidance counselors), to first year university students making initial choice of course of study and major, and to continuing university students facing choices of whether to remain focused on a path of study enabling them to pursue power engineering careers. The specific charge provided to this breakout session instructed the participants to address the following questions:

- What are the most effective and innovative strategies for increasing the pipeline of power engineering students? Strategies could include best outreach practices, leveraging existing programs, and roles of industry, government and universities.
- What are the ways that we can move forward to increase the pipeline of new students?

The sessions charge further indicated that the group should devote about 75% of its effort towards on ideas of educational innovation, and 25% of its effort on the process to move forward.

In seeking to address the charges given, in the context of this workshop, the session participants found it natural to consider first those program and resources for engineering pipeline enhancement offered by the NSF. It was also recognized by the group that creating excitement for engineering among K-12 students rests heavily on the shoulders of teachers at these grade levels, so that programs that can help equip such teachers to do this job are extremely valuable. To this end, the session participants highlighted NSF Research Experience for Teachers (RET) as a very important program, and agreed that at present it is not exploited to anywhere near its full potential. Several university faculty members in the session reported positive experiences they had involving a K-12 teacher in their research under the support of the RET program, but agreed that the number of such cases involving teachers in NSF-supported research relevant to power engineering were very few nationally. Therefore, it seemed the consensus of the group that both NSF personnel and university power systems researchers should make greater efforts to more fully utilize the RET support resources currently available, as the general belief of the group was requests for such RET support currently do not fully use the dollars available. Then, assuming that greater utilization of this program could be encouraged, further efforts could then be made to expand its resources, perhaps matching industry support through the IEEE Power and Energy Society with NSF funding.

Several session participants noted that a range of pre-college programs to raise awareness of careers in engineering and science exist, with the goal of enhancing the pipeline of available students (e.g., "Project Lead the Way" funded nationally by the Kern Foundation). Suggestions were made that the power industry could seek partnerships with these national efforts (perhaps with IEEE PES as the organizing entity), and offer to enhance them with exposure to electric energy topics that would particularly raise student awareness of power engineering. Among the popular suggestions discussed were development of hands-on experiments that would be attractive for use in K-12 curriculum. Related to these efforts, many session participants saw mentoring of K-12 students by individuals with real-world experience in the power industry as being very important. Among the suggestions in this context was one of drawing on young IEEE PES members, those with "GOLD" (Graduates of the Last Decade) status, as particularly effective ambassadors to middle and high school students.

In addition to reaching out to K-12 teachers, it was felt that middle and high school guidance counselors formed a particularly important target for outreach efforts because they are among the key "influencers" of student choices affecting future study paths and careers. In this regard, it was felt that the IEEE PES could (and indeed, already does) play an important role in producing informational and promotional materials that help make counselors better aware of the attractiveness of career paths related to power engineering, and of the preparatory coursework that would help equip students for such a career. Ongoing efforts in IEEE to assemble exciting video footage to highlight power engineering and electric energy were cited as a resource that could be exploited. It was reported that this footage is being put together with the goal of creating a possible public television piece entitled "Circuit Earth." Participants were encouraged to keep informed of this effort, both in regard to any resulting program itself, and as high quality source material to feed other possible promotional videos.

The importance of means to enhance the "coolness factor" of power engineering was noted as an issue that extends into university students' choices, both in selection of majors among first year students, and later in retention of students through their degree programs, when the possibility of exiting an engineering major for another field is a concern. This issue was viewed as being of universal importance for all engineering students, but was recognized as being of particular importance as power engineering seeks to broaden its appeal to female students and students from traditionally underrepresented groups. As with the "Circuit Earth" effort cited above, promotional video materials were seen as important, as well as more "hands-on" exposure to relevant projects. Several university participants cited the growing trend for engineering curricula to include a first year design-oriented course, and to provide broad exposure to engineering challenges. It was recognized that alternative energy projects provide a particularly attractive vehicle for accomplishing this. Efforts to incorporate wind energy projects into the first year engineering design course at the University of Wisconsin were noted, and participants made aware of an associated promotional video available on the web ("Freshman Engineers Seize the Wind," http://www.news.wisc.edu/13833).

Another vehicle of outreach for grade school through high school students noted by session participants was summer technology camps. Several participants cited the success over the last decade of computer skills camps for youngsters. It was felt that with the growing public awareness regarding energy, there would exist sufficient excitement about the electric energy field to attract students to analogous camps that could have power engineering as a significant component. Both for this type of summer camp experience, and more generally, session participants felt that that the close inter-relation of energy and the environments gives the power field an opportunity to appeal to students' enthusiasm for topics that serve the public good. Several session members indicated that they saw a growing altruism among students and young employees, and felt that highlighting the role that power engineering plays in serving society would be important mechanism to enhance student excitement for the field.

As a means to best organizing planning for efforts in K-12 and early university outreach, and to disseminate best practices, the session members suggested that a matrix presentation of the following form would be useful. Along one axis should be the division by the nature of the target student group to which power engineering opportunities and ideas are to be communicated. Natural groupings along this axis might be K-4, 5-6 grade, middle school, high school, early university, undergraduate engineering majors, and graduate students. Along the other axis would be groups of people or institutions identified as mechanisms for influencing the target groups. This axis might include peer groups, teachers, guidance counselors, television, print media, etc. The entries in the matrix, at each point of intersection, would be an example of a "best practice" or an innovative idea for making a particular audience of students aware of power engineering, through a particular group or social mechanism of influence.

Conclusions. Reach out to increase and sustain the pipeline of power engineering students by:

- *Promoting the social importance of solving electric energy challenges and of delivering electricity economically, reliably and sustainably.*
- *Making the education more interesting, such as by developing hands-on group projects across course levels.*
- *Leveraging government programs through collaboration, such as the NSF programs "Research Experience for Teachers," and "Grant Opportunities for Academic Liaison with Industry."*

A.3.4 Collaboration Among Industry, Government and Universities Breakout

Chair: Alan Courts, Bonneville Power Administration
Co-Chair: Karen Butler, Texas A&M University

Breakout Questions

1. Is systematic, multi-stakeholder collaboration among industry, government and universities needed to sustain university power programs?
2. What are the best strategies for collaboration among industry, government and universities to effectively sustain university power programs?
3. What would be the keys to establishing and maintaining those collaborations?

Breakout Session Notes

The initial discussions focused on whether a well-defined statement of the problem had been given. While there was an acknowledgement that there is an aging power workforce, there was no consensus on whether there will be a shortage of power engineers. Data is needed on the future power engineering employment needs, and how many programs are needed to produce the graduates at all levels to meet those needs. Also we must include industries beyond the utilities in defining the power engineering workforce needs. Another area of lengthy discussion was whether a better justification for sustaining university power programs is the need for innovation to meet the environmental, defense, and natural resources challenges.

Several strategies were discussed for establishing and maintaining collaborations among the three groups. A formal organization is needed that would serve as a common voice for the stakeholders and have the responsibility for carrying out the actions. The organization can be an existing or new organization. The actions and structure of several existing collaborative organizations can be used as models.

Healthy collaborations result from mutual understanding of the respective cultures. One suggestion for achieving this understanding is through faculty/student and employee exchanges among industry, government, and universities. Also the intellectual property barriers should be addressed to enable healthy industry and university research collaborations. Further National Laboratory and Department of Defense collaborations in power electronics should be drawn upon.

Lastly the power industry needs re-imaging in a positive way through collaborative efforts. This includes reinventing jobs and more inclusive work cultures.

Discussions on establishing and maintaining the collaborations centered on performing a more thorough assessment of need to better define problem with support data. This would include identifying goals and end states, and short, medium, and long-term horizons. Also, it was stated that more sustainable research funding should be secured. For example, the Federal Energy Regulatory Commission (FERC) or state public utility commissions in coordination with

National Association Regulatory Utility Commissioner (NARUC)) could set perhaps a 1 mil rate for R&D use; a related approach would be to extend California's PIER program to every state.

Conclusions. Expand industry, government and university collaboration by:

- *Motivating collective action through creating a better understanding of the emerging challenges in meeting the demand for high quality power engineers, such as by gathering more data on the number of students going into the power engineering field, on the state of the educational infrastructure, on the future demand for power engineers, on the need knowledge and skills of the future power engineers, and on metrics for describing the job market and the state of the education system.*
- *Creating a national organization to drive collaboration among industry, government and universities, and to facilitate communication of national electric power and energy research and education priorities.*
- *Working collectively to improve the image of power engineering to attract more students to the field.*
- *Identifying the keys for effective collaboration among industry, government and universities, such as through knowledge transfer on collaboration methods, through case studies, through identification of barriers (e.g., intellectual property) and best practices.*

A.4 Executive Summit

Some twenty key leaders from industry, government and universities were invited to attend an Executive Summit on the Friday morning of the workshop. The attendance list is in Appendix E. The Summit focused on identifying solutions to the challenges associated with scaling-up and sustaining university power engineering programs throughout the nation while addressing the need for a good pipeline of students into the programs. The summit attendees were told that collaborative thinking among industry, government and academia is important to ensure that the educational infrastructure is strong and sustainable. These attendees helped develop a list of action ideas to assure an ample supply of new power engineers for the 21st Century. Most of the Executive Summit attendees did not participate in the workshop sessions.

The discussion covered a range of workforce, education and research topics. For this report, the wide-ranging comments were compiled into a number of major topics with individual points made by one or more of the participants.

Comments at the Executive Summit

Facilitator and Co-Facilitator: Wanda Reder and Frank Wayno
Discussion Editors: Pete Sauer and Kevin Tomsovic

Facts and data

- There is still a strong need to consolidate facts and data to make a case.
- We need data on how many engineers are needed at each level of education.
- Where will the industry be in 10 years?

- What should the basic engineer know?

Society needs

- Economic growth tracks energy growth.
- Blackouts have serious consequences.
- See green energy issues below.

Green energy perspectives

- Students are attracted to it.
- Climate change is important and popular. We need to use it.
- Saving the planet could be the big motivator for students.
- Power engineering is now an environmental issue - capitalize on it with everyone.

Industry views

- Human resources are as important as wires and generation (people are an infrastructure).
-
- The industry should be supporting more university research.
- The industry must recognize the value of research.
- There is not enough research being done on new equipment.
- The industry would like more continuing education opportunities.

Industry roles

- Utilities need to partner with schools.
- Utilities need to adopt schools.
- Industry could help by visiting deans and department heads of universities.
- Need better coordination across universities and industry (and state government).

University views

- Faculty at research universities must be active in research in order to survive.
- Need a long-term research agenda.
- University power programs will disappear without research funding.
- Universities are driven my rankings, which are driven by research dollars.
- Faculty are promoted based on their research success more than their teaching success.
- Scholarships help attract students – money is important.
- Internships and coops attract students and expose them to jobs.
- We need to create a student demand that can be seen in the universities.

University roles

- Deans and department heads need to replace retiring power faculty.
- Universities should collaborate and share ideas.
-
- Need better coordination across universities and industry (and state government).

Regulator and government roles

-
- There needs to be a national voice for power engineering education and research.
- We need to let people know the importance of keeping an educational infrastructure.
- Need better coordination across universities and industry (and state government).

- Provide tax incentives – e.g., tax credits for supporting research and education.

Outreach and education

- Children of blue collar workers tend to do better, but they can't afford tuition.
- Children of white collar workers don't seem to want to do math.
- Is the exporting of jobs really a problem?
- Need to do a better job explaining the realities of energy to the public.
- Continue outreach to explain that energy comes from others.
- Important to get young people to talk with young people.
- Need to work with high school teachers to let them know what engineers are.
- Math illiteracy is a problem – maybe we can help?
- Schools with a high level of underrepresented groups are an untapped resource.
- Companies need to hire them as interns and give them scholarships.
- We need to create a demand that can be seen in the high school.
- We need to educate congress and the regulatory community.
- We need to let people know the importance of keeping an educational infrastructure.

Image and marketing

- Start early – K-12.
- Need some way to attract students into power – maybe pay them?
- Get into the minds of kids and see what motivates them.
- We need to make engineering flashy and cool.
- Engineering is hard, but fun.
- Nuclear survived the image and marketing problems.
- We should examine what nuclear did to come back. (See Appendix H in the report.)
- Consider some of the national competitions to excite students.
- First robotics theme next year is energy.
- The National Academy of Engineering will be issuing a report on the image of engineering in 2008.
- We need to get a video out there – how about "The adventures of Eleanor Electron"?

Retention

- Support networks for underrepresented groups are important.
- Need a book of best practices.

Labor Economics

- Are salary offers going up for power engineers?
- If there is a shortage of power engineers, wouldn't salary offers go up?

Research

- The industry must emphasize innovation.
- Need a consensus on the high priority areas (storage, power electronics, controls etc.).
- ISO's can help articulate the problem and focus R&D.
- Feeling overwhelmed with complex problems dealing with this.
- Green revolution is on us - 144,000 MW of wind in queue.
- Flood of demand-side and distributed resource: 10% within two years.
- Nano remains the major funding area – try and fit into that area.

- Consider nano projects to excite students.
- Flywheel technologies are catching interest.

A national issue

- Create a body that speaks with one voice.
- The body should have a regional sub-layer.
- Local companies support local universities.
- Problem won’t be solved by any one entity.
- Collaboration is needed.
- Contacts at high levels are needed (i.e., CEOs, etc.).
- Need awareness at high levels in organizations.
- Need data to support the assertions about the magnitude of problem.
- Need to make the workforce and university power program problems credible.
- We need to have our influential people in front of Congress.
- Congress listens when there’s a group of diverse stakeholders working together.
- Computer science uses people at high levels as spokespersons.
- IEEE might be able to help.
- ASEE could be brought to the table for access to deans.
- There is a regulatory role.
- We need to bring this to the conscience of FERC and local regulators.
- Think globally --- Act locally.
- The connection between the workforce and reliability should be identified.
- Need a champion organization to coordinate between DOE, NSF, etc.
- Need to collaborate across many agencies, and use universities in the process.
- We need to build awareness of issues.
- Meet with National Governor’s Association - their focus next year is on clean energy.
- New investments: solicitation for grant applications to support energy workforce.
- Link regional economies to federal partners.
- Add value to regional economies by leveraging work at EPA, etc.
- If we get together correctly, we can have a major impact.
- Need a partnership across industry, government and universities.
- Approach NARUC Electricity Committee and get on agenda.
- Need a national focus with macro guidance (and perhaps funding) but local relationships.

A.5. Workshop Session: Identifying Actions for Industry, Government and Universities

The final session was used for the workshop attendees to discuss ideas that had been raised in prior sessions, including the Executive Summit. The session:

- Revisited the definition of the problem or problems
- Brainstormed on the actions that could have the most impact
- Identified actions that might be undertaken.

There was no voting in this session so no attempt was made to develop consensus. Therefore, the ideas listed in the section of the report are simply those shared by the workshop attendees in the final session.

Facilitator: Chen-Ching Liu
Discussion Editors:

- Joe Chow, Rensselaer Polytechnic Institute
- Leonard Bohmann, Michigan Tech University

A.5.1 Notes on Problem Assessment

The discussion was focused around there areas, i.e., universities, university/government/industry interactions, and the broader society.

From a broader societal point of view, we have an inadequate focus of math and science in K-12. At present, no one seems to own the problem of workforce planning for power engineering. Legislation is needed to support workforce development in energy. IEEE needs to support coordination of workforce. Policymakers need to aware of the problem. The Department of Energy needs to be persuaded to support solutions.

The universities need to replace professors as they retire or programs will fade away. A curriculum redesign is much needed. Educators need to re-connect with their students. The relationships between students and professors need to be strengthened.

We need strong interactions among the universities, government and industry. This is a commitment that needs to be sustained. We need to create more value from R&D dollars. There is an important issue, however, in how we measure value; we need to identify good metrics. There is a disconnect between the perceived value of R&D and the actual value. One must build the business case. The intellectual property issues often get in the way of university and industrial collaboration. It is important to build relationships between the North American Electric Reliability Corp. (NERC), the power industry, and universities. Government programs on critical infrastructures need to be exploited. One example is the NSF Emerging Frontiers in Research and Innovation (EFRI) program.

A.5.2 Notes on Action Items

The power engineering community needs to create a single voice for industry/government/academia on workforce issues. There should be a single point of responsibility. As a community we need to develop a communications plan and a strategic action plan. The K-12 outreach is important, but we need to find better models. It is also critical to educate teachers about engineering. The NSF RET program is a good resource.

To facilitate effective industry and university collaborations, we need to develop proven models. It is beneficial to leverage federal funding. To address the workforce issue, we need to develop multiple sites on centers for power education and research.

Further action items include:

- Create an executive board to achieve a higher level of credibility
- Create an R&D roadmap – research drivers for transformative energy
- Collect data - make sure it is credible and not just another survey.
- Take educational actions – for K-12 students: what would it take for them to make Engineering a curriculum of their choice. Math and science education need to be stronger.
- Create educational surcharge on energy rates.
- Modularize courses and develop articulation agreements across universities.
- Provide maintenance and development for power courseware websites.
- Recommend NSF to fund a green elective energy curriculum.
- Hold focus groups of 18-25 year olds to understand their motivation, topics, and attraction.
- Communicate with to K-12 students to understand their motivations.
- Promote R&D on educational methods.
- Facilitate high school teacher training, such as the NSF "Research Experience for Teachers" program.
- Find mechanism for ownership of workforce issue spanning academia, government, industry
- Develop a roadmap for academic/industry collaboration – including a list of new technology development with potential benefits to utilities/grid operators and opportunities for software/hardware vendors to develop new products.
- Meet with Secretary of Energy to discuss expanded funding for energy
- Emphasize power/energy as an exciting area for an education, and a challenging and satisfying career to pursue, at every level: create websites to attract K-12 students into power (and engineering in general); develop a power curriculum with courses that deliver knowledge and values to attract top-notch students; provide opportunities for undergraduate and graduate students to work on power industry projects, paid for by power companies (preferably leveraged with DOE, State, and EPRI funding).
- Convince university administrators and NSF/DOE/State officials to fund and build micro-grid laboratories at selective universities where collaborative renewable energy research can be conducted with participations from multiple universities. Experimental work tends

to require a larger number of students and thus will expand the workforce supply pipeline.

Appendix B: Workshop Agenda

Thursday, Nov. 29 (Ballroom)

7:30 - 8:30	Registration and Breakfast
8:30 - 8:45	Welcoming Remarks: • Usha Varshney, National Science Foundation • Dagmar Niebur, National Science Foundation • Wanda Reder, IEEE Power and Energy Society • Mark Lauby, North American Electric Reliability Corporation • Vijay Vittal, Power Systems Engineering Research Center
8:45 - 10:15	Presentations: • Patricia Hoffman, U.S. Department of Energy • Mary Miller, Edison Electric Institute • Richard Lordan, Electric Power Research Institute • Catherine Cottingham, Canadian Electricity Association Discussion (Editors: Yilu Liu, Virginia Tech; Alex Flueck, Illinois Inst. Tech)
10:15 - 10:30	Break
10:30 - 12:00	Presentations: • Carol Berrigan, Nuclear Energy Institute • Dennis Ray, Power Systems Engineering Research Center • Géza Joés, McGill Univ., Canada Discussion (Editors: Yilu Liu, Virginia Tech; Alex Flueck, Illinois Inst. Tech)
12:00 - 1:00	Lunch (Buffet)
1:00 - 2:30	Presentations: • Terry Boston, Tennessee Valley Authority • Dagmar Niebur, National Science Foundation • Anjan Bose, Washington State Univ. Discussion (Editors: Gerald T. Heydt, Arizona State Univ.; Joydeep Mitra, New Mexico State Univ.)
2:30 - 2:45	Break
2:45 - 4:30	Breakout Groups: *Innovations in Education*

Chair: Hamid Elahi, GE Energy
Co-Chair: Noel Schulz, Mississippi State Univ.

R&D and Technology Innovation
Chair: Vijay Vittal, Arizona State Univ.
Co-Chair: Greg Reed, KEMA

University/Industry/Government Collaboration
Chair: Alan Courts, Bonneville Power Administration
Co-Chair: Karen Butler, Texas A&M Univ.

Outreach Programs
Chair: Chris DeMarco, Univ. of Wisconsin - Madison
Co-Chair: Robert Teichman, American Electric Power

Discussion Editors: Breakout Session Chairs and Co-Chairs

4:30 - 4:45 Break

4:45 - 5:30 Briefings from the Breakout Groups and Plans for Friday

5:30 - 7:30 Reception-Dinner (Everyone is invited to stop by for a short time or longer.)

7:30 - 8:30 Breakout Session Chairs/Co-Chairs Meeting with Workshop Steering Committee

Friday, Nov. 30 (Ballroom)

8:00 - 9:00 Breakfast

9:00 –9:30 Welcoming Remarks – Allen Soyster, National Science Foundation
Wanda Reder, Briefing for the Executive Summit

9:30-10:30 Executive Summit
Discussion Facilitator: Wanda Reder, IEEE Power and Energy Society; Co-Facilitator: Frank Wayno, Cornell Univ.

Discussion (Editors: Peter Sauer, Univ. of Illinois at Urbana-Champaign; Kevin Tomsovic, Washington State Univ.)

10:30 - 10:45 Break

10:45 - 12:00 Executive Summit (continued)

12:00 - 2:30 Action Plan Development and Working Lunch
Discussion Facilitator: Chen-Ching Liu, Iowa State Univ.

Discussion (Editors: Joe Chow, Rensselaer Polytechnic Inst.; Leonard Bohmann, Michigan Tech Univ.)

2:30 Adjourn

Appendix C: List of NSF Participants

Graham	Giovanetti	Science Assistant
Susan	Kemnitzer	Deputy Division Director (Education)
Dagmar	Niebur	Program Director
Michael	Reischman	Deputy Assistant Director (Engineering)
Allen	Soyster	Division Director
Usha	Varshney	Division Director
Paul	Werbos	Program Director
Calvin	Zulick	Science Assistant

Appendix D: List of All Participants

Edina	Bajrektarevic	Operations Engineering, MSEE	American Transmission Co.
Thomas	Baldwin	Associate Professor	FSU Center for Advance Power Systems
Carol	Berrigan	Director, Industry Infrastructure	Nuclear Energy Institute
Gilbert	Bindewald	Program Manager	Department of Energy
Leonard	Bohmann	Chair, Electrical and Computer Engineering	Michigan Tech University
Anjan	Bose	Regents Professor	Washington State University
Terry	Boston	Executive Vice President, Power System Operations	Tennessee Valley Authority
Thomas	Brockley	President	Waukesha Electric Systems
Michael	Brown	Senior Consultant	Hay Group
Karen	Butler-Purry	Professor	Texas A&M University
Ronald	Carstens	Director - System & Reliability Plan	Baltimore Gas & Electric
Joe	Chow	Professor and Associate Dean	Rensselaer Polytechnic Institute
Catherine	Cottingham	Executive Director & CEO	Electricity Sector Council
Alan	Courts	Vice President, Engineering & Technical Services	Bonneville Power Administration
Mariesa	Crow	F. Finley Distinguished Professor	University of Missouri-Rolla
José	Delgado	President & CEO	American Transmission Company
Christopher	DeMarco	Professor	University of Wisconsin-Madison
Hamid	Elahi	GM-Energy Consulting	GE Energy
Terry	Ericsen	Program Officer	Office of Naval Research
Alex	Flueck	Associate Professor	Illinois Institute of Technology

Linda	Fowler	Director of Strategic Partnerships	U.S. Department of Labor
Graham	Giovanetti	Science Assistant	National Science Foundation
Jay	Giri	Director	AREVA T&D Inc.
Jim	Gover	Professor of Electrical Engineering	Kettering University
Ray	Grosshans	Program Coordinator, Center for Advanced Energy Studies	Idaho National Laboratory
Scott	Henry	VP, Electric Systems Operations	Duke Energy
Diana	Herr	Sr Human Resources Consultant	Baltimore Gas & Electric
Gerald	Heydt	Regents' Professor	Arizona State University
Narain	Hingorani	Consultant	
James	Hoecker	Partner	Vinson & Elkins
Patricia	Hoffman	Deputy Director for Reseach and Development, Office of Electricity Delivery and Energy Reliability	U.S. Department of Energy
Elizabeth	Howell	Vice President of Operations	ITC Transmission
Mike	Hyland	Vice President	American Public Power Association
Geza	Joos	Professor	McGill University
Kevin	Kelly	Director, Policy, Office of Markets Regulation	Federal Energy Regulatory Commission
Susan	Kemnitzer	Deputy Division Director (Education)	National Science Foundation
Mark	Lauby	Manager, Reliability Assessment	North American Electric Reliability Corporation
Chen-Ching	Liu	Palmer Chair Professor	Iowa State University
Richard	Lordan	Director	Electric Power Research Institute
James	McCalley	Professor	Iowa State University
Mary	Miller	Vice President, Human	Edison Electric Institute

		Resources	
Joydeep	Mitra	Associate Professor	New Mexico State University
Ned	Mohan	Professor	University of Minnesota
David	Mohre	Executive Director, Energy & Power Division	National Rural Electric Cooperative Association
James	Momoh	Professor and Director	Howard University
Bradley	Nickell	Technology Manager - Wind Systems Integration	U.S. Department of Energy
Dagmar	Niebur	Program Director	National Science Foundation
Philip	Overholt	Program Manager	U.S. Department of Energy, OE-10
David	Owens	Executive Vice President	Edison Electric Institute
John	Pazik	Division Director	Office of Naval Research
Margaret	Pego	Senior Vice President and Chief Human Relations Officer	PSEG Services Corporation
Ann	Randazzo	Director	Center for Energy Workforce Developmet
Dennis	Ray	Executive Director	Power Systems Engineering Research Center
Wanda	Reder	VP Power Systems Services	S&C Electric Company
Gregory	Reed	Senior Vice President / Adjunct Professor	KEMA Inc. / University of Pittsburgh
Michael	Reischman	Deputy Assistant Director (Engineering)	National Science Foundation
Patrick	Ryan	PES Executive Director	IEEE Power and Energy Society
Bob	Saint	Principal Engineer, Technical Service	National Rural Electric Cooperative Association
Surya	Santoso	Assistant Professor	University of Texas at Austin
Peter	Sauer	Professor	University of Illinois at Urbana-Champaign
Noel	Schulz	Associate Professor & TVA Professor	Mississippi State University

Rick	Sergel	President & CEO	North American Electric Reliability Corporation
Robert	Sheridan	VP Distribution Engr & Asset Mgt	National Grid
Allen	Soyster	Division Director	National Science Foundation
Wei	Sun	Graduate Research Assistant	Iowa State University
Le	Tang	Vice President and Head of Corporation Research Center	ABB Inc.
Jerry	Taylor	Senior Engineer	Federal Energy Regulatory Commission
Robert	Teichman	Engineering Training Coordinator	American Electric Power
Robert	Thomas	Professor and Founding Director of PSERC	Cornell University
James	Thorp	Professor and Department Head of Electrical and Computer Engineering	Virginia Tech
Kevin	Tomsovic	Professor	Washington State University
Gordon	van Welie	President & CEO	ISO New England Inc.
Usha	Varshney	Division Director	National Science Foundation
Giri	Venkatara-manan	Associate Professor	University of Wisconsin-Madison
Vijay	Vittal	Professor	Arizona State University
Frank	Wayno	Professor	Cornell University
Paul	Werbos	Program Director	National Science Foundation
Steve	Williamson	Director - Bulk Power Operations	Southern Company Services, Inc.
Craig	Williamson	Director	SC Universities Research and Education Foundation
Calvin	Zulick	Science Assistant	National Science Foundation

Appendix E: Participants in the Executive Summit

Carol	Berrigan	Director, Industry Infrastructure	Nuclear Energy Institute
Anjan	Bose	Regents Professor	Washington State University
Terry	Boston	Executive Vice President, Power System Operations	Tennessee Valley Authority
Thomas	Brockley	President	Waukesha Electric Systems
Mariesa	Crow	F. Finley Distinguished Professor	University of Missouri-Rolla
José	Delgado	President & CEO	American Transmission Company
Linda	Fowler	Director of Strategic Partnerships	U.S. Department of Labor
Jim	Gover	Professor of Electrical Engineering	Kettering University
James	Hoecker	Partner	Vinson & Elkins
Patricia	Hoffman	Principal Deputy Assistant Secretary	U.S. Department of Energy
Mike	Hyland	Vice President	American Public Power Association
Susan	Kemnitzer	Deputy Director for Engineering Education and Centers Division	National Science Foundation
David	Mohre	Executive Director, Energy & Power Division	National Rural Electric Cooperative Association
David	Owens	Executive Vice President	Edison Electric Institute
Margaret	Pego	Senior Vice President and Chief Human Relations Officer	PSEG Services Corporation
Wanda	Reder	VP Power Systems Services	S&C Electric Company
Rick	Sergel	President & CEO	North American Electric Reliability Corporation
Jerry	Taylor	Senior Engineer	Federal Energy Regulatory Commission
Robert	Thomas	Professor and Founding Director of PSERC	Cornell University
James	Thorp	Professor and Department Head of Electrical and Computer Engineering	Virginia Tech
Gordon	van Welie	President & CEO	ISO New England Inc.

Appendix F
Instructions for Breakout Groups

1. Set-up: There will be a flip-chart in your room with two “chisel-tipped” markers.
2. The general process will be one of brainstorming followed by discussion and prioritization through voting. During the brainstorming, every person will be given the opportunity to make a contribution. For further suggestions on process, see Frank’s write-up.
3. Begin the session by introducing the questions that will be considered, noting the questions that the other break-out groups have been assigned.
4. Describe the discussion protocol that will be used (see 2 above). Research, education, and outreach break-out sessions should allow at least 25% of the time for the last question.
5. Introduce the first question.
6. Collect responses to the brainstorming, noting them on flipchart pages. Put the pages on the wall when they are full.
7. Prioritize the responses by voting. Each person will be given 6 red dots for voting for the responses that will have the most impact if implemented. The cost of implementation and the timing of implementation should not be considered at this point.
8. Prioritize the responses that received 3 or more votes in note item 7 by having the participants vote with dots (of a different color or different location on the flipcharts). The prioritization criterion will be implementation feasibility within two years at a cost that is not extreme. Each person will have 3 dots for the votes.
9. Repeat note items 7 and 8 for the next question.
10. After completing the prioritization, check with the group on the ideas that seem to have the most weight with the group. If possible, rank order them based on the voting and subsequent discussion to bring back to the combined groups for presentation.
11. Return the Ballroom with all of the flipcharts and put them on the wall for presentation. Be prepared to describe the ideas that were judged the most important.

Appendix G
Conclusions from the Breakout Sessions

Educating students for power engineering careers

1. Build strong and on-going industry relationships with universities to enhance the educational program and to support faculty in their education activities.
2. Increase industry and government collaboration with universities to identify education topics and implement new delivery methods that make electric power and engineering education more exciting, relevant, and efficient for a new generation of students.

Reaching out to increase and sustain the pipeline of power engineering students

1. Promote the social importance of solving electric energy challenges and of delivering electricity economically, reliably and sustainably.
2. Make the education more interesting, such as by developing hands-on group projects across course levels.
3. Leverage government programs through collaboration, such as the NSF programs "Research Experience for Teachers," and "Grant Opportunities for Academic Liaison with Industry."

Encouraging and facilitating university research for innovation and education

1. Help university researchers and students to better understand industry research need priorities so that they can make informed choices in their research directions (such as power electronics and energy conversion, planning and operating margins in real time, and storage).
2. Increase industry, university and government research collaboration to support research and student education, to facilitate creation of innovative solutions to industry challenges, and to establish global competitiveness and leadership.
3. Ensure that sustained support is provided for university research and education efforts to maintain strong electric power and energy university programs.

Expanding industry, government and university collaboration

1. Motivate collective action through creating a better understanding of the emerging challenges in meeting the demand for high quality power engineers, such as by gathering more data on the number of students going into the power engineering field, on the state of the educational infrastructure, on the future demand for power engineers, on the need knowledge and skills of the future power engineers, and on metrics for describing the job market and the state of the education system.
2. Create a national organization to drive collaboration among industry, government and universities, and to facilitate communication of national electric power and energy research and education priorities.
3. Work collectively to improve the image of power engineering to attract more students to the field.
4. Identify the keys for effective collaboration among industry, government and universities, such as through knowledge transfer on collaboration methods, through case studies, through identification of barriers (e.g., intellectual property) and best practices.

Appendix H
Renaissance of University Nuclear Engineering Programs[i]

In 1975 there were 47 universities offering degrees in nuclear engineering.[ii] In 2001 there were only about 30 programs with at least 6 of those programs being threatened with closure. In 1979, there were approximately 1,800 students enrolled in B.S. degree programs; 900 in M.S. programs; and 600 in Ph.D. nuclear engineering programs. In 1999, there were 550 B.S. degree students, 250 M.S. degree students and 190 Ph.D. students. This decline in the nuclear engineering education system became a major concern as the need for more nuclear engineers began rising after 2000.[iii]

In the 1990s, nuclear engineering programs were diversifying into other areas, such as nuclear technology for medicine, non-power applications of radiation in industry, plasma-aided manufacturing, and materials. The students in these other applications of nuclear engineering were still getting nuclear engineering degrees, and the faculty in these non-power areas were still counted as nuclear engineering faculty. Consequently, the real decline in faculty and students involved in education related to power applications of nuclear engineering was greater than indicated by the statistics on enrollment and degrees granted.

Now the demand for nuclear engineering university graduates is soaring as interest in nuclear energy, medicine, and security grows. Owners of some 84 reactors that have received or have applied for 20-year operating license extensions. There are plans for building some 22 new reactors; there are increasing concerns regarding fuel management; and new innovations in nuclear medicine have increased the need for nuclear engineers. The number of students has risen (as shown in Table 1 below) as job certainty after graduation is assured, as salaries rise, and as nuclear technology is viewed more positively by the public. Funding for nuclear science and engineering research is higher than it has been since the 1970s.

Table 1: Nuclear Engineering Degrees, 1998-2006

Year	B.S.	M.S.	Ph.D.
2006	346	214	70
2005	268	171	74
2004	219	154	75
2003	166	132	78
2002	195*	130	67
2001	120	145	80
2000	159	133	74
1999	199	142	86
1998	222	160	98

* There were 31 universities reporting nuclear programs during the 2005 (i.e., 2005/6) academic year. Two programs were discontinued after 2005 and one new nuclear program was added in 2006. In the 2002/3 survey, there were 33 programs with 3 programs discontinued/out of scope and one new program.[iv]

H.1 Historical Periods in Government Support of University Nuclear Engineering Programs

Government support of university nuclear engineering programs over the last 20 years might be characterized as going through three periods.

1. **Pre-1998**: Making the case for increased support. Reports on the need for supporting university nuclear programs were completed through various collaborative efforts; however, little substantive support was actually generated.
2. **1998-2007**: DOE support directed toward university nuclear engineering programs. Making the case for this rise in support from DOE began with a DOE national comprehensive energy policy that included nuclear energy. Subsequently, there were strong recommendations for increased support in research and education from the Nuclear Research Advisory Committee to DOE's Office of Nuclear Energy, Science, and Technology (NE). This advisory committee viewed its major objective as being to assist university nuclear engineering programs. Following their advice, NE began a number of new programs to assist universities.
3. **Post-2006**: Decline of targeted DOE support and growth in collaborative consortia. In FY 07, DOE reported that it provided $15.2 M for university nuclear energy programs, including $3.8 M in $100,000 increments to 38 universities to enhance nuclear research and development under President Bush's Global Nuclear Energy Partnership (GNEP).[v] Research on fusion energy is also provided by DOE, the national labs, and the Department of Energy. Due to budget cut-backs and refocusing of nuclear reactor support toward GNEP, targeted government support of university nuclear engineering programs is now declining, with several programs already unfunded and more by FY 09. As interest in medical physics and radioactive waste management has grown, other agencies have taken an interest in supporting nuclear research and education. In the place of funding from DOE, consortia have emerged that are integrating funding from such sources as industry, national laboratories, DOE, National Nuclear Security Administration, Defense Threat Reduction Agency, the Department of Homeland Security, among other sources. For example, at present the Southeast Universities Nuclear Reactors Institute for Science and Education (SUNRISE, formed in 2007) and the South Carolina Universities Research and Education Foundation (SCUREF)[vi] provide some $4.5M a year in public and private support for university research and educational at participating universities, principally in nuclear science and engineering areas. Consortia have also been formed in Canada among other countries.[vii]

   Taking into account all funding source, the overall research funding outlook for university nuclear research is more positive than it has been in some 20 years; however, what is declining is targeted government support for universities, such as for basic research, for education and research infrastructure, and for student development, such as with scholarships. The new consortia are now trying to address this need.

In looking back over the last twenty years, the keys to the revival of university nuclear engineering programs through DOE support have emerged from industry and universities being able to make the case for the need for supporting university education programs, DOE's receptivity to recommendations from a collaborative advisory council supporting university education, and Congressional appropriation of new funds. As Congressional support has waned in recent years due to severe budget constraints, the on-going support of university education has come from support from the national labs, new sectors in nuclear science and engineering, the emergence of consortia supporting universities, and a much improved job market for nuclear engineering students.

These keys to successfully revival of university nuclear engineering programs are summarized in Table 2.

Table 2: Historical Keys to Successful Revival of University Nuclear Engineering Programs

1. All Periods
• Universities speaking as one voice through the Nuclear Engineering Department Heads Organization
• Industry support in communicating education and research needs to DOE. and in obtaining positive Congressional responses to budget requests by DOE
2. Pre-2006
• Commitment by DOE Office of Nuclear Energy, Science and Technology to university programs
• Strong recommendations from the DOE Nuclear Energy Research Advisory Committee
3. Post-2006
• Support from DOE national laboratories and growth of new sectors in nuclear engineering, including medical physics and radioactive waste management
• Emergence of collaborative consortia
• Increased job opportunities for nuclear engineering graduates

H.3 Faculty Hiring

During the 1990s, there was very little hiring of young faculty. As a consequence, concerns were raised about the outlook for the nuclear engineering programs as older faculty retired, but were not replaced. The hiring trend changed in the early 2000s as government research and education support for nuclear engineering programs grew. Now, hiring of young faculty is widespread as the research funding outlook improves and as the number of students grows.

H.4 Historical Background

H.4.1 Concerns Driving New DOE University Programs around 2000

Concerns about the outlook for nuclear engineering education, as summarized in *U.S. Nuclear Engineering Education: Status and Prospects* (1990), included:

> *..declining number of U.S. university nuclear engineering departments and programs, the aging of their faculties, the appropriateness of their curricula and research funding for industry and government needs, the availability of scholarships and research funding, and the increasing ratio of foreign to U.S. graduate students. A fundamental issue is*

> *whether the supply of nuclear engineering graduates will be adequate for the future.* (p. xi)

Besides a decline in the number of schools offering nuclear engineering curricula, and the number of students, the report also noted the decline in the rate of hiring of new faculty, an increase in the average age of faculty, and a decline in the number of research reactors. One of its conclusions was that "the imminent retirement of a significant fraction of the faculty jeopardizes both undergraduate and graduate programs." (p. 84)
This report was prepared under the auspices of the Energy Engineering Board of the National Research Council. The impetus for the study came from a number of sources, including the American Nuclear Society, the Institute of Nuclear Power Operations, the Nuclear Engineering Department Heads Organization, and the U.S. Department of Energy; however, without the one voice from the Nuclear Engineering Department Heads Organization, the study would not have occurred.

The Committee on Nuclear Engineering Education was formed to review nuclear engineering education in the U.S. and to recommend any appropriate responses. It was composed of thirteen people from universities, national labs, industry, and the Nuclear Regulatory Commission. The Committee was charged with:

- Characterizing the current status of nuclear engineering education
- Estimating the supply and demand for undergraduate and graduate nuclear engineers over the next 5 to 20 years
- Addressing the content of nuclear engineering curricula and how the curricula should relate to allied disciplines
- Recommending actions to ensure that the need for competent nuclear engineers at the undergraduate and graduate degrees were met over the next 5 to 20 years, with consideration of career opportunities, potential student base, research funding, and ensuring an excellent background in individual students.

The decline in enrollments and research funding was driven by the decline in the construction of commercial nuclear power plants and the reduction in the defense programs, with the last order placed in 1978 for a commercial reactor as of the time of report. Government research support for nuclear reactor research declined to almost zero in 1996.

Regarding supply and demand, the Committee concluded that the rising demand for nuclear engineers would outstrip the supply within a few years. Among other recommendations on education programs, the Committee said that greater funding for research related to nuclear power reactors was needed.

The Committee concluded that the responsibility for nuclear energy education was shared by the federal government, private industry, and the academic community. Its recommendations included:

- Federal government: Increasing research funding, helping to ensure an adequate student pool (such as funding fellowship programs), providing access to research reactors and enhancing the DOE database on the supply and demand of nuclear engineers

- Industry: increasing participation and support of nuclear engineering education (such as for cooperative student programs, research sponsorship, scholarships and fellowships), advocating for nuclear engineering education with other affiliated organizations.
- University: revising the nuclear engineering curricula to align more with current workforce needs, focusing on and seeking more funding for research related to nuclear reactors, and developing innovative personnel procedures to maintain adequate faculty levels, such as through partial or phased retirements and addition of junior faculty in a timely fashion.

This was not the first report addressing concerns about the outlook for nuclear power engineering programs. In *University Research Reactors in the United States – their Role and Value* (1988), prepared at the request to the National Research Council's Energy Engineering Board by the Office of Energy Research, U.S. Department of Energy, the Committee on University Research Reactors provided recommendations for federal and other support of university research reactors to ensure that more were not closed. Universities had been closing their reactor facilities due to increasing costs, decreasing enrollments, decreasing research, anticipated increases in regulation, and concerns about safety and security. Although focused on how to maintain active reactor facilities, the report noted that "(f)aculty in nuclear engineering and other fields need an incentive to emphasize teaching nuclear science, such as chairs funded specifically for nuclear education." (p.97) The Committee concluded, in part, that $20 million per year in funding was needed from the federal government to assist in university reactor operations and upgrades.

H.4.2 Making the Case for Increased University Support

Table 3 summarizes some of the reports that addressed key concerns about the outlook for nuclear engineering programs and recommendations for addressing those concerns.

Table 3: Reports Helping to Make the Case for Increased University Support

Federal Energy Research and Development for the Challenges of the Twenty First Century. President's Committee on Advisors on Science and Technology (PCAST) Nov. 1997	One of the conclusions was the DOE should support a portfolio of energy supplies that includes nuclear energy. Specifically, it recommended that DOE establish the Nuclear Energy Research Initiative to support new and innovative scientific and engineering research while helping to arrest the decline of nuclear energy researchers. Although funded substantially below the levels recommended by PCAST, funding levels for NERI in its first two years were $19M and $22.5M in 1999 and 2000.
Comprehensive National Energy Strategy, US DOE, April 1998	To reach a goal of "promoting energy production and use that respect health and environmental values," one strategy was to maintain the nuclear energy option." To reach the goal of expanding future energy choices, strategies included conducting basic research to find long-term energy breakthroughs. Nuclear technologies were explicitly identified as long-term energy options that should be developed. The report listed a public comment that "the U.S. was losing its technical advantage in the nuclear field through declining educational infrastructure."

Table 3: Reports Helping to Make the Case for Increased University Support (continued)

Long-Term Nuclear Technology Research and Development Plan, Nuclear Energy Research Advisory Committee advising the Secretary and Director, Office of Nuclear Energy, Science, and Technology (NE), U.S. D.O.E., June 2000	This the first edition of a long-term (i.e., 10-20 years) research and development plan for nuclear technology in the US. The report states: *…one of DOE-NE's primary responsibilities is to assure the worldwide leadership in scientific, nonproliferation commercial, and other uses of nuclear science, technology, and materials. This leads to the need to support undergraduate and graduate nuclear-students, faculty, and both university and DOE infrastructure as well as to fund long-term nuclear-related R&D that is in the national interest.*(pp. 5) It goes on to say that: *Nuclear expertise and nuclear engineering programs in U.S. universities are disappearing. The remaining expertise and programs are at risk of following in the next decade, or less. With concerned action by DOE, supported by the Office of Management and Budget and the Congress, most of the existing nuclear engineering programs soon will evaporate or be absorbed and diffused I other engineering disciplines… Direct support to researchers at academic institutions is needed, in addition to support provided through projects run by industry or the national laboratories…* (p. 5) The Nuclear Energy Research Advisory Committee to DOE recommended that the DOE's support of nuclear R&D ramp up by $240M in new funds (not transfers) in FY 2005. This was in addition to the $55M that was being spent in 2000.
Report of the University Research Reactor Task Force to the Department of Energy Nuclear Energy Research Advisory Committee (April 30, 2001)	The report concluded that there was a well-documented need for federal government support for a nuclear engineering, science and technology infrastructure in U.S. educational institutions. The URR Task Force urged DOE to act on the recommendations of (1) the NERAC Blue Ribbon Panel on the Future of University Nuclear Engineering Programs and University Research & Training Reactors, (2) the National Organization of Test, Research and Training Reactors, (3) the Nuclear Engineering Department Heads Organization and (4) the URR Task Force.

H.4.3 Actions Taken to Support University Education Programs

Table 4 provides a description of some the actions taken by DOE and others to support universities.

Table 4: Examples of Actions Taken to Support University Education Programs

<table>
<tr><th>Objective</th><th>Actions</th></tr>
<tr><td>Increase the pipeline of students into post-high school education</td><td>This work is mostly performed by the American Nuclear Society through its Public Education Program. It provides classroom materials and projects to students and teachers. It also provides materials and other assistance to people sponsoring and coordinating outreach projects. DOE did support the development of “The Harnessed Atom,” a comprehensive classroom resource for middle school teachers. It has recently been updated by the American Museum of Science and Energy (in Oakridge, TN) with support from the DOE’s Office of Scientific and Technical Information.</td></tr>
<tr><td>Support education facilities and university students</td><td>There are a number of programs through DOE, such as the following (with approximate figures, when known, for budget levels in past years - although funding levels may be in transition today):
DOE/Industry Matching Grant Program ($1M from DOE supplemented by industry contributions)
Innovations in Nuclear Infrastructure and Education ($10M)
International Student Exchange Program
Nuclear Engineering and Health Physics Education Research Program ($18M)
Nuclear Engineering and Health Physics Fellowship and Scholarship Program ($6M)
Nuclear Engineering and Science Education Recruitment Program
Nuclear Engineering University Partnership Program ($5M)
Radiochemistry Education Award Program ($2M)
Summer Internships at National Laboratories
University Partnership Program
University Reactor Sharing Program ($2M)
Nuclear Energy Research Advisory Committee to DOE recommended several of these programs.
Additional Information:
The DOE/Industry Matching Grant Program above provided $60K to individual university programs, but with no limit on private contributions. Since they were contributions, they were not subject to normal university overhead. The program objective was simply to enhance nuclear engineering education within the United States, and to contribute towards maintaining a viable workforce for the nation’s nuclear industry. Awards were given based on review of proposals. The Nuclear Engineering and Health Physics Fellowship and Scholarship Program in 2007 awarded 42 scholarships and 19 fellowships. This is one of the programs that will be phased out unless Congress adds support for it.</td></tr>
</table>

Provide research support	There were three DOE research programs: Nuclear Engineering Education Research ($5M), Nuclear Energy Research Initiative, and the Junior Faculty Award Program ($2M) run through the DOE Office of Nuclear Energy, Science and Technology. The Nuclear Engineering Education Research Program sponsored about $5M in nuclear research at U.S. colleges and universities with nuclear engineering degree programs, options, or research reactors. The purpose of the program was to support basic research in nuclear engineering, assist in nuclear engineering student development, and strengthen the academic community's nuclear engineering infrastructure. The Nuclear Energy Research Initiative seeks to develop advanced nuclear energy systems and provide state-of-the-art research concerning nuclear science and technology. Since its inception in FY 1999, there have been 186 projects with a total funding of $185M. About 70 universities have received about 58% of the funding support, with rest going to national labs (30%), and industry (13%). Plasma Physics Junior Faculty Development Program (through the Office of Fusion Energy Sciences and the Office of Science) program is to support the development of the individual research programs of exceptionally talented researchers early in their careers. Applications are made by tenure-track faculty investigators. In FY 2007, $555K was available with awards up to $185K per year for 3 years.

H.5 Implications for Power Engineering Programs

There are important differences between nuclear engineering programs and power programs that will make it necessary to consider closely whether the particular approaches and programs that emerged in the 2000s to help nuclear engineering programs could similarly help power engineering programs. Some important distinctions are:

- there are more ambiguities about the definition of a power engineer than a nuclear engineer, and certainly more ambiguities about who is a power engineering undergraduate student since electrical engineering departments do not award power engineering degrees, thus making it more difficult to communicate the need to support the education infrastructure that produces power engineers;
- power engineering course offerings exist at many more universities, thus making it more difficult to get a single-voice from universities on ways to address educational concerns; and
- the priority of research support as part of the solution varies across universities.

With those distinctions in mind, in general terms, the keys to success in Table 2 are likely to also apply to the situation university engineering programs face in educating the next generation of power engineers.

End Notes

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[i] This appendix was prepared by Dennis Ray, Executive Director, Power Systems Engineering Research Center. Information and insights were provided by Craig Williamson, Director, SC Universities Research and Education Foundation; Professor Michael Corradini, Chair, Engineering Physics, University of Wisconsin-Madison, and Professor Emeritus Gil Emmert, former Chair, Engineering Physics, UW-Madison. Any errors or omissions are the responsibility of the author.

[ii] U.S. Department of Energy, Office of Nuclear Energy, Science and Technology. *Innovations in Nuclear Infrastructure and Education Research Grants: Program Description*. http://www.ces.clemson.edu/inie/aboutINIE.html

[iii] Historical highs in enrollments occurred in the 1970's: 2160 bachelor's (1977), 1414 Masters (1975) and 659 doctoral (1972). Deborah Sweeney, et. al., *Nuclear Engineering Enrollments and Degrees, 1982*. Office of Energy Research. U.S. Department of Engineering. DOE/ER-0165. May 1993.

[iv] Source**:** *Nuclear Engineering Enrollments and Degrees Survey*, 2006 Data, Oak Ridge Institute for Science and Education. 2007 (http://orise.orau.gov/sep/files/ne_e_d_brief60_03-07.pdf)

[v] "DOE awards $3.8M in funding for nuclear research infrastructure." Idaho National Laboratory. http://www.inl.gov/featurestories/2007-08-24.shtml.

[vi] Information about SUNRISE can be found at http://www.me.sc.edu/sunrise/ and information about SCUREF can be found at http://www.clemson.edu/SCUREF/.

[vii] In Canada, the University Network of Excellence in Nuclear Engineering is an alliance of industry and universities. It is providing about $16 M in university cash support principally from industry and NSERC. The UNENE web site is at www.unene.ca. Source: Bill Garland, "University-Based Nuclear Education and R&D," A PowerPoint presentation. November 2007. http://www.unene.ca/info/UnivBasedNuclear-Nov2007.ppt.