THE FUTURE OF UNIVERSITY NUCLEAR SCIENCE AND ENGINEERING PROGRAMS

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

JUNE 10, 2003

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TUESDAY, JUNE 10, 2003

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:07 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Judy Biggert [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
SUBCOMMITTEE ON ENERGY
U.S. HOUSE OF REPRESENTATIVES

The Future of University Nuclear Science and Engineering Programs

Tuesday, June 10, 2003

10:00 AM – 12:00 PM
2318 Rayburn House Office Building (WEBCAST)

Witness List

Dr. Gail H. Marcus
Principal Deputy Director
Office of Nuclear Energy, Science and Technology
U.S. Department of Energy

Dr. Daniel M. Kammen
Professor
Energy and Resources Group, Goldman School of Public Policy
& Department of Nuclear Engineering
University of California at Berkeley

Ms. Angelina S. Howard
Executive Vice President of Policy, Planning, and External Affairs
Nuclear Energy Institute

Dr. James F. Stubbins
Head of the Nuclear, Plasma, and Radiological Engineering Department
University of Illinois at Urbana-Champaign (UIUC)

Dr. David M. "Mike" Slaughter
Director
Center for Excellence in Nuclear Technology, Engineering, and Research
Chair
Nuclear Engineering Program
University of Utah, Salt Lake City

HEARING CHARTER

SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

The Future of University Nuclear Science and Engineering Programs

TUESDAY, JUNE 10, 2002
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

On Tuesday, June 10, 2003, the Energy Subcommittee of the House Science Committee will hold a hearing to examine the future of university nuclear science and engineering programs, and how those programs might affect the future of the nuclear power industry in the United States. This hearing builds upon H.R. 238, the Energy Research, Development, Demonstration, and Commercial Application Act of 2003, which the Science Committee unanimously approved on April 2, 2003. The bill would authorize increased funding to the Department of Energy (DOE) for several university-based programs targeted at nuclear science and engineering. The structure and funding levels included in the bill generally follow the May 2000 recommendations of the Nuclear Energy Research Advisory Committee (NERAC), an outside advisory committee to the Secretary of Energy. H.R. 238 was subsequently incorporated into the omnibus House energy bill H.R. 6, which passed the House and now awaits action in the Senate. Any differences with the Senate energy bill will need to be resolved in conference.

It is the Administration's stated policy to encourage the expansion of nuclear energy in the United States. Despite this, many of DOE's university nuclear science programs continue to receive the same funding levels that they have for the last several years, even as other portions of the nuclear R&D budget have doubled. The Administration's most recent budget request for university programs is shown in Table 1.

In this hearing, the subcommittee will focus on DOE's support for university nuclear science and engineering programs, and the role they play in sustaining the U.S. nuclear power industry or allowing it to expand. It will explore the following questions:

1. How can we best meet the workforce needs of the future?
2. How should university nuclear research evolve to ensure its vitality? How, if at all, should the federal research and development programs be modified to support these changes?
3. How do we determine the right level of support for university nuclear programs, including infrastructure such as university research reactors?

Nuclear Industry Overview

With an installed capacity of 98.1 gigawatts, nuclear power now provides 20 percent of the electricity generated in the United States. Thirty-one states, most in the Eastern half of the United States, are home to nuclear power plants, with five states—New Jersey, Vermont, New Hampshire, South Carolina and New York—producing the largest percentage of their electricity from nuclear power, according to the Nuclear Energy Institute (NEI). The Energy Information Administration forecasts that nuclear generating capacity will increase slightly by 2025, to 99.6 gigawatts, due to nuclear life extensions and uprating of existing plants. However, with the May 2001 announcement that the U.S. Federal Government will "support the expansion of nuclear energy in the United States as a major component of our national energy policy,"[1] some observers now project a far larger increase in nuclear power. For example, if nuclear energy were to remain 20 percent of U.S. electricity

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[1] *National Energy Policy,* Report of the President's National Energy Policy Development Group, May 2001, pp. 5–17.

production, nuclear generation capacity would have to increase by more than 60 gigawatts by 2020.[2]

DOE University Nuclear Energy Programs

DOE is the sole federal sponsor of university nuclear programs that support the university nuclear engineering programs and research reactors shown in Figure 1 below. Funding for programs of particular relevance to this hearing are shown in Table 1 and described below. These programs were authorized by the Committee on Science and are now included in H.R. 6, the omnibus energy legislation that passed the House on April 11, 2003.

Figure 1. Geographical Distribution of University Nuclear Engineering Programs and Research Reactors.

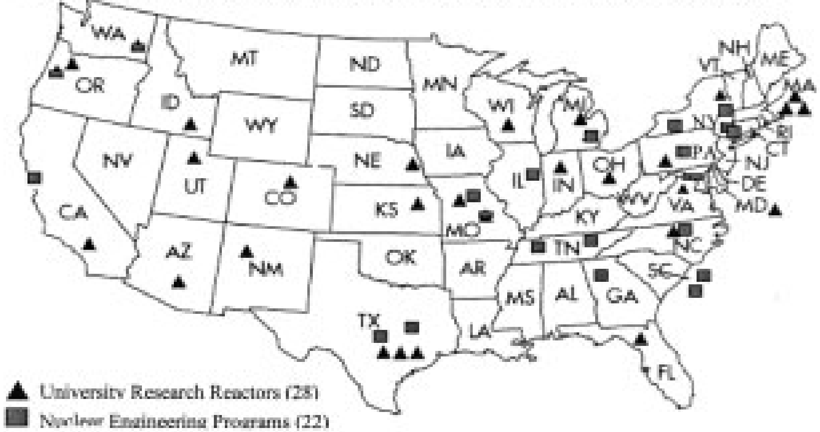
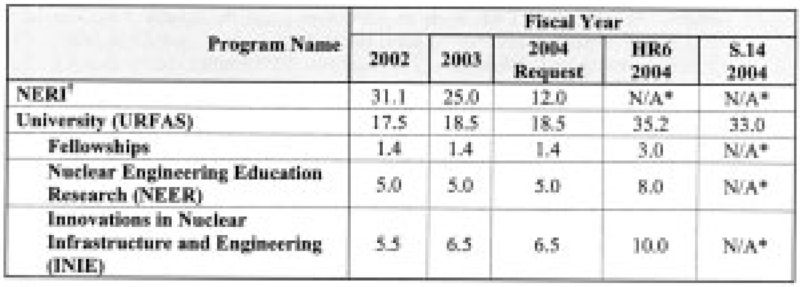


Table 1. Recent University Nuclear Science and Engineering Budgets *(dollars in millions)*



Program Name	Fiscal Year				
	2002	2003	2004 Request	HR6 2004	S.14 2004
NERI[†]	31.1	25.0	12.0	N/A*	N/A*
University (URFAS)	17.5	18.5	18.5	35.2	33.0
Fellowships	1.4	1.4	1.4	3.0	N/A*
Nuclear Engineering Education Research (NEER)	5.0	5.0	5.0	8.0	N/A*
Innovations in Nuclear Infrastructure and Engineering (INIE)	5.5	6.5	6.5	10.0	N/A*

[†] This is the total NERI budget of which roughly one third is awarded to universities on a competitive basis.

[*] Neither HR 6 nor S. 14 break out NERI funding. S. 14 does not breakout funding for programs under URFAS

The Nuclear Energy Research Initiative (NERI) features a competitive, investigator-initiated, peer-reviewed selection process to fund innovative nuclear energy-related research. Modeled after successful research programs, such as those conducted by the National Science Foundation and DOE's Office of Science, the NERI program solicits proposals from the U.S. scientific and engineering community for research at universities, national laboratories, and industry. About one third of NERI's funding goes to university researchers.

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[2] Based on EIA demand forecasts for U.S. electricity in AEO 2003.

University Programs in nuclear science and engineering (identified in the DOE budget as the University Reactor Fuel Assistance Support *[URFAS]* Program) include:

> *Fellowships:* Funds for undergraduate scholarships and graduate scholarships have been shown to help increase student enrollments in nuclear engineering and related programs. DOE fellowship funding in this program has remained constant for six years. The fiscal year 2004 request would support about 25 graduate students at research universities.
>
> *The Nuclear Engineering and Education Research Program (NEER)* was refunded in fiscal 1998. In 1993, funding for this broad-based university science grants program had ceased. Since its renewal, NEER has been a major source of research funding for the academic nuclear science and engineering community. These research grants cover areas of basic nuclear science and engineering research and augment the more application-oriented programs funded through NERI. The NEER program has been funded for the past five years at $5 million, supporting one out of every ten competitive proposals in a given year.
>
> *Innovations in Nuclear Infrastructure and Engineering (INIE):* In 2002, the DOE initiated the INIE program to support regional university research reactor (URR) centers. Seven regional URR consortia, distributed across the country, were selected through an independent peer-review panel for funding. In fiscal year 2002, DOE provided funding for four consortia. The fiscal year 2003 funding did not increase enough to initiate funding for the remaining three URRs. One of these, the University of Michigan, will shut down and decommission its reactor in July 2003.

Issues

People: One of the most important questions in considering the appropriate size of DOE's university programs is how many nuclear scientists and engineers are needed. Clearly, the answer depends in large measure on the expected size of the nuclear power industry, which currently employs about 2,000 nuclear engineers. If the industry expects to grow, the demand for nuclear engineers might be expected to grow, too. According to data compiled by the Oak Ridge Institute for Science and Education (ORISE), the number of graduates in the field declined steadily throughout the 1990s. Also, the number of university programs that train students in this area have declined from 87 in 1990 to 37 in 2001. Furthermore, the American Association for the Advancement of Science (AAAS) recently reported that in the next five years the U.S. nuclear power industry could lose as many as 30 percent of its nuclear engineers to retirement.

On the other hand, the ability to predict how many employees the industry will need is complicated by a number of factors. First, the number of engineers needed to run a nuclear power plant has declined. A survey conducted last March by an industry consultant found that utilities intend to replace only about half of all departing employees, making up for the rest by applying new technology, improving processes, etc. Finally, there is disagreement about how much the industry will grow.

Also complicating easy predictions of workforce demand is the tendency of a large portion of graduating nuclear engineers to find employment outside the nuclear power industry (some, for example, work for the military while others work in related careers like health physics). Conversely, not all employees of the industry have nuclear engineering degrees. Nor do they require one, as graduates with other technical degrees have successfully made careers in the nuclear industry. In fact, a recent report by NEI suggests that the future needs of the nuclear industry could be met by such a shift in career choice of a mere 0.25 to 0.35 percent of all graduates with other technical degrees.

Other questions regarding the future nuclear power workforce involve who will compose it. If the U.S. universities cannot meet the demand for skilled graduates, the industry may be forced to turn to foreign students, which could raise concerns about security. Also, the overwhelming number of nuclear engineers in the workforce today is white and male. It is unclear how the culture of the industry will need to change if more women enter the field and how those changes will affect the industry.

Finally, another important question any evaluation of DOE's university programs raises is who should bear the responsibility for workforce training—the government, the industry, or some combination of the two.

Ideas: The health of the nuclear research enterprise can be measured by the number and quality of new ideas in the field. Fewer students and graduates can mean fewer new ideas and ways to cope with important issues such as waste disposal and nuclear proliferation. For example, there are currently only two university professors that have published papers on the use of nuclear energy for producing hydrogen. How the U.S. encourages more effort in such innovative new areas could have important implications for the success of government initiatives, such as the making the transition to a hydrogen economy. A number of questions remain to be answered: In what ways can the government most economically encourage new ideas and research? What role is there for matching funding requirements, whether from states, industry, or the academic community? How do we determine the right level of government support for these efforts?

Tools: The nuclear research and education community needs the tools—the facilities and equipment—necessary to carry out its work. How many facilities universities need to train students and conduct research is unclear. One the one hand, the number of university research reactors declined from 64 research reactors in the 1960s, to 27 in 2002 (see Figure 1 for the current locations of university reactors). On the other hand, many of the remaining reactors operate well below capacity. Universities continue to contemplate reactor shutdowns for a variety of reasons, not the least of which is low utilization by the university community. Low utilization, however, could result from several causes: antiquated equipment that has outlived its usefulness, a lack of resources for utilization, or simply a decline in demand generally. Some experts have even questioned the importance of university reactors to training the nuclear workforce of tomorrow, pointing out that numerous successful and well respected nuclear engineering programs do not have an on-campus reactor, and some campuses have a reactor but no nuclear engineering program. Again, a number of questions remain unanswered: What is the right number and distribution of research reactors? Is the research enterprise best served, as it was in the past, by many small reactors, each owned by an individual university; or by a few larger facilities shared by a number of institutions? If the latter, how will smaller colleges and universities fare? Would a shared approach lead to a more rational distribution of infrastructure and promote new ideas, or could it reduce the diversity of ideas that otherwise might develop among independent research groups? How does DOE decide what the right nuclear research infrastructure should be? How does DOE then ensure that these programs will lead to such infrastructure?

Witnesses

The following witnesses have been confirmed for the hearing:

Dr. Gail H. Marcus is the Principal Deputy Director, Office of Nuclear Energy, Science and Technology at the Department of Energy. Dr. Marcus served as President of the American Nuclear Society (ANS) in 2001–2002. Dr. Marcus is a former member of the 1990 National Research Council Committee on the Future Needs of Nuclear Engineering Education. Dr. Marcus also worked at U.S. Nuclear Regulatory Commission (NRC) and the Congressional Research Service. She also is the first woman to earn a doctorate in nuclear engineering in the United States.

Dr. Daniel M. Kammen holds multiple appointments at the University of California, Berkeley. He is a professor in the Energy and Resources Group, the Goldman School of Public Policy, and in the Department of Nuclear Engineering. He is also the founding director of the Renewable and Appropriate Energy Laboratory. A physicist by training, his work is focused on the scientific and policy issues relating to energy systems, with a particular focus on renewable energy technologies. Kammen served on the Generation IV Roadmap NERAC Subcommittee (GRNS) from 2000–2002 for the U.S. Department of Energy.

Ms. Angelina Howard is the Nuclear Energy Institute's Executive Vice President of Policy, Planning and External Affairs with responsibility for nuclear workforce issues. Before joining NEI, Ms. Howard was with the Atlanta-based Institute of Nuclear Power Operations (INPO). Before joining INPO in 1980, Ms. Howard was employed by Duke Power Company. She has completed the Reactor Technology Program for Utility Executives sponsored by the Massachusetts Institute of Technology and the National Academy for Nuclear Training. She also is a member of the Clemson University Research Foundation Board.

Dr. James F. Stubbins is head of the Nuclear, Plasma, and Radiological Engineering Department at the University of Illinois at Urbana-Champaign, Illinois (UIUC), where he has been a faculty member since 1980—and is the current Chair of the Nuclear Engineering Department Heads Organization (NEDHO). He also is a member of the ANS workforce committee and the DOE Nuclear Engineering (NE) University Working Group. Dr. Stubbins has maintained associations as a Faculty Appointee at Associated Western Universities, with Battelle Pacific Northwest National Laboratory in Richland, WA; is a Faculty Appointee at the Division of Educational Programs, Argonne National Laboratory; is an Affiliate of the Los Alamos National Laboratory, and is a Visiting Scientist with Oak Ridge National Lab.

Dr. David M. "Mike" Slaughter of the University of Utah is Chair of the Nuclear Engineering Program and Director of the Center for Excellence in Nuclear Technology, Engineering, and Research (CENTER). He also is the 2001–2002 Chair of the National Organization of the Test, Research, and Training Reactors (TRTR).

Questions for the Witnesses

The witnesses have been asked to address the following questions in their testimony.

Questions for Dr. Marcus

- What kind and how large a role in producing the Nation's energy does DOE expect the nuclear power industry to play in the future?
- What kind of a workforce, how robust a research enterprise and what kind and how many university research facilities will be necessary to support such an industry? What are DOE's projections for society's nuclear workforce and research needs beyond those directly related to nuclear power?
- To what extent will DOE's university nuclear science and engineering programs, as currently configured, ensure the Nation has the necessary workforce and nuclear research base to maintain nuclear power and provide for society's other nuclear needs? What metrics should policy-makers use to determine whether the DOE programs are on target to achieve their goals—especially in the next ten years?

Questions for Dr. Kammen

- What kind and how large a role in producing the Nation's energy do you expect the nuclear power industry to play in the future?
- What kinds of innovations or other changes in the industry, in university programs, and in federal nuclear research policy do you believe are necessary if industry is successfully to play that role?

Questions for Ms. Howard

- What kind and how large a role in producing the Nation's energy does NEI expect the nuclear power industry to play in the future? How does this projection differ from that of the Energy Information Administration?
- What are the current trends in the number, age, and skills of the nuclear workforce and in the number and availability of university research reactors, and what implications, if any, do these trends hold for the industries ability to achieve the goals that NEI expects?
- How likely are DOE's university nuclear science and engineering programs, as currently configured, to ensure the industry has the necessary workforce and nuclear research base? What changes to these programs, if any, are needed? Other than these programs, what actions should policy-makers take to ensure that an adequate workforce is available?
- What steps does industry plan to take to ensure it has the workforce it needs in the future?

Questions for Dr. Stubbins

- What were the most important recommendations the Nuclear Engineering Department Heads Organization (NEDHO) recently made regarding DOE's university nuclear science and engineering programs? What are the implications for the health of university nuclear science and engineering programs and for the nuclear power industry if DOE were to fall short of implementing those recommendations?
- To what extent is the existing university nuclear infrastructure, including nuclear research reactors, sufficient to maintain a vibrant nuclear research enterprise the United States? To what extent is it sufficient to provide the workforce training and research opportunities necessary to sustain the nuclear power industry and provide for other societal needs into the future?
- To what extent does the quality of a university's nuclear science and engineering program depend upon the university having a nuclear reactor? To

what extent can the national laboratories and industry support university programs?

Questions for Dr. Slaughter

- To what extent is the existing university nuclear infrastructure, including nuclear research reactors, sufficient to maintain a vibrant nuclear research enterprise the United States? To what extent is it sufficient to provide the workforce training and research opportunities necessary to sustain the nuclear power industry and provide for other societal needs into the future?
- To what extent do you believe DOE uses the right criteria in determining whether to support university research reactors? What changes to DOE's university nuclear science and engineering programs, if any, do you believe are needed?
- To what extent does the quality of a university's nuclear science and engineering program depend upon the university having a nuclear reactor?

Chairman BIGGERT. I now call the Subcommittee on Energy to order.

I want to welcome everyone to the hearing on—of the Energy Subcommittee of the House Science Committee entitled “The Future of University Nuclear Science and Engineering Programs.”

Nuclear science and engineering in the United States is a 50-year success story that has been written by some of the brightest minds the world has ever known. America has been truly blessed as the world leader in this area.

But even as there is renewed interest in nuclear energy as one of the solutions to our nation’s energy problems, there has been a growing concern that fewer Americans are entering the nuclear science and engineering field and even fewer institutions are left with the capacity to train them. In fact, at about the same time that nuclear generation of electricity hit an all-time high, the supply of four-year trained nuclear scientists hit a 35-year low.

These statistics tell only the beginning of the story, however. The American Association for the Advancement of Science recently warned that “experts are predicting that up to 30 percent of current nuclear engineering workforce could retire within the next five years.” And today, there are only 27 universities that operate reactor—research reactors, less than half the number that there were in 1980, and a majority of which will be relicensed in the next five years, a lengthy process that most universities can not afford.

That is why I introduced legislation in the 107th Congress to strengthen university nuclear science and engineering programs at the DOE and ensure an adequate supply of educated personnel. Four of the key provisions from this bill were updated and incorporated into the comprehensive energy bill, H.R. 6, approved by the House in early April, including: number one, financial support for the operation, maintenance, and improvement of expensive, yet essential, university nuclear research reactors; two, resources for the professional development of faculty in the field of nuclear science and engineering; three, incentives for students to enter the field and opportunities for education and training through fellowships and interaction with national laboratory staff; and four, general research funds for students, faculty, and national laboratory staff.

The DOE is the only federal agency that supports these critical university programs, and the limited support it does provide often forms the core, pardon the pun, of these programs. While the budget has increased during the course of the last several years, the Department’s fiscal year 2004 budget request of just $18.5 million represents flat funding compared to fiscal year 2003 funding levels for these vital programs.

And now, more than ever, nuclear scientists and engineers are needed for much more than simply operating nuclear power plants. Trained at American universities and national labs, these specialists are needed: to help design, safely dispose, and monitor nuclear waste, both civilian and military; to create radio isotopes for the thousands of medical procedures performed every day; to operate and safely maintain our existing supply of fission reactors and nuclear power plants; to help stem the proliferation of nuclear weapons and respond to any future nuclear crisis worldwide; to design, operate, and monitor current and future Naval reactors; and to teach the next generation of nuclear scientists.

The good news is that universities' enrollments are showing some signs of rebounding. Two universities have actually established new programs in nuclear engineering. But not so much has changed as to eliminate the uncertainty of future demand for nuclear scientists and engineers or the predicted gap between supply and demand. Universities continue to question the need for nuclear science and engineering programs as they confront challenges, fiscal and otherwise, associated with maintaining research reactors. And additional security requirements mandated for university research reactors, in the wake of September 11, 2001, have increased costs, just as many cash-strapped states are cutting university budgets.

How this story ends and what role DOE programs will play, remains to be seen. If we, as a nation, are to continue to rely on nuclear energy for 20 percent of our electricity, and that number reaches 50 percent in my home state of Illinois, then we must focus on the people, ideas, and tools necessary to provide an adequate supply of trained and educated personnel. That is what we are here to explore today, and I want to thank the witnesses for their contributions.

[The prepared statement of Ms. Biggert follows:]

PREPARED STATEMENT OF CHAIRMAN JUDY BIGGERT

I want to welcome everyone to this hearing of the Energy Subcommittee of the House Science Committee, entitled "The Future of University Nuclear Science and Engineering Programs."

Nuclear science and engineering in the United States is a 50-year success story that has been written by some of the brightest minds the world has ever known. America has truly been blessed as the world leader in this area.

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1. Financial support for the operation, maintenance, and improvement of expensive—yet essential—university nuclear research reactors;
2. Resources for the professional development of faculty in the field of nuclear science and engineering;
3. Incentives for students to enter the field, and opportunities for education and training through fellowships and interaction with national laboratory staff; and
4. General research funds for students, faculty, and national laboratory staff.

The DOE is the only federal agency that supports these critical university programs, and the limited support it does provide often forms the core—pardon the pun—of these programs. The Department's fiscal year 2004 budget request of just

$18.5 million represents flat funding compared to fiscal year 2003 funding levels for these vital programs.

And now, more than ever, nuclear scientists and engineers are needed for much more than simply operating nuclear power plants. Trained at American universities and national laboratories, these specialists are needed:

- To help design, safely dispose and monitor nuclear waste, both civilian and military;
- To develop radio isotopes for the thousands of medical procedures performed every day;
- To operate and safely maintain our existing supply of fission reactors and nuclear power plants;
- To help stem the proliferation of nuclear weapons, and respond to any future nuclear crisis worldwide;
- To design, operate and monitor current and future Naval reactors; and
- To teach the next generation of nuclear scientists.

The good news is that university enrollments are showing some signs of rebounding. Two universities have actually established new programs in nuclear engineering. But not so much has changed as to eliminate the uncertainty of future demand for nuclear scientists and engineers, or the predicted gap between supply and demand. Universities continue to question the need for nuclear science and engineering programs as they confront challenges—financial and otherwise—associated with maintaining research reactors. And additional security requirements mandated for university research reactors in the wake of September 11th, 2001 have increased costs—just as many cash-strapped states are cutting university budgets.

How this story ends, and what role DOE programs will play, remains to be seen. If we, as a nation, are to continue to rely on nuclear energy for 20 percent of our electricity—and that number reaches 50 percent in my home state of Illinois—then we must focus on the people, ideas, and tools necessary to provide an adequate supply of trained and educated personnel. That's what we are here to explore today.

Chairman BIGGERT. The Chair now recognizes Mr. Lampson, the Ranking Minority Member of the Energy Subcommittee, for an opening statement.

Mr. LAMPSON. I thank the Chairwoman, Judy Biggert, for calling this hearing and for recognizing me. And I look forward to the testimony that is coming today.

The Department of Energy's university science programs are, indeed, an important part of the nuclear power industry of the United States. The energy in my area is much produced—my area of Southeast Texas is produced largely by a company called Entergy, who is very much into nuclear generation of power here in the United States. And even my own cousin is commander of a nuclear submarine. So he has gotten some of that training about which we will be talking today.

I am anxious to hear from our witnesses today on how they believe the Department of Energy should best utilize these university nuclear science and engineering programs, especially in the light of the Bush Administration's announcement in 2001 of plans to expand the use of nuclear energy in the United States. I realize the importance of strong, university-based science and engineering programs in our country. We need to increase the number of U.S. students studying and receiving Associates or Bachelors degrees in establishing—in established or emerging fields within science, mathematics, engineering, and technology.

The DOE's university nuclear energy programs are an important part of this effort, and I am pleased that this committee included language to strengthen these programs in H.R. 6, the House energy bill. And I have seen firsthand in Texas how important these undergraduate and graduate scholarships and fellowships are nationally. Texas A&M and the University of Texas have both seen—have both been important partners in the DOE nuclear energy program.

So I thank you all for joining. I look forward to hearing your testimony and asking you a couple of questions when you are through.

Thank you, Ms. Chairman.

[The prepared statement of Mr. Lampson follows:]

Prepared Statement of Representative Nick Lampson

1 would like to thank Chairwoman Judy Biggert for calling this hearing today. The Department of Energy's university science programs are an important component of the nuclear power industry in the United States.

I am anxious to hear from our witnesses today on how they believe the Department of Energy should best utilize these university nuclear science and engineering programs, especially in light of the Bush Administration's announcement in 2001 of plans to expand the use of nuclear energy in the United States.

I realize the importance of strong university-based science and engineering programs in the United States. We need to increase the number of U.S. students studying and receiving Associate's or Bachelor's degrees in established or emerging fields within science, mathematics, engineering, and technology.

The DOE's University Nuclear Energy programs are an important part of this effort. I am pleased that this committee included language to strengthen these programs in H.R. 6, the House energy bill.

I have seen first-hand in Texas how important these undergraduate and graduate scholarships and fellowships are nationally. Texas A&M and the University of Texas have both been important partners in the DOE nuclear energy program.

Thank you all again for joining us today and I look forward to your testimony.

Chairman BIGGERT. Thank you. If there is no objection, all additional opening statements submitted by the Subcommittee Members will be added to the record. Without objection, so ordered.

[The prepared statement of Mr. Nethercutt follows:]

Prepared Statement of Representative George R. Nethercutt, Jr.

I would like to thank the Chairwoman for calling this important hearing on the future of nuclear research at our nation's universities. I am a strong supporter of university research, and specifically nuclear fission research. It is imperative that we continue programs to ensure the long-term safety, technology and workforce needs. A University in my district, Washington State University, has an excellent program researching Actinide chemistry for radioactive waste disposal. I submit the attached white paper for the record on the WSU's program to highlight the good work they are doing.

Note: The attachment is printed in Appendix 2, p. 116.

Chairman BIGGERT. At this time, I would like to introduce our distinguished panel of witnesses. I also want to thank them for sharing their time and talent with us today so that we might better understand the potential workforce shortage and what is being done and needs to be done to address it.

Dr. Gail Marcus is the Principal Deputy Director of the Office of Nuclear Energy, Science and Technology at the Department of Energy. Dr. Marcus, who is the first woman to earn a doctorate in nuclear engineering in the United States, will describe DOE's university programs.

Second, we have Dr. Daniel Kammen, who holds multiple appointments at the University of California at Berkeley. He is a professor in The Energy and Resources group, the Goldman School of Public Policy, and in the Department of Nuclear Engineering. Dr. Kammen will make recommendations for changes in DOE's university programs to encourage greater innovation and thus increase their attractiveness to students.

Ms. Angelina S. Howard is Executive Vice President of Policy, Planning, and External Affairs at the Nuclear Energy Institute and has primary responsibility for nuclear workforce issues. She is highlighted by the bells that you have just heard. Ms. Howard will discuss industry's workforce needs and how DOE's university programs can help address them.

Dr. James Stubbins, excuse me, is Head of the Nuclear, Plasma, and Radiological Engineering Department at the University of Illinois at—or—this says—at Champaign-Urbana is the way I say it. I don't know. This says Urbana-Champaign. Maybe there is a story to that. And past Chair of the Nuclear Engineering Department Heads Organization, NEDHO. Dr. Stubbins will present NEDHO's recommendations and survey many new developments that make this hearing timely.

Dr. David M. "Mike" Slaughter is Director of the Engineering—the Center for Excellence in Nuclear Technology, Engineering, and Research and Chair of the Nuclear Engineering Program at the University of Utah. He is also a past Chair of the National Organization of the Test Research and Training Reactors and will discuss the broad range of social needs addressed by the university reactors.

As our witnesses know, spoken testimony is limited to five minutes each after which the Members of the Subcommittee will have five minutes each to ask questions after all of the panel has presented their testimony. So we will begin with Dr. Marcus.

STATEMENT OF DR. GAIL H. MARCUS, PRINCIPAL DEPUTY DIRECTOR, OFFICE OF NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY, U.S. DEPARTMENT OF ENERGY

Dr. MARCUS. Thank you very much, Chairman Biggert, Mr. Lampson, Members of the Committee.

I am very pleased to be here today to discuss university nuclear science and engineering programs and DOE's role in maintaining the university nuclear infrastructure. But first, as my bio indicates, I am also past President of the American Nuclear Society. And with my ANS hat on for just one moment, and with your indulgence, I would like to introduce some very special members of the audience.

May I ask the WISE (Washington Internship for Student Engineering) students and their Professor, Jim Dennison, to please stand up for a moment? These students are participating in a policy internship program for engineering students supported by engineering societies, including the ANS. I would also ask the ANS students—Jennifer Cole of the University of Tennessee, and Laura Beth Bienhoff of Kansas State University—to please raise your hands. Thank you. It is for students like these that we are holding this hearing today, and I am very pleased that they were able to join us.

I want to begin by observing that, at least since the late 1980's, that I am aware of, there has been concern about university nuclear infrastructure. I was a member of the National Research Council Committee that produced the 1990 report on this issue. I don't believe much changed as a result of that report, largely because there have been no new orders for nuclear power plants. So

I have to ask: Why are we discussing this issue yet again today? Is this dejà vu all over again?

I believe that this time things are different. We are in a new environment. For the first time in a very long time, utilities are giving very serious consideration to building new nuclear power plants in the U.S. As you said, Chairman Biggert, there are also a lot of other interesting trends and initiatives: consideration of nuclear power for hydrogen production, continuing and growing demand for radioisotopes for medicine and other applications, and interest in developing the next generation of advanced nuclear power plants. As activity in all of these areas increases, so has the interest in nuclear engineering training among students at universities. Even so, demand for trained and qualified nuclear engineers continues to outpace enrollments.

As you indicated, partly as a result of the improved prospects, enrollments are turning around at many universities. For the first time in about 30 years, we have two new nuclear programs at universities: the University of South Carolina, and South Carolina State University.

Yet other programs and facilities do remain at risk.

As you know, the DOE university nuclear program supports universities in a variety of ways, and you know these well. In the interest of time, I will focus mainly on our newest initiative—the Innovations in Nuclear Infrastructure and Education, or INIE, program. This program was established just last year, to encourage partnerships between universities, national laboratories, and industry to share facilities and expand academic and research opportunities. It is designed specifically to help maintain the nuclear infrastructure that you spoke about, Chairman Biggert.

I am very pleased to be able to announce today that DOE is funding two additional INIE consortia above and beyond the four funded last year. The two new grants are for the University of Missouri consortium and the Southeast consortium, led by North Carolina State University. This will bring to six the total number of consortia supported and these will encompass 23 universities and a number of other organizations. Only a few university nuclear programs are now not affiliated with one of the six INIE consortia, and these are going to be encouraged to affiliate. Therefore, we hope to have most of the programs under this partnership program, and consequently, to realize the maximum benefit from our academic resources.

The last point I would like to make is that university support is well integrated into all of our R&D programs, and we plan to make that even more the case in the future. Building on the successes we have had in involving universities and students in programs such as NERI (Nuclear Energy Research Initiative) and AFCI (Advanced Fuel Cycle Initiative), I am pleased to announce that we intend to pursue a new strategy for our R&D funding in the future. We anticipate that we will devote a fixed percentage of our total R&D funds, likely between five and ten percent, to universities. This will be a win/win, both for the universities, by providing more funding support for them, and for DOE, by tapping the creativity and expertise of the university community for all of our research programs.

In summary, we believe there are continuing needs in the nuclear industry for the unique training provided by nuclear engineering programs at the universities and that these needs will increase if new nuclear power plants are ordered, and some of the other expansions of nuclear applications are realized. As I noted at the outset, there are some signs of improvement in the university nuclear programs in recent years, but problems do remain, and therefore the programs that we operate need continuing attention and support. I commend the Committee for holding a hearing in this important area, and thank you for the opportunity to describe DOE's programs and plans.

[The prepared statement of Dr. Marcus follows:]

PREPARED STATEMENT OF GAIL H. MARCUS

Chairman Biggert and Members of the Subcommittee, it is a pleasure to be here to discuss the current readiness of university nuclear programs to meet the anticipated workforce needs of the nuclear industry and the Department of Energy's role in maintaining and improving the university infrastructure.

Concern over the health of the nuclear academic infrastructure is not new. As long ago as the late 1980s, the National Research Council conducted a study entitled "U.S. Nuclear Engineering Education: Status and Prospects" (published 1990). I was a member of the Committee on Nuclear Engineering Education that conducted that study. By that time, all of the trends we are discussing today were apparent: enrollments in nuclear departments and programs were declining, nuclear departments were being converted to programs under other engineering disciplines, research reactors were being shut down. The study foresaw potential shortages of nuclear engineers, both for existing government and industry activities, and for an anticipated renewal of interest in nuclear power. Despite the study, not much changed, and enrollments, numbers of departments, and numbers of university research reactors continued to decline.

The predicted industry crisis from this declining academic trend failed to materialize, largely because other factors mitigated against new nuclear power plant orders. Today, however, we have the greatest prospects in several decades for the renewed construction of nuclear power plants. Power generators are actively considering the business case for new nuclear power plants. Furthermore, the world nuclear community is looking beyond the next nuclear power plants, and beginning to formulate plans to conduct research on Generation IV nuclear technologies that can help meet global energy demands in the future.

All these activities will need growing numbers of highly trained nuclear professionals. While the nuclear industry has always employed scientists and engineers from a broad range of disciplines, and will continue to do so, the National Research Council study found that there is a need for personnel with specialized nuclear training. In particular, the study highlighted the importance of the broad interdisciplinary knowledge in physics, mathematics and engineering processes that characterizes the training of nuclear professionals. There is also a need for personnel with the hands-on reactor experience that can be gained from research and training reactors.

With that in mind, I am pleased to report that today, we seem to have turned a corner in the academic community. Enrollments are on the upswing, two new nuclear engineering programs have opened their doors, and concerted efforts are underway in the Department to maintain and strengthen the remaining nuclear academic infrastructure. University nuclear departments have broadened their offerings, and some of their growth is helping to meet an increasing demand for personnel in non-power nuclear applications.

While the picture looks much better today, it is too soon to declare victory. Not only do some university nuclear programs remain at risk, but even more important, the growing prospects for construction of new nuclear power plants in the United States suggests that the need for trained nuclear engineers will continue to grow.

I would like to take this opportunity to outline for you some of the Department's programs aimed at helping address the needs for a growing nuclear workforce in the future. I will cover both our direct university-related support and our research programs which have supported a number of students.

As you know, our university support is multifaceted. It includes scholarships, fellowships, research grants for universities, provision of fuel for university research reactors and funding for upgrades of university reactors. We also support reactor sharing, a matching grant program, university partnerships between majority and minority institutions, an international student exchange program, summer internships, and workshops for middle and high school teachers. In addition, university nuclear programs supply the needs of the non-power portion of the nuclear industry—such as the health physicists and the nuclear medical professionals—and we provide support in some of these areas as well.

Innovations in Nuclear Infrastructure and Education

I would like to focus first on our newest program, Innovations in Nuclear Infrastructure and Education (INIE), because we believe this program will provide critical support to help integrate nuclear research facilities and educational programs in a way that enhances both. This program, established in FY 2002, encourages strategic partnerships between universities, the DOE national laboratories, and U.S. industry. The partnerships result in a sharing of facilities and an expansion of academic and research opportunities for the students. With the award last week to the Missouri consortium and the Southeast consortium (led by North Carolina State), there are currently six consortia of institutions in INIE. In total, these comprise 23 universities and a number of national laboratories, utilities, and other research organizations. Only a few universities with nuclear programs are not affiliated with one of the consortia, and these remaining universities are being encouraged to affiliate.

University Partnerships

I would also like to highlight our university partnerships, which have played a significant role in the first establishment of a new nuclear program in about three decades. South Carolina State University is the first Historically Black College or University (HBCU) to offer a degree in nuclear engineering. Their degree is offered in collaboration with the University of Wisconsin under a partnership initiated and sponsored by the DOE. Current DOE support for their nuclear program includes funding for two junior faculty and scholarships for 12 to 14 students. The University of South Carolina also started a nuclear engineering graduate program in 2002, and currently has 15 students beginning their graduate programs, and plans to double in size this year.

Another element I would like to emphasize is that we partner with, and involve, many organizations in implementing our programs. I have already mentioned the university-research institute-national laboratory partnerships encouraged by our INIE program. I should also note that many of our other academic programs also engage various elements of the nuclear community. For example, we support student internships at national laboratories and international student exchanges with several countries. We also operate a matching grant program with industry. We have about 35 private sponsors each year, and more offers by industry than we have been able to match with our funding. This program not only demonstrates the strong industry support for the university programs, but it also multiplies the effectiveness of our funding. And finally, as Past President of the American Nuclear Society, I am particularly proud to point out that the American Nuclear Society, with support from the Department, has conducted a number of workshops for high school and middle school teachers. These workshops help train teachers to allow them to provide accurate information on nuclear technology to middle and high school students, and to help attract technically-minded students to the study of nuclear engineering.

In addition to these programs, which are explicitly designed to benefit the university community, I would like to point out that a number of our other programs also provide significant benefit to academic institutions. In particular, I want to emphasize some of our research support, because research has proven to be one of the most effective mechanisms to attract talented students to the field. While the university programs are vital, from a student's point of view, they are largely structural. To be sure, they keep research reactors going and they provide scholarships and fellowships, which are all good things, but there is no substitute for the opportunity to engage in exciting, cutting-edge research.

Our Nuclear Energy Research Initiative (NERI) has proven to be a particularly effective recruiting tool in this regard. Although we do have research programs geared specifically to universities, in particular, the Nuclear Engineering Education Research (NEER) grant program, the NERI program has added significantly to the support we provide to the academic community. The NERI program was designed as a broad-based research program to conduct exploratory research on advanced reactor and fuel-cycle concepts. The program is open to all researchers, including universities, industry, and national laboratories. It was not a tool targeted specifically or exclusively at the university community. Nevertheless, the academic community has won a significant share of the NERI awards (approximately one third of all funding between 1999 and 2002), and the latest figures available show that these awards have involved over 250 students (71 BS, 131 MS, and 65 Ph.D.). Furthermore, a great majority of the NERI grants involve collaborations among multiple institutions, both U.S. and foreign (the foreign institutions are not supported financially by DOE). Therefore, students working on NERI-funded projects often have the opportunity to work with top researchers in industry, the national laboratories and foreign countries in completing their theses.

Our growing recognition of the value of involving students in the advanced research we support has caused us to build support for students directly into our newer programs. Perhaps the best example is the student support element of our Advanced Fuel Cycle Initiative (AFCI). AFCI, as you know, is looking at options for partitioning and transmutation of spent nuclear fuel in order to reduce the burden on a repository and recycle useful elements of the fuel. The AFCI program has supported student and faculty research at several universities through laboratory funded research; since FY 2001 the Program has supported approximately 115 students. In addition, we have in the past awarded fellowships for master's degree students in science and engineering, and in the future, we hope to develop a fellowship program for doctoral candidates.

This approach is part of a new strategy to provide funding for university nuclear engineering programs. In the future, we are planning to devote a percentage of the research funds from all our programs to be implemented by universities. Doing so will increase the level of experience of students entering the workforce, make more funding available to the universities, and allow the creativity and energy of the university community to be applied to our programs. In addition to AFCI, we anticipate we will operate in this mode for our Generation IV effort and many of our other research endeavors.

Therefore, one must look beyond our University programs alone for a true measure of our support of universities, and for a true measure of the extent to which we contribute to university vitality.

We believe these programs and others, which I did not describe in detail, form a solid foundation for a strong university infrastructure to support nuclear workforce needs. However, some concerns remain. One important university research reactor—at Cornell University—was recently shut down, while another—at the University of Michigan—plans to cease operating this summer. These decisions were made despite the evidence that nuclear power was experiencing a renaissance and despite offers of assistance from the Department. Several more university research reactors and academic programs are still at risk. While acknowledging the revival of the industry, university administrators are under severe fiscal pressures, and the historical weakness of student enrollments and under-utilization of campus reactors make nuclear programs and facilities an inviting target for economizing.

In the long-term, it is apparent that the viability of university nuclear engineering departments is tied to the success of industry in deploying new nuclear power plants in this country. New nuclear construction will increase demand for nuclear engineers and interest in the study of nuclear engineering. As a result, programs in trouble today will likely experience growth and revitalization. It will be vital to maintain the remaining research reactors and to sustain a strong base of academic programs to meet the expected needs for trained personnel to support the design, construction and operation of nuclear power plants and to conduct research on future generations of nuclear technology. A vital academic nuclear infrastructure will also be able to meet the needs of the non-power nuclear community.

In conclusion, we are at a real crossroads for nuclear engineering education. There are a number of signs of revitalization in our academic programs, and the Department of Energy sponsors a strong and diverse program, both through its university funding and through its general research support, which should help assure that these positive trends continue.

BIOGRAPHY FOR GAIL H. MARCUS

Dr. Gail H. Marcus serves as Principal Deputy Director, Office of Nuclear Energy, Science and Technology. In this capacity, she assists William D. Magwood, IV, Director, Office of Nuclear Energy, Science and Technology in providing technical leadership for DOE's nuclear energy programs and facilities, including the development of next-generation nuclear power plants and advanced nuclear fuel cycle technologies, and the production and distribution of isotopes required for medical treatment, diagnosis and research. In addition, she assists in overseeing the operation of DOE test and research reactors, and of various DOE research, environmental and facility management activities.

Dr. Marcus came to DOE from the U.S. Nuclear Regulatory Commission (NRC). She had been at NRC since 1985, serving in a variety of positions including Deputy Executive Director of the Advisory Committee on Reactor Safeguards/Advisory Committee on Nuclear Waste; Director of Project Directorate III–3, providing regulatory oversight of seven nuclear power plants in the Midwest; and Director of the Advanced Reactors Project Directorate, where she was responsible for technical reviews of advanced reactor designs.

She served as technical assistant to Commissioner Kenneth Rogers at the NRC for over four years, providing advice and recommendations on a broad range of technical and policy issues of interest to the Commission. From this position she was detailed for five months to Japan's Ministry of International Trade and Industry, where she was NRC's first assignee to Japan, studying Japan's licensing of the Advanced Boiling Water Reactor.

From 1998–1999, Dr. Marcus spent a year in Japan serving as Visiting Professor in the Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology. She conducted research on comparative nuclear regulatory policy in Japan and the United States.

Prior to her service at NRC, Dr. Marcus was Assistant Chief of the Science Policy Research Division at the Congressional Research Service (1980–1985). In this position, she was responsible for policy analysis in support of Congress covering all fields of science and technology, and played a lead role in broad issues of energy policy and in the development of policies for risk assessment and management.

Dr. Marcus served as President of the American Nuclear Society (ANS) in 2001–2002. She also serves on the Board of Directors of the Washington Internships for Students of Engineering (WISE), and on the American Management Association R&D Council. She is a Fellow of the ANS and of the American Association for the Advancement of Science.

Dr. Marcus is a former member of the National Research Council Committee on the Future Needs of Nuclear Engineering Education. She served three terms on the MIT Corporation Visiting Committee for the Nuclear Engineering Department. She has authored numerous technical papers and publications. Her research interests have included nuclear regulatory policy, energy technology and policy, risk assessment and management, international nuclear policy, and advanced nuclear technologies.

Dr. Marcus has an S.B. and S.M. in Physics, and an Sc.D. in Nuclear Engineering from MIT. She is the first woman to earn a doctorate in nuclear engineering in the United States.

Chairman BIGGERT. Thank you, Dr. Marcus. And thank you for introducing the students to us. I can't help but notice how many young women there are that are involved in these programs. And I think this is—you know, as—we see more and more women entering into this field, and it is very gratifying. I know when I go out to speak to schools of children of all ages, I am always encouraging them that, you know, the fields of scientists and engineering and mathematics are very important and that we need more young women to take advantage of the opportunity. And I think it is working. So thank you very much and also for you young men. I know that that is a very important field for you. I don't want to be—have any partisanship between men and women here, but I am gratified to see that they are here, so thank you very much. Thank you all for coming.

Dr. Kammen, if you would like to present.

STATEMENT OF DR. DANIEL M. KAMMEN, PROFESSOR, ENERGY AND RESOURCES GROUP, GOLDMAN SCHOOL OF PUBLIC POLICY, AND DEPARTMENT OF NUCLEAR ENGINEERING, UNIVERSITY OF CALIFORNIA–BERKELEY

Dr. KAMMEN. Well, I, too, would like to applaud the WISE[1] students here. My wife, actually, a Nigerian immigrant, did a WISE program, and is now a pediatric radiologist, so it branches off in a number of interesting and important ways.

Chairperson Biggert, I would like to thank you for letting me appear before you. Again, I had the pleasure to testify before you in a field hearing when you and Congresswoman Woolsey held a very interesting hearing on fuel cells and on renewable energy.

The United States, today, faces a significant number of technological, environmental, and strategic issues related to our energy future. And the critical role that nuclear could or might or will play in that, and currently does play, I am delighted to see we are talking about that, because I have—I see too little discussion about the integrating aspects of our energy policy and our energy future overall.

The questions that—before us today are not just about the training of students, but they are also the mix of fossil fuels and nuclear renewables, energy efficiency, and which of these measures the United States plans to support. Most of these questions have not received as much attention as one might think, despite the current interest, the revived interest, I would say, in energy issues. So I am very concerned about us looking more broadly at these energy questions as the hearing progresses.

I direct the Renewable Energy Lab at UC–Berkeley, and our focus is on a mix of energy sources. We do scientific, technical, economic, and policy work on looking at how energy systems can work together in harmony and not compete for what are often seen as a small pool of resources. And as you mentioned in your opening statement, nuclear fission provides 1/5 of U.S. electricity at the present. At the same time, it is certainly the most controversial form of power production in the country.

The future for nuclear power could be anything from a dominant energy supply, as it is in Illinois with 50 percent of the power, to a technology, which faces elimination if certain other groups had their way. That tremendous range of possibilities, from conceivably zero to 50/60 percent of power, means that the role of university training is critical, because to answer those questions would require an expanded amount of research into how these technologies work together and what we are likely to do about that.

In my estimation, and I would take it up in the questioning period, the 20 percent share that nuclear power has now is likely to be the level it stays at for some time for a whole variety of reasons that I do detail in the written testimony.

While Dr. Marcus provides an excellent review of the innovative programs currently underway and Dr. Slaughter and Stubbins make compelling cases for addressing the shortages of trained professionals in certain areas, I would like to focus the Committee's attention a little bit on the degree to which I am more concerned

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[1] Washington Internship for Student Engineering

about the lack of new innovative approaches than I am directly about the number of programs, per se. And I think that is probably the bottom line for me, I think, through this process.

The Generation IV process, of which I was on the Gen IV subcommittee, the oversight—one of the oversight committees, is an example of this. In my view, the Gen IV committee did an excellent job of thinking through near-term R&D issues, the kind of Generation III+ plans that we are—we were operating today, but it didn't do the job that I actually thought the Generation IV process was about, and that was to really think more long-term about how we would manage the R&D program for plans that we would commission conceivably 2030 and 2040 and beyond. And it is in this area that, again, I do have concerns more about quality than about quantity of programs and of emerging nuclear professionals.

Work in hydrogen is an example of this sort of concern. Nuclear power plants that produce—that could produce hydrogen may, in fact, be very different in style and structure, operating temperature regimes than plants we operate today. And yet work on nuclear-generated hydrogen is an active area of research, but one researcher in the United States accounts for almost all—half of all of the papers in this field over the past five years. This is a testament to this individual's tremendous intellectual capacity and work, but it is also a warning sign. This individual at Oak Ridge, Tennessee also comments regularly that that is a dangerous situation on a variety of levels.

Engineering programs in nuclear power, in my view, need to take on this challenge and find ways to innovate more at the expense, potentially, of generating more overall programs. Some of the ways that one might do that are to look at the ABET, the accreditation process for undergraduates, and find ways at the graduate level to support more diverse energy education for future nuclear engineers. I detail a few mechanisms, like encouraging students to have Master's Degrees in more than one field of engineering. And I also, since I serve on the faculty of nuclear engineering at Berkeley, am stunned by the degree to which an elective course for a nuclear engineering student is often Advanced Calculus as opposed to finding ways to diversify the education so that the range of issues that they will face as nuclear professionals are covered in their training. And I can think of a variety of mechanisms, and I detail them in the testimony: exchange programs with universities, exchange programs overseas.

But the bottom line message is that I don't think that the amount of cross-disciplinary training that future nuclear engineers receive is up to the task. I certainly also feel that hydrogen is a critical area where we are not supporting as much research, not only in nuclear, but in the other technologies that could produce hydrogen that may work in concert with nuclear hydrogen production. Solar, other technologies may, in fact, be compliments of a broader system.

And finally, there are some issues in the nuclear industry where many nuclear operators also have coal-fired power plants in their portfolio. That means that the motivations for these operators may be mixed. So for example, a system for carbon trading may be very beneficial to nuclear power, but it may also compete with other sides of the business of these same companies. So there is a variety of issues here that we need to address, the bottom line being the interdisciplinary nature of the training that I think the next generation of nuclear engineers need to get, to a larger degree than they have today.

Thank you very much for your time and attention.

[The prepared statement of Dr. Kammen follows:]

PREPARED STATEMENT OF DANIEL M. KAMMEN

United States: Facing a Defining Moment of Energy Choices

Chairperson Biggert, Members of the Subcommittee on Energy, and other invited guests, thank you for this opportunity to appear before you today to provide testimony on the university capacity to educate and innovate to meet the challenges of nuclear energy capacity. I am a professor in the Energy and Resources Group, the Goldman School of Public Policy, and the Department of Nuclear Engineering at the University of California, Berkeley. I am also the founding director the Renewable and Appropriate Energy Laboratory. From 2000–2002 I served on the Subcommittee for Generation IV Technology Planning of the Nuclear Energy Research Advisory Committee (NERAC). This subcommittee, also referred to as Generation IV Roadmap NERAC Subcommittee (GRNS), was formed in October 2000 to provide advice to the Director, Office of Nuclear Energy, Science and Technology of the U.S. Department of Energy on the development of the Generation IV Roadmap. GRNS was also tasked with developing the technology goals for Generation IV nuclear energy systems. The Generation IV documents can be accessed at: http://gen-iv.ne.doe.gov/ . I am the co-author of *Should We Risk It?,* an instructional text on technical, social, and policy aspects of risk management. I serve as a board member of The Utility Reform Network (TURN). I am Fellow of the American Physical Society, and have served on American Academy of Arts and Sciences Committee on the Social Impacts of Technology (Section X).

The United States faces a significant number of technological, economic, environmental, and strategic issues and options surrounding the future evolution of our energy infrastructure. These questions include the mix of fossil-fuel, nuclear, renewable energy, and energy efficiency measures that the U.S. will support, the degree of environmental damage that we will implicitly or explicitly permit to take place as a result of our energy choices, the overall role of innovation and global energy leadership that the U.S. will assume, and our commitment to a transition to a more sustainable and socially desirable energy infrastructure. Most of these questions have not been addressed in a significant way, even with the increased attention that energy issues have recently commanded at the state, federal, and international levels.

The role of nuclear energy in the current and future mix of energy technologies, markets, and risks is of major importance to the overall energy strategy that we will pursue. The role of nuclear power, specifically the impacts, economics, and risks of the full nuclear fuel cycle, is arguably one of the most ideologically divisive energy policy issues facing the country.

In this testimony I will address a number of critical issues that must be addressed if we are to develop and implement a reasoned and diverse sustainable energy strategy for the United States. In this testimony, specifically regarding nuclear power I will comment on:

- The current status of the U.S. nuclear energy industry and its relationship to the rest of our energy resource base;
- The university capacity to manage the current and future nuclear energy infrastructure; and,
- The areas where federal attention is most critically needed to evaluate and plan for our future energy infrastructure.

Finally, I will provide a set of recommendations that I believe are critical if nuclear energy is to be evaluated in the wider context of national energy choices and international energy leadership on both the technical and socioeconomic aspects of our current and envisioned sustainable energy infrastructure.

Overview of the Nuclear Industry/University Status

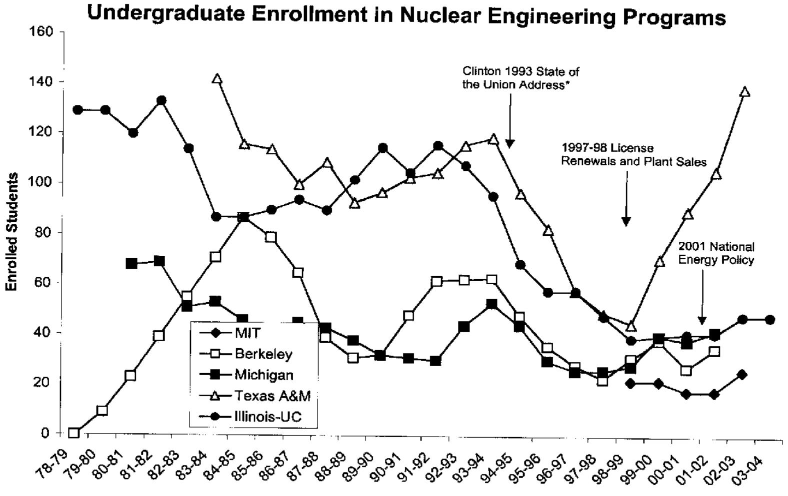
The commercial nuclear industry in the United States has undergone a roller coaster evolution over the past decade.

Signs of Decline

Many of the trends during the early 1990s were particularly negative for the industry. A decade ago few commercial reactors appeared headed for re-licensing, and undergraduate and graduate enrollments were declining, and a significant number of university programs were headed for closure. In addition, the busbar cost of electricity generated from nuclear plants was actually climbing, largely as the result of increased operation and maintenance (O&M) costs. This trend was in stark contrast to that seen for virtually every other energy technology where the costs have been declining according to a predictable pattern. For most power systems the costs have been seen to decline by 10 percent for each doubling of installed capacity. Photovoltaics, biomass power plants, wind turbines, and gas turbines, for example, have each been well studies, and follow this relationship particularly well. This trend, known as a *learning curve* is well understood, and has been used as the basis of forecasts for the future cost declines for wide range of energy systems and other technologies that can be mass-produced. Nuclear power plants—in addition to their largely unresolved issues of closed, reprocessing cycles, uncertain waste management costs, questionable federal oversight, and strong public skepticism—are largely unique, 'one-off' facilities in the United States, and thus not expected *even theoretically* to exhibit this attractive learning curve. The prospects for nuclear power in the United States were dim. Figure 1 illustrates the decline in enrollment by new undergraduates at three leading nuclear engineering programs in the United States.

Enrollment decline is particularly serious for the industry, which is already on average significantly aging, in part because university resources as well as those from federal agencies decline with lower enrollment levels, creating a negative feedback loop that further reduces, innovation and resources. This problem became even more sever as the next natural step took place: the closing or dramatic reduction of over one-third of U.S. nuclear engineering programs between 1991 and 1998. These changes have been well described in a 2000 report on *The Future of University Nuclear Engineering Programs and University Research & Training Reactors.* This excellent analysis, known widely as the "Corrandini report" found among other things that there was:

- A serious decline of nuclear science and engineering personnel, the relevant technical facilities and the needed institutional support for each of them;
- A growing imbalance between the supply of qualified personnel and the demand;
- A persistent lack of effective communication with the public, both technical and non-technical, which leads to public opinion based on incomplete information (page 7).

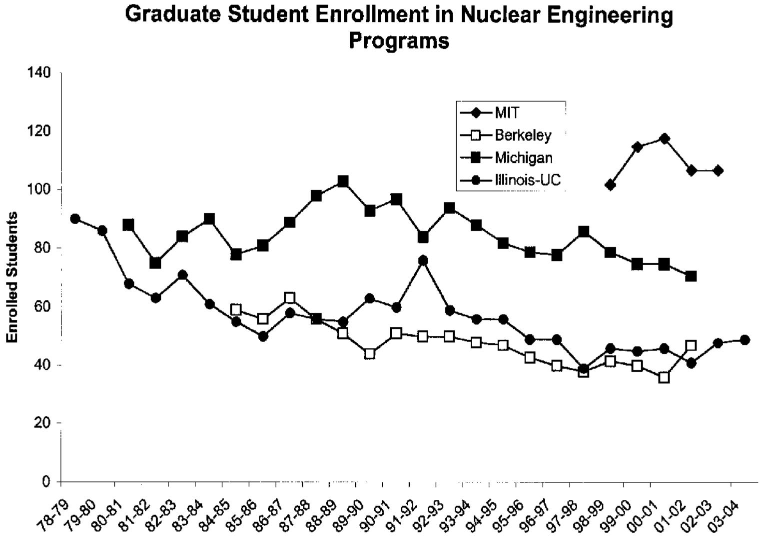


Source: University Records

Figure 1: First year undergraduate enrollment in nuclear engineering programs at three leading universities, with pointers indicating seminal policy events during this period, 1978 – 2003. Texas A&M, which engaged in a significant faculty and resource expansion, is a notable exception.

Figure 1 also illustrates the dramatic importance of policy direction and leadership to the nuclear industry. The statement by President Clinton in his 1993 State of the Union Address that nuclear energy will be largely removed from U.S. energy policy, coupled with the lack of any prospects for new nuclear reactors, led to a dramatic decline in enrollment in nuclear science and engineering departments. By the same token, the new emphasis that nuclear power is receiving under the current Bush administration has lead to a resurgence in the industry that I will discuss below. In both these negative and positive phases high-level policy leadership is clearly a vital factor in the direction and vitality of the industry and the academic departments.

Graduate enrollment trends during this period remained more stable (Figure 2), but this in, in fact deceptive. While overall enrollment has not changed significantly, the composition of the graduate nuclear engineering pool shifted during the past decade. At the University of California, Berkeley, foreign students comprised less than 20 percent of full-time doctoral enrollment, while in 2000 foreign students accounted for almost 70 percent of the student population. This trend has taken place in departments across the country to varying degrees.



Source: University Records

Figure 2: Graduate enrollment in four leading nuclear engineering programs, 1978 – 2003.

In the mid-1990s the few optimists about nuclear power saw Asia as the primary market for growth, both in terms of new plant construction and as a region of nuclear economic viability.

Signs of Growth

Over the last several years the situation in the nuclear industry has changed dramatically. U.S. nuclear power plants have increased their *capacity factor,* defined as the percentage of time during the year that the plant is available for electricity generation, has increased sharply. From a low of roughly 55 percent two decades ago, the nuclear industry implemented a range of reforms and the capacity factor began to change. A steady improvement in the operation of nuclear facilities was followed in the mid-1990s by an even more rapid upsurge in plant availability. This second phase was driven by in part by changes in the energy industry, where deregulation experiments, and increasing concerns over the impacts of fossil-fuel based plants expanded the market for nuclear-generated electricity.

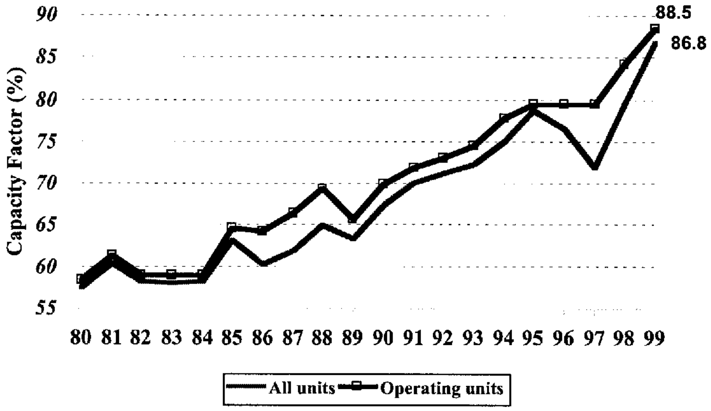


Figure 3: Dramatic change in the capacity factor of nuclear energy facilities, 1980 – 1999.

The impact of this whole-scale change in the industry cannot be underestimated. Over the past decade the nuclear industry in the U.S. has added the *equivalent* of over 20 power plants to the national fleet without building a new facility. In 2000 nuclear power provided 19.8 percent of total U.S. electricity, or 754 billion kilowatt hours, and in each of the past two years the industry has set new production records.

In addition to the dramatic change in the industry capacity factor, nuclear power plants have gone from readily available on the market for investors, to difficult to impossible to find available for sale. At the same time virtually every U.S. nuclear facility either has, or is expected to apply for re-licensing/license extension. In 2003, nearly half of the Nation's 103 nuclear power plants have either renewed their licenses (14 reactors), filed with the Nuclear Regulatory Commission for license renewal (16 reactors), or officially informed the NRC that they expect to apply for license renewal over the next six years (20 reactors). In all, this will increase the lifespan of the U.S. fleet of nuclear reactors by roughly 20 years per plant.

The nuclear industry has received a significant boost from efforts such as those of the Nuclear Energy Institute (www.nei.org) to portray the industry as not only the source of low-cost electricity, but also as carbon-free power (Figure 4, below).

That's why nuclear energy is
so important to America's energy
future. Nuclear energy already
generates more than 20 percent
America's electricity, and nucle
power plants don't pollute the
air. That's important, because
we need a reliable source of
electricity to meet our needs
the 21st Century – but we als
need clean air. With nuclear ene
we can have both.

The nuclear energy industry has also received arguably the most important support from the current administration which has included nuclear power as part of its core energy strategy.

Industry arguments for nuclear power of course also highlight the low production cost of fission-generated electricity, currently at a little over 2 cents per kilowatt-hour. It is in this area of economics that the complexities of nuclear become most apparent. While pro-nuclear analyses, such as those of the Nuclear Energy Institute, list capital costs of 3.8–4.8 cents/kWh, nuclear opponents such as Rocky Mountain Institute (www.rmi.org) cite costs of 8–12 cents/kWh. A credible argument can be made for either cost calculation.

In fact, a key issue that must be addressed in evaluating nuclear power is degree to which ideology—either for or against—drives the analysis of cost. The differences in the costs for a variety of nuclear energy related factors are often extreme. The NEI, for example, lists the 20 construction times of 4–5 years possible for new nuclear power plants, while RMI quotes the historical construction time of over 10 years per plant, and costs, including overruns of $2200–4,000/kW. NEI cites the initially computed costs of $1550–1880/kW. In perhaps the most egregious example, NEI quotes the cost of waste management at 0.1 cent/kWh, while RMI cites the same 0.1 cent/kWh per plant, but then adds in 1 cent/kWh more if the cost of Yucca mountain facility is included in the cost. Similarly, NEI quotes 0.05–0.1 cent/kWh for the decommissioning cost (a fee paid into the decommissioning fund) while RMI quotes a cost of 0.4–1.0 cent/kWh for decommissioning when the California nuclear bailout (AB1890) is included in the cost. These differences reflect an important disconnect between the nuclear energy industry and much of the rest of the national energy infrastructure.

If I were to guess, nuclear power is likely to continue to provide *roughly* 20 percent of our electricity for many years to come. This is based on the continuing tension between the pro- and anti-nuclear energy lobbies. The current level represents an uneasy truce where current facilities continue to operate, with the potential for some new plants there, but unlikely to greatly exceed those that must be retired due to age or other factors. A significant increase in nuclear plants is in my view both unlikely due to opposition, and unnecessary in light of the growing number of low-carbon alternatives, that include energy efficiency, biomass, wind, and solar energy. A wealth of models exists, of course, that collectively are used to forecast anything from a complete elimination of the industry, to a dramatic expansion of our nuclear fleet. Experts who pretend to have a more precise forecast than this are not being realistic: the extent of our nuclear future is a consequence of policy, not an economic forecasting.

University Capacity for Nuclear Energy Training and Innovation

There is a great deal of concern within the nuclear industry and the academic community over the decline in the number of nuclear engineering programs and research reactors in the United States (see, e.g., the Corrandini report; footnote 3). A recent GAO analysis, however, estimated that the number of nuclear engineering graduates would be sufficient to meet the personnel demands of even a "high growth" scenario (with the U.S. nuclear fleet growing to ~110 plants by 2020) for an expansion of nuclear power such as that advocated by the Nuclear Energy Institute. While the GAO is quick to caution that this calculation is fraught with uncertainties, in particular over the number of nuclear engineering graduates that find employment in other fields, it is consistent with my own estimates and those of several colleagues. The current set of graduate nuclear science and engineering programs in the U.S. is more than capable of producing 50–70 new graduates per year, which would be more than enough to sustain this industry.

In light of this rough calculation, efforts to create more nuclear engineering departments are, in my view, misguided. A smaller number of departments that are strong in research and teaching will serve the country better than a larger number of diluted, weaker, ones. In fact, nuclear engineering departments already suffer from an important weakness: nuclear science and engineering is not, on average, attracting the best students. There are some outstanding students, to be sure, but even with the recent upturn in the industry enrollments are flat, at best. The current wave of plant re-licensing, while important to the industry, does not provide the excitement to draw in the best students. In fact, nuclear engineering programs are losing students to electrical and computer science departments.

In every field the surest way to attract the best students is to be innovative, daring, and relevant. Nuclear engineering programs, while staffed with many excellent individuals, are not at the cutting edge. New vision is needed. In my service on the Department of Energy's GRNS Committee in the Generation IV process I was greatly disturbed to discover that the roadmap process was not overflowing with individuals excitedly discussing new reactor ideas, ways to dramatically reduce the waste stream, and ideas for how to integrate nuclear energy training more fully into the wider energy infrastructure. The Generation IV mandate was to develop a process for a truly innovative research and development process for the *next generation* of nuclear plants. Instead, it was a very well managed, analytically sound, evaluation of a range of relatively near-term extensions of current plant designs. This is *not* a criticism of the individuals, many of whom are outstanding, but it is a strong recommendation that the ways that nuclear energy systems are conceived and researched needs an overhaul.

In an important example, the Gen IV discussions of hydrogen production by nuclear power plants was painfully limited and conventional. Over the past five years half of the papers in the field of nuclear hydrogen, a field that could revolutionize both the nuclear energy industry and potentially the U.S. energy system overall, were authored or co-authored by one individual. This researcher, Charles Forsberg of Oak Ridge National Laboratories, is outstanding and has made *major* contributions. However, at the point in history when hydrogen is now on the threshold of potentially becoming a major energy carrier for both stationary and vehicle applications, the lack of a diverse research base on the critical issues of nuclear hydrogen production is startling.

Each of these concerns with the university capacity for nuclear science and technology training largely reflects the overly insular nature of many departments and programs. Engineering programs generally are infamous for packing the schedules of their students so that they have little opportunity to diversify their education. The ABER 2000 accreditation process is thankfully imposing conditions of departments that force them to not only offer a wider range or courses themselves, but to broaden the training of students with courses in other engineering *and* non-engineering areas. This is absolutely critical to prevent "in-breeding" and to challenge students and faculty to thin in new, innovative ways. Graduate students in nuclear engineering departments very much need this more diverse education. A number of mechanisms exist to support this broader energy education, including:

- Encourage students to obtain Master's degrees in a different discipline than their intended Ph.D. field (for example through fellowships or support for added time and flexibility in graduate school)
- Develop a curriculum in "energy engineering" that schools could consider, and adopt in sum or in part to provide nuclear engineering students and even post-doctoral fellows with a broader energy systems and even energy economics and policy perspective
- Develop university exchange programs, particularly with overseas departments where very different teaching styles exist, and where the nuclear energy industry is very different from that in the U.S.

An important first step would be to convene a group of U.S. and foreign nuclear energy experts, along with scholars, practitioners, and policy makers from other energy sub-fields to develop a more comprehensive suite of mechanisms that could be implemented to diversify and to add excitement and innovation to the field.

The Federal Role

The Federal Government plays the pivotal role in the encouragement of innovation in the energy sector. Not only are federal funds critical, but as my work and that of others has demonstrated, private funds generally follow areas of public sector support. One particularly useful metric—although certainly not the only measure—of the relationship between funding and innovation is based on patents. Total public sector funding and the number of patents, across all disciplines, in the United States have both increased steadily over at least the past three decades (Figure 5).S6602

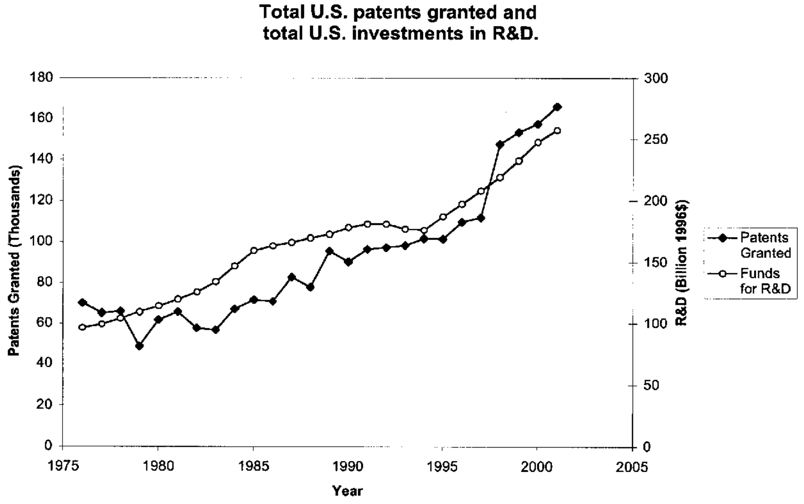

Total U.S. patents granted and total U.S. investments in R&D.

Figure 5: Total public sector spending on R&D (right axis) and total patents (left axis). Figure from Margolis and Kammen (1999) *Science*, **285**, 690 – 692.

The situation depicted here, with steadily increasing trends for funding and results (patents) is not as rosy when energy R&D alone is considered. In that case the same close correlation exists, but the funding pattern has been one of decreasing resources (Figure 6A). Figure 6A shows energy funding levels (symbol: ○) and patents held by the national laboratories (symbol: ◆). The situation need not be as bleak as it seems. During the 1980s a number of changes in U.S. patent law permitted the national laboratories to engage in patent partnerships with the private sector. This increased both the interest in developing patents, and increased the interest by the private sector in pursuing patents on energy technologies. The squares (■) in figure 6 show that overall patents in the energy sector derived from public sector funds increased.

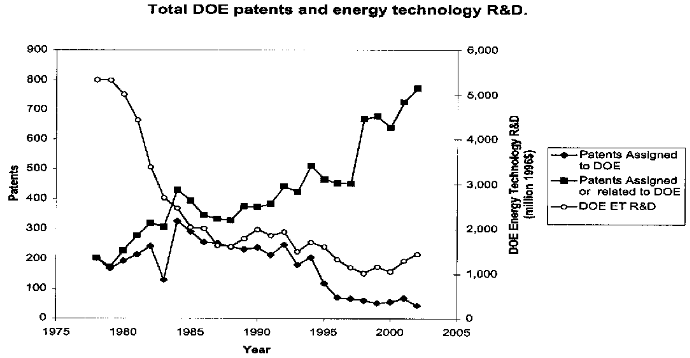


Figure 6A: Public sector R&D funding and patents across all energy technologies, both held and shared by the federal energy laboratories. Figure from Kammen and Margolis .

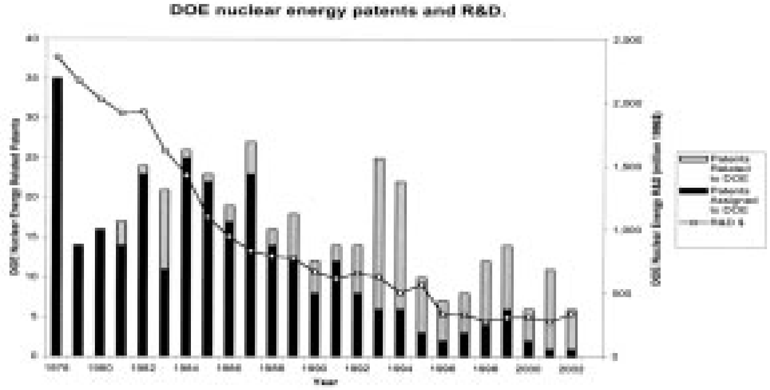
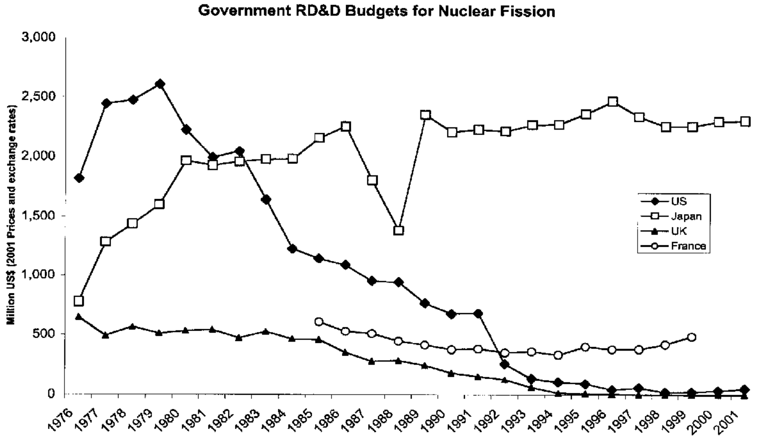


Figure 6B: Nuclear energy funding and patents. Figure from Kammen and Margolis (1999).

Figure 6B reveals the crucial truth: patent levels in the nuclear field have declined, but not only that, public-private partnerships have not developed significantly in the nuclear field in the United States. This is a particularly important message for federal policy. Novel approaches are needed to encourage new and innovative modes of research, teaching, and industrial innovation in the nuclear energy field. To spur innovation in nuclear science a concerted effort would be needed to increase the types and levels of cooperation by universities and industries in areas that depart significantly from the current “Generation III” and equally, away from the “Generation IV” nuclear power plans. Similar conclusions were reached by M. Granger Morgan, head of the Engineering and Public Policy Program at Carnegie

Mellon University, in his evaluation of the organization and sociology of the U.S. nuclear power industry.

A second important issue that this committee should consider is the degree of federal support for nuclear fission relative to other nations. Funding levels in the U.S. are significantly lower than in both Japan and France. Far from recommending higher public sector funding, what is arguably a more successful strategy would be to increase the private sector support for nuclear R&D and student training fellowships. Importantly, this is precisely the sort of expanded public-private partnership that has been relatively successful in the energy sector generally (Figure 6B) but is largely lacking in nuclear science and engineering.



Source: IEA 2003

Figure 7: Comparison of government funding levels for nuclear fission, 1978 – 2001.

This emphasis on industry resources used to support and expanded nuclear program, under careful public sector management, has been echoed by a variety of nuclear engineering faculty members:

> *I believe that if you were to survey nuclear engineering department heads, most would select a national policy to support new nuclear construction, over a policy to increase direct financial support to nuclear engineering departments. A firm commitment by the Federal Government, to create incentives sufficient to ensure the construction of a modest number of new nuclear plants, with the incentives reduced for subsequent plants, would be the best thing that could possibly be done for nuclear engineering education and revitalization of the national work force for nuclear science and technology.*

Professor Per Peterson, Chair,
Department of Nuclear Engineering,
University of California, Berkeley

Recommendations

Cross-disciplinary training is critical in the energy field, and is particularly critical for the nuclear power sector, which should be more fully integrated into energy planning and evaluation across a wide range of energy technologies and systems. Nuclear science and engineering departments should be supported and encouraged to provide a more widely interdisciplinary training at both the undergraduate and graduate levels.

The economics of nuclear power provide a telling example of it being managed as a "technology apart" instead of engaging in a more consistently comparable evaluation of energy options and issues as part of a true national energy policy.

Hydrogen is a particularly important promising future energy carrier. The potential for nuclear power plants to play an important role in a hydrogen future exists, but far more research needs to be conducted on this relationship.

Acknowledgments

I would like to thank Charles Forsberg, Bill Kastenberg, and Per Peterson for their input on the issues of the relationship of university programs and the U.S. nuclear energy industry. Greg Nemet, doctoral student in the Energy and Resources Group provided invaluable research assistance in the preparation of this testimony. E-mail: gnemet@socrates.berkeley.edu

BIOGRAPHY FOR DANIEL M. KAMMEN

Daniel M. Kammen received his undergraduate education in physics from Cornell University 1984. He received his Masters (1986) and Doctorate (1988) degrees in physics, from Harvard University. He was a Bantrell & Weizmann Postdoctoral Fellow at the California Institute of Technology, and then a lecturer in the Department of Physics at Harvard University. From 1992–1998 Kammen was on the faculty of the Woodrow Wilson School of Public and International Affairs at Princeton University, where he was Chair of the Science, Technology and Environmental Policy Program. Kammen is now Professor of Energy and Society in the Energy and Resources Group (ERG), and in the Department of Nuclear Engineering at the University of California, Berkeley. At Berkeley Kammen is the founding director of the Renewable and Appropriate Energy Laboratory (http://socrates.berkeley.edu/~rael), and is campus representative to the University of California Energy Institute. He has been a Lecturer in Physics and Natural Science at the University of Nairobi.

Kammen's research centers on the science, engineering, economics and policy aspects of energy management, and dissemination of renewable energy systems. He also works on the health and environmental impacts of energy generation and use; rural resource management, including issues of gender and ethnicity; international R&D policy, climate change; and energy forecasting and risk analysis. He is the author of over 140 journal publications, a book on environmental, technological, and health risks (*Should We Risk It?* Princeton University Press, 1999) and numerous reports on renewable energy and development. Kammen received the *1993 21st Century Earth Award* and is a Fellow of the American Physical Society. He is a Permanent Fellow of the African Academy of Sciences. He appears frequently in the media as a commentator on energy and environmental issues.

For information of any of these activities, see http://socrates.berkeley.edu/~dkammen.

Chairman BIGGERT. Thank you, Dr. Kammen.

Ms. Howard.

STATEMENT OF MS. ANGELINA S. HOWARD, EXECUTIVE VICE PRESIDENT OF POLICY, PLANNING, AND EXTERNAL AFFAIRS, NUCLEAR ENERGY INSTITUTE

Ms. HOWARD. I believe we are putting some slides up. Here we go.

Chairwoman Biggert, Ranking Member Lampson, and distinguished Members of the Subcommittee, I am Angie Howard, Executive Vice President of the Nuclear Energy Institute, which is the Washington, DC-based policy institute for the nuclear energy industry.

[Slide.]

America's 103 nuclear power plants are the safest, most efficient, and reliable in the world, and are the largest source of emission-free electricity in the United States. Last year, our nuclear plants reached record levels for safety, efficiency, and electricity production. Sixteen reactors have received renewed operating licenses, and will expect—and we expect the vast majority of the remaining reactors in our country will extend their lives from 40 years to 60 years. In fact, the workers who will operate the Quad Cities plant in Illinois or the Comanche Peak in Texas are not even in the workforce yet. And to meet future electricity demand and protect the environment, new nuclear power plants will be needed in the future. In fact, the industry has a program in order to achieve and maintain the 20 percent of electricity that we have today in this country generated from nuclear energy. We will need to add 50,000 megawatts of new nuclear generation by 2020 in order to just maintain the 20 percent non-emitting generation that we enjoy today.

So we feel that it is essential for Congress to adopt policies that will foster the vital training and research infrastructure of the nuclear technology sector. Today, I would like to touch on the staffing crisis that we are seeing in the industry, how federal funded programs are critical to meeting the staffing needs, including nuclear engineering, health physics, and other engineering disciplines, and also the federal support for skilled craft and technician training, which is vital to the industry.

[Slide.]

A study conducted by the NEI last—two years ago indicates a need for 90,000 new workers in the industry between 2002 and 2011 and 26,000 in just the power sector alone. A key part of this slide shows that not only does the power sector need a significant number of individuals in the coming years, there will be great competition for the available pool of workers. We expect to see the first wave of retirements in the next three to five years, but far more in the 7- to 10-year range. In a report on the issues facing the Department of Energy, the General Accounting Office concluded that the shortage of technical staff at DOE could reach crisis proportions within the next 10 years. And also, in addressing the Nuclear Regulatory Commission, the GAO found that 33 percent of the Commission's technical professionals will be eligible for retirement by the end of 2005, again threatening the agency's ability to achieve its missions.

[Slide.]

Workers—unfortunately, the supply of workers for key areas of nuclear technologies will decrease in the next decade, as shown in this slide. And most effected will be in the health physics and nuclear engineering. The number of four-year programs across our nation to train future nuclear scientists has declined to approximately 25, a 50 percent reduction since 1970 and this year, as the Chairwoman said, 27 operating research and training reactors, more than a 50 percent decline since 1980.

The industry supports H.R. 6, which includes Chairwoman Biggert's legislation. This legislation will fully fund the university programs by increasing funding for student recruitment, teaching facilities, fuel, and other reactor equipment, and instructors to educate a new generation of American nuclear specialists. We hope to see these provisions in the final legislation that should pass both Houses of Congress. NEI encourages the Committee to consider, also, a new $2 million program within the Office of Nuclear Energy to support universities that have undergraduate and graduate programs in health physics.

[Slide.]

We also need support for technical training programs and skilled craft. As you can see from this slide, the need for technical and craft personnel is the third most vital for the industry. And the industry supports the implementation of a program to support technician and craft training within the context of the energy bill now being considered in the Senate. This bill sets aside $20 million each year through fiscal year 2008 to train skilled personnel. This funding will supplement the aggressive workforce programs conducted by organized labor and supplement the industry's activities.

And the industry continues to support this vital and—these vital issues. Scholarships and fellowship programs at the rate of about $1 million a year are awarded annually by the industry. And plus we have in place programs to help retain—attract and retain young professionals to the industry.

We urge you to continue to support Chairwoman Biggert's legislation contained in H.R. 6 and the investments in the DOE university programs. To maintain our nation's position as the international leader in nuclear technology, it is vital that these start to turn around.

Thank you very much.

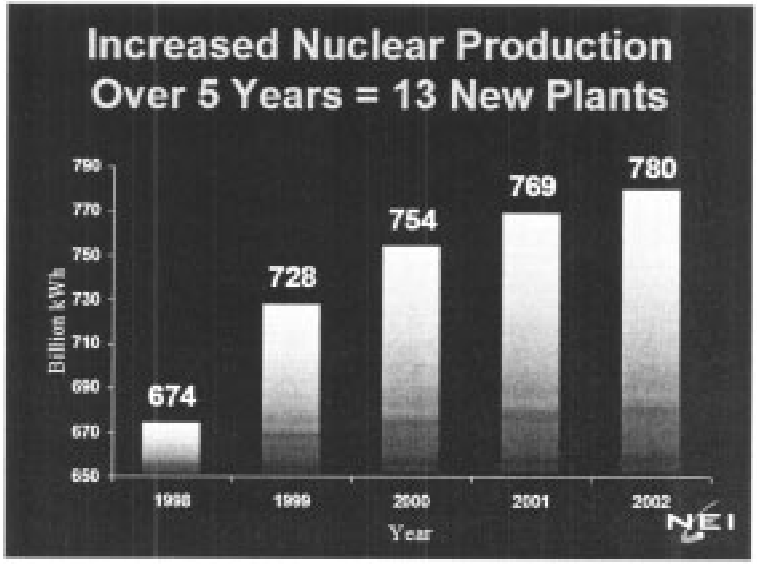
[The prepared statement of Ms. Howard follows:]

PREPARED STATEMENT OF ANGELINA S. HOWARD

Chairman Biggert, Ranking Member Lampson and distinguished Members of the Subcommittee, I am Angie Howard, Executive Vice President of the Nuclear Energy Institute (NEI). NEI is the Washington, D.C.-based policy organization for the nuclear energy industry.

NEI's 270 corporate and other members are engaged in the beneficial use of nuclear technologies. They represent a broad spectrum of interests, including every U.S. energy company that operates a nuclear power plant. NEI's membership also includes nuclear fuel cycle companies, suppliers, engineering and consulting firms, national research laboratories, manufacturers of radiopharmaceuticals, labor unions, law firms and 57 universities.

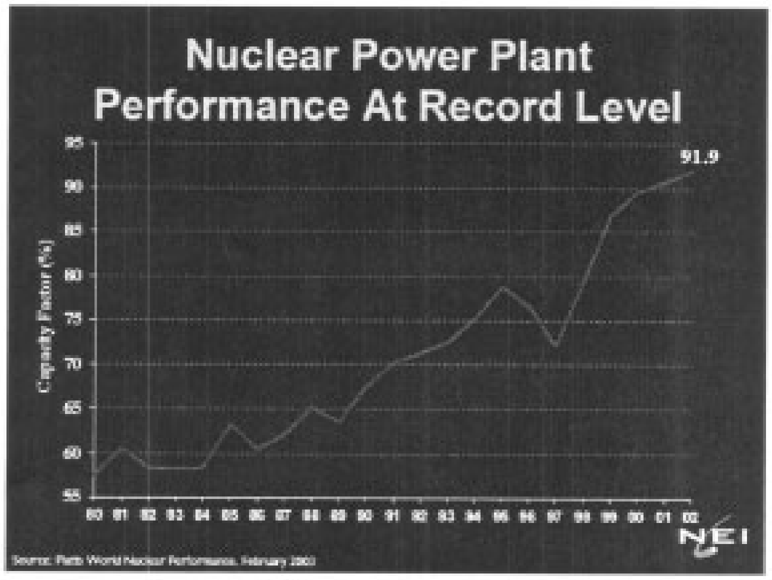
America's 103 nuclear power plants are the safest, most efficient and reliable in the world. Nuclear energy is the largest source of emission-free electricity generation in the United States. Nuclear power plants in 31 states provide electricity for one of every five homes and businesses in the Nation, and the industry again last year reached record levels for efficiency and electricity production.



The first illustration shows how much more electricity has been produced by our nuclear plants over the past five years through greater efficiency—increased electricity output from our existing nuclear reactors. From 1998 to 2002, the increases in efficiency were equivalent to adding 13 1,000-megawatt power plants to our nation's electricity grid.

Last year's record performance capped the best decade in the industry's history. Even with growth in overall energy demand and production, America's nuclear power plants have kept pace and, as our nation's second largest source of electricity, continue to provide approximately 20 percent of the Nation's electricity.

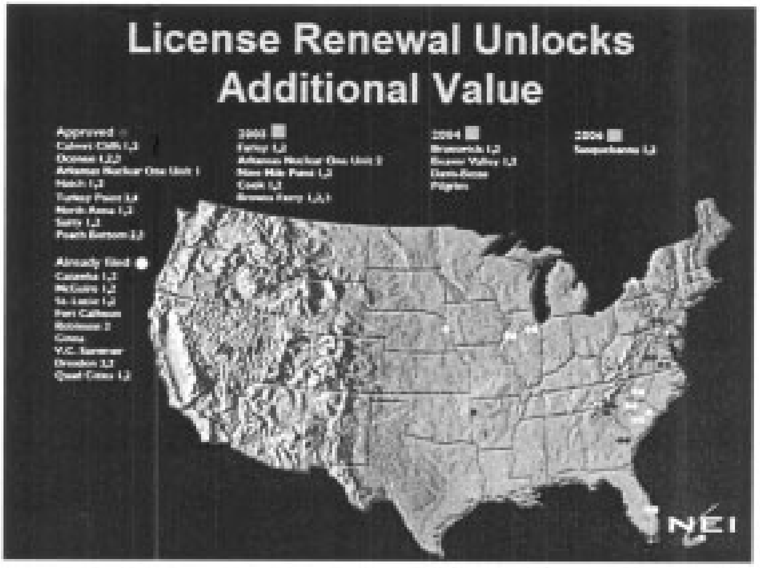
The growth in nuclear power production avoided the environmental disruptions and impacts that would have occurred if new electric generation had to be brought on line to meet our country's electricity needs. The lack of new nuclear construction since the 1980s often is identified as a sign of industry stagnation, when in fact, expanded operation of existing facilities has actually been the environmentally preferable alternative for making additional electricity.



Nuclear Power Plant Performance At Record Level

Source: Platts World Nuclear Performance, February 2003

As you can see from my next illustration, nuclear power plant capacity increases and operating efficiencies continue. Plant uprates, improved maintenance and reduced outage times will contribute to even higher operating efficiency and additional electricity output from existing power plants. But these increases are finite, limited to the maximum capacity of each reactor. What can we expect from our current operating fleet as far as lifetime service is concerned?



License Renewal Unlocks Additional Value

Approved
Calvert Cliffs 1,2
Oconee 1,2,3
Arkansas Nuclear One Unit 1
Hatch 1,2
Turkey Point 3,4
North Anna 1,2
Surry 1,2
Peach Bottom 2,3

Already filed ●
Catawba 1,2
McGuire 1,2
St. Lucie 1,2
Fort Calhoun
Robinson 2
Ginna
V.C. Summer
Dresden 2,3
Quad Cities 1,2

2003 ■
Farley 1,2
Arkansas Nuclear One Unit 2
Nine Mile Point 1,2
Cook 1,2
Browns Ferry 1,2,3

2004 ■
Brunswick 1,2
Beaver Valley 1,2
Davis-Besse
Pilgrim

2006 ■
Susquehanna 1,2

In the 1990s, we began the process of extending the operating licenses of our nuclear reactors for an additional 20 years, to a total of 60 years. Congress selected the original 40-year license period because it was a typical amortization period for an electric power plant. Congress also allowed for license renewal. As this illustration shows, 16 reactors have renewed operating licenses. We expect the vast majority of plants to extend their operating licenses beyond the initial 40-year period. The people who will operate and maintain these plants toward the end of the licenses are not even in the work force yet.

We should expect total electric output from nuclear plants to continue to increase along with increases in productivity and additional plant uprates. But to meet future demands of an electricity-hungry digital economy, especially when environmental requirements limit some options, several electric companies are beginning to examine the market for new nuclear power plants. Demand for electricity is expected to grow by 40 percent by 2020, according to the Department of Energy. In order to maintain at least one-third of our total electricity production from emission-free sources, the industry has set an ambitious goal for the future: building 50,000 megawatts of new nuclear energy production by 2020, and gaining another 10,000 megawatts of capacity by making today's plants even more efficient.

Already, the industry is working in a private-public partnership with the Department of Energy. DOE's Nuclear Power 2010 initiative has as its goal to help the first of those new nuclear plants begin operation by the end of this decade. But it is essential that Congress adopt policies that foster the further development of this vital part of our nation's energy mix—including support to the vital training and research infrastructure of the sector.

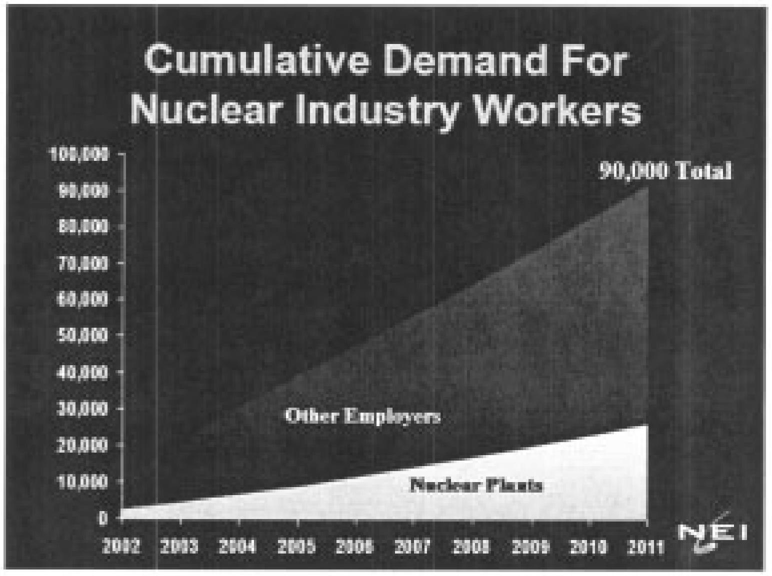
My testimony today will address three key points:

1. The nuclear industry is facing a looming staffing crisis.
2. Federally funded university programs are critical to meeting staffing needs in several critical areas, including nuclear engineering, health physics and various engineering disciplines.
3. Federal support for skilled craft and technician training also is key to meeting the need for the highly qualified work force our industry needs to continue its high levels of efficiency and electricity production.

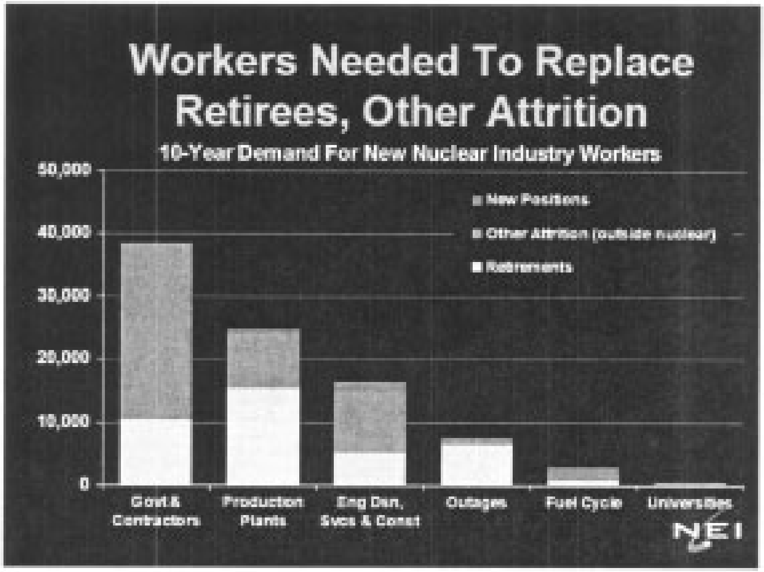
Without question, nuclear energy in the United States is experiencing a renaissance. We see clear signs that this renaissance is gaining new recognition in Congress—through bipartisan legislation introduced this year in the House and Senate, by the Administration in its national energy policy and among the American public. The renaissance is driven by the overwhelming need to maintain our diverse mix of energy generation and to meet the ambitious energy and environmental requirements of the future.

The industry is entering a new phase—one of developing new plants incorporating new, advanced reactor technologies that could be used uniformly across the Nation to meet increasing electricity demand. As we enter this dynamic new era, it is critical that we do so on the safe foundation that only a strong federal research and development base can provide.

Looming Workforce Crisis



Last year, NEI conducted a major study on the staffing needs of the nuclear industry, which includes plant operations, plant outages, government personnel and government contractors, front- and back-end fuel cycle, engineering design, services and construction, and universities. Although the study did not take into account the possibility for new plant construction and operation, it indicates a need for 90,000 new workers in our industry from 2002 to 2011.



A more recent study of staffing for the nuclear power sector alone indicates that many plants are facing significant attrition in such areas as maintenance, engineering, operations, safety and radiation protection. Most of the attrition in the nuclear power sector will be due to retirement. We expect to see the first wave of retirements in the next three to five years, but a far more significant number of retirements seven to 10 years from now.

Data show that the need for nuclear engineers and health physicists will outstrip supply.

A recent study conducted by the Health Physics Society[1] concluded that a critical shortage exists in the supply of qualified radiation protection professionals throughout a broad spectrum of activities, including nuclear power production. The society also concluded that the current imbalance between supply and demand will significantly worsen in the near-term after which it will become completely untenable. The present demand for radiation protection professionals is approximately 130 percent of supply, and over the next five years demand will outstrip supply by 160 percent. The Nuclear Energy Institute study[2] concluded that the demand will be 210 percent of supply in 10 years.

A shortage of radiation protection professionals has also been identified as a major strategic issue by the Institute of Nuclear Power Operations (INPO)[3] and several power producers.

Another area where we project a critical shortage is in nuclear engineering. According to NEI's study, demand for nuclear engineers will be about 150 percent of supply over the next 10 years.

To give you some figures, DOE reports that the number of nuclear engineering Bachelor of Science enrollments declined from 1,400 in 1993 to about 500 in 1998. Oak Ridge Institute for Science and Education found that total U.S. undergraduate nuclear engineering degrees decreased by 20 percent in 2000 and masters by 6 percent.[4] Although some universities are seeing a stabilization or slight upturn in nuclear engineering enrollments, we still must address this shortfall.

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[1] "Human Capital Crisis in Radiation Safety; Position Statement of the Health Physics Society," August 2001.

[2] "Nuclear Pipeline Analysis," Nuclear Energy Institute. December 2001.

[3] "A Strategic Look at the Future of Radiological Protection," *Proceedings of the 2001 Radiation Protection Manager's Workshop,* Institute of Nuclear Power Operations. September, 2001.

[4] "Nuclear Pipeline Analysis," Nuclear Energy Institute. December 2001.

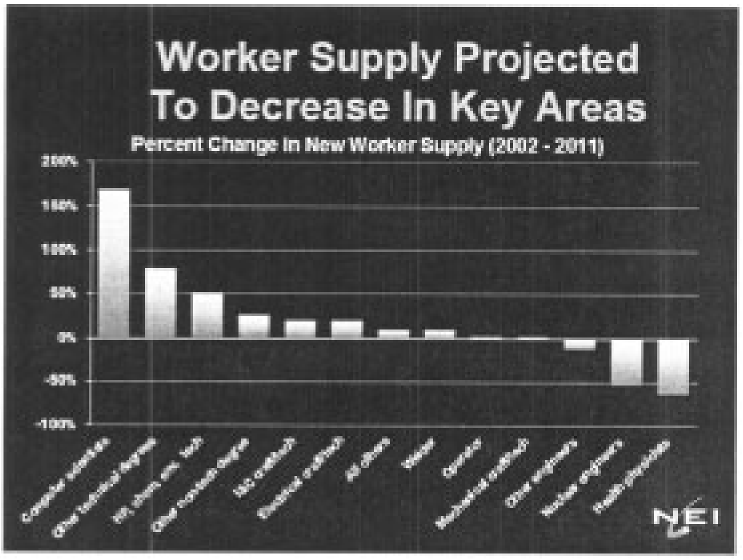
The Government Accounting Office (GAO) has prepared a series of reports analyzing the looming crisis in human capital and its effects on key government agencies, designating the issue of human capital as a government-wide high-risk area.[5] In a report on the issues facing the Department of Energy,[6] the GAO concluded that the shortage of technical staff at DOE will reach crisis proportions within the next 10 years.

In a report on the issues facing the Nuclear Regulatory Commission,[7] the GAO concluded that 33 percent of the technical professionals will be eligible for retirement by the end of 2005. In a further analysis of the NRC's human capital issues, the GAO also concluded that the NRC's ability to maintain the skills needed to achieve its mission is threatened by the decline in university enrollments in nuclear engineering and other fields related to nuclear safety.[8] In response to this, the NRC has already initiated an aggressive recruiting campaign and has instituted a practice of hiring non-nuclear-educated personnel and providing customized training programs in nuclear technology. This is a laudable stop-gap measure, but it will not resolve the problem over the long-term.

With the advent of advanced medical techniques, competition between the medical community and nuclear industry for nuclear engineers and health physics degreed personnel has also increased. The government—including the Department of Homeland Security—also will be competing for this same labor pool.

Need for DOE University Programs

As our industry matures, so does our workforce. Our dramatic improvements in productivity and efficiency are due in large part to our highly skilled and excellently trained employees.



This training comes primarily from two sources: Universities and accredited industry training (through INPO). With the looming waves of retirement throughout

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[5] GAO–01–357T, "Human Capital: Meeting the Governmentwide High-Risk Challenge," Statement of David M. Walker, Comptroller General of the United States, in testimony before the U. S. Senate. February 1, 2001.

[6] GAO–01–246, "Major Management Challenges and Performance Risks: Department of Energy," Government Accounting Office. January, 2001.

[7] GAO–01–259, "Major Management Challenges and Performance Risks; Nuclear Regulatory Commission," Government Accounting Office. January, 2001.

[8] GAO–01–241, "Major Management Challenges and Performance Risks; A Governmentwide Perspective," Government Accounting Office. January, 2001.

the nuclear technologies sector, it will be vital that the new employees coming into the industry are highly skilled upon entrance and the best and brightest our nation has to offer. For example, new nuclear engineers will be needed to replace retiring staff in the commercial sector, as well as faculty members at leading educational institutions.

Unfortunately, the pipeline for key areas of nuclear technologies will continue to go unfilled in this decade as identified in this illustration.

With nuclear plant relicensing and plans for new plants, demand for highly educated and trained professionals will continue. The only program that provides Federal Government support for educating and training our nuclear energy science, technology and engineering knowledge base is DOE's University Support Program. This program supports vital research and educational programs in nuclear science at the Nation's colleges and universities.

The number of four-year programs across our nation to train future nuclear scientists has declined to approximately 25—a 50 percent reduction since about 1970. Current state budget shortfalls are exacerbating the closure rate. Universities across the United States cannot afford to maintain their small research reactors, forcing their closure at an alarming rate. This year there are only 28 operating research and training reactors, more than a 50 percent decline since 1980. Two-thirds of the nuclear science and engineering faculty are over age 45, with little ability to draw new and young talent to replace them.

NEI recommends $26.5 million for DOE's University Support Program for fiscal year 2004 to stop the disintegration of this valuable infrastructure. To maintain our nation's position as the international leader in nuclear technology, it is vital that the trends mentioned here be reversed and that our nation's best and brightest technical minds be attracted to the nuclear technologies. We support H.R. 6, which includes Chairman Biggert's legislation, H.R. 2126. This legislation will fully fund university programs by increasing funding for student recruitment, teaching facilities, fuel and other reactor equipment, and instructors to educate a new generation of American nuclear specialists. We hope to see these provisions in final legislation that passes both houses of Congress.

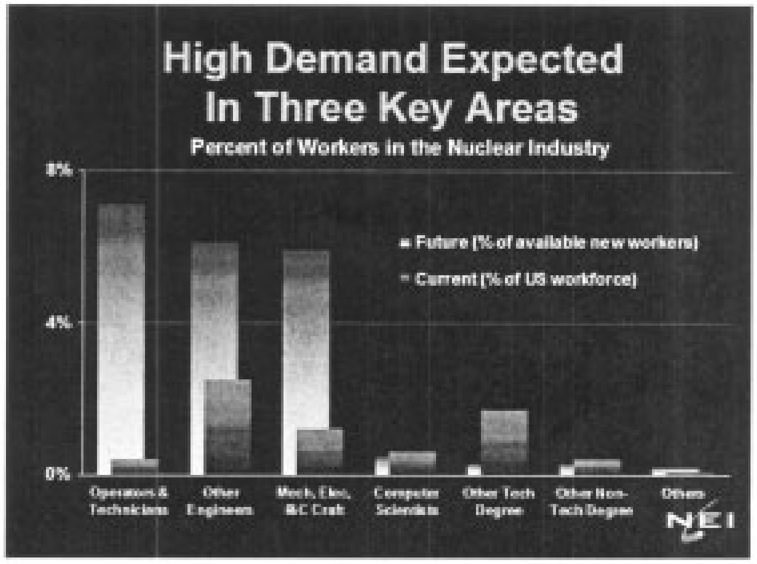
NEI encourages the Committee to consider a new $2 million program within the Office of Nuclear Energy to support universities that have undergraduate and graduate programs in health physics. The industry's most recent survey of human resources revealed that health physics professionals are declining in numbers and the need will become acute in the next few years, when many will retire. This critical resource will be necessary to support the industry, government programs at DOE sites and national laboratories, NRC activities and homeland security programs.

For more than 20 years, the industry has had a program to support higher education.

To foster the training of engineers, the nuclear industry funds several educational assistance programs through the National Academy for Nuclear Training. The National Academy Educational Assistance Program supports U.S. nuclear engineering education, encourages students to consider careers in the nuclear energy industry, and supports students who would be likely candidates for employment in the industry after graduation. Each year, the program awards $560,000 in graduate fellowships and $375,000 in undergraduate scholarships. Since 1980, the industry has provided more than $19 million to support some 3,400 students.

Need for Skilled Craft and Technician Training Programs

One area that is not currently supported by the Federal Government to any great degree is technical and skilled craft training programs. The industry supports the implementation of such a program within the context of the energy bill now being considered in the Senate. The bill sets aside $20 million each year through fiscal year 2008 to train skilled technical personnel. This funding will supplement the aggressive work force programs conducted by organized labor and the industry.



As you can see from this illustration, the need for this type of personnel is the third most vital for the industry. The legislation does the Nation a great service by recognizing and addressing vital personnel and training needs for the energy sector. In so doing, Congress is cultivating the vital talent and skill needed to power our homes, our cities, our economy and our future.

I commend the Science Committee for its foresight in addressing secondary school technical education last year. It is important to foster science and math education for young children, because they ultimately will fill college classrooms in technical fields. In particular, I want to thank Rep. Ehlers for working to secure appropriations for the National Science Foundation. The law that was passed, Public Law 107–368, includes many exciting provisions that support science and math education. And although the focus in the past has been on advanced education, Section 9 authorizes grants to institutions of higher learning, or eligible nonprofit organizations, to establish math and science education partnership programs to improve secondary school instruction. It also emphasizes training master teachers and encouraging girls to pursue studies in science, math, engineering and technology. This is exciting and far-sighted legislation that further supports America's need for technically trained professionals.

In conclusion:

1. The nuclear industry is facing a looming staffing crisis.
2. Federally funded university programs are critical to meeting staffing needs in several critical areas, including nuclear engineering, health physics and other engineering disciplines.
3. Federal support for skilled craft and technician training is key to meeting the need for the highly qualified work force our industry needs to continue its high levels of efficiency and electricity production.

There are critical steps to be taken in cultivating the next generation of nuclear professionals to advance the use of proven and vital nuclear technologies, including nuclear power plants. These plants are and will continue to be a vital part of our nation's energy mix—and the only large source of emission-free electricity that is readily expandable. I ask for your continued support in the effort to ensure an adequate supply of highly qualified technical professionals for nuclear energy and other beneficial uses of nuclear technologies. Thank you.

BIOGRAPHY FOR ANGELINA S. HOWARD

Angie Howard is Executive Vice President of Member Relations and External Affairs for the Nuclear Energy Institute. Ms. Howard, who joined NEI in 1996, has also been responsible for the organization's Industry Communications activities.

Before joining NEI, Ms. Howard was Vice President and Director of Industry Relations and Information Services for the Atlanta-based Institute of Nuclear Power Operations. She also was involved in the formation of the World Association of Nuclear Operators and the development of communications activities for the WANO–Atlanta Center, which is co-located with INPO. Before joining INPO in 1980, Ms. Howard was employed by Duke Power Company from 1969 to 1980.

Ms. Howard received a Bachelor's degree from Clemson University, and is a graduate of the Advanced Management Program at the Harvard University Graduate School of Business. She has completed the Reactor Technology Program for Utility Executives sponsored by the Massachusetts Institute of Technology and the National Academy for Nuclear Training. Ms. Howard is an accredited member of the Public Relations Society of America and is a member of the American Nuclear Society. She also is a member of the Clemson University Research Foundation Board.

Chairman BIGGERT. Thank you, Ms. Howard.

Dr. Stubbins.

STATEMENT OF DR. JAMES F. STUBBINS, HEAD OF THE NUCLEAR, PLASMA, AND RADIOLOGICAL ENGINEERING DEPARTMENT, UNIVERSITY OF ILLINOIS–URBANA-CHAMPAIGN (UIUC)

Dr. STUBBINS. Chairwoman Biggert, Mr. Lampson, and Members of the Committee, thank you for the opportunity to provide your Committee with some information and perspectives about the future of university nuclear science and engineering programs.

This topic is of central concern to the Nuclear Engineering Department Heads Organization, NEDHO, which I chaired until last week. This organization includes Heads and Chairs of all of the nuclear engineering departments in the U.S. and broadly represents our common interests to see the nuclear engineering discipline flourish at universities.

I am also speaking for my personal interest as Head of the Department of Nuclear, Plasma, and Radiological Engineering at the University of Illinois at Urbana-Champaign. It is the single department of nuclear engineering in the State of Illinois, the most highly nuclear state in the U.S. and the home of the first manmade nuclear reactor.

The timing of this hearing is particularly opportune since there are several forces interacting currently to focus attention on the need to support and grow university programs in nuclear science and engineering, and some of those you have already heard. These forces included several recent positive developments to expand the use of nuclear technology for advanced nuclear energy systems, nuclear medicine, nuclear fusion, and to deal directly with the lingering issues of nuclear waste management, and national and international security. In fact, the many current positive activities are too numerous to mention in this short time.

These positive trends have refocused the national outlook on important and broad role of nuclear technology and techniques can play in meeting our societal needs. The role of government has been critical in shaping and supporting many of these positive trends.

These positive dynamics, however, are balanced by several concerns, which present major challenges to further development of nuclear power and technology. These include: as you have seen, an aging workforce; pressures on nuclear academic programs and university research reactors, pressures that are increasing now in times of tight university budgets; lingering public perceptions about nuclear power, nuclear waste, and international nuclear security; and difficulties in the emergence of a competitive nuclear utility industry through deregulation.

In fact, both the positive and challenges—positive aspects and challenges have been helpful in attracting a new generation of students to study nuclear science and engineering. These students are buoyed by the positive trends in the nuclear industry and are willing to accept the challenges that lie ahead. These students see meaningful and rewarding future in the nuclear engineering profession due to the expanding and long-term opportunities that the field now offers. This is a real turnaround from the low-enthusiasm enrollments of the 1990's, a difficult period not only for the nuclear industry, but also for university degree programs and university research reactors. This period saw the continued decline of several nuclear engineering departments and academic programs and the loss of university-based research reactors. This decline is still underway despite the current upward enrollment trends and increased research support for nuclear engineering programs.

Two of the most recent serious concerns were the impending closure of the Ford Nuclear Reactor at the University of Michigan, the reactor that I used for my undergraduate Nuclear Engineering Degree program days, and the moves to terminate my department at the University of Illinois and change its status to a program, or to disperse the faculty and program altogether. It is important to note that these are major issues at two of the largest and best science and engineering universities in the country and will have broad, negative, and lasting impact.

There are currently 17 ABET accredited Bachelor of Science Degree programs in Nuclear Engineering and one accredited Master of Science program. This number is in decline in recent years and be—and can be contrasted to the 295 BS Degree programs in Electrical Engineering and the 250 BS Degree programs in Mechanical Engineering in the U.S. It should be noted that the Nuclear Engineering Degree programs are—require excellent math and science skills and attract the very best students. These programs reside in the best science and engineering universities in the country. Nevertheless, at least two of the existing BS programs are under severe pressure and may not survive. These are the program at Maryland—the University of Maryland, and my program at the University of Illinois, as mentioned above.

The situation for university research reactors is no better. The current number of university research reactors is 27, down from a high of 65. Furthermore, the losses have not been orderly. Several of the largest, most well maintained reactors have closed due to local university pressures. My reactor at the University of Illinois is among this group. We closed in 1998 due to a local administrative decision not to re-license one of the top reactors in the country, our Advanced TRIGA Reactor, the last research reactor in the State of Illinois. Several of the best reactors have been shut down due to local pressures rather than some view to national needs.

Now the DOE recognizes the need to better support these national assets and instituted a few directed studies, which led to the development of the Innovations in Nuclear Infrastructure and Education, the INIE program, last year. This program, which is only partially funded, has provided support to several university reactor consortia with significant national lab and industry participation. It has encouraged enhanced cooperation among university nuclear programs and will lead to much broader use and support of the small fleet of remaining university research reactors.

The DOE has taken several other critical steps to direct support—to directly support university degree programs, including the Nuclear Engineering Education Research, NEER, Program, the DOE–Industry Matching Grant Program, and several fellowship and scholarship programs, though none of these are yet supported at full funding levels.

These efforts are critical for supporting nuclear programs, but challenges remain. For almost all university programs, resources are based on undergraduate enrollments. The decade of low undergraduate enrollments in the 1990's has compromised the position of many nuclear engineering departments that we have seen. We need to continue to address the undergraduate enrollment issue for a number of reasons. The most important is the need to cultivate a highly-qualified, well-educated group of nuclear engineers to meet national manpower requirements. This should also help stabilize the still shaky status of many of the university Bachelor of Science Degree programs.

In conclusion, the government has played the key role in defining and supporting nuclear development in the U.S., an area which, in many aspects, the U.S. continues to lead. Nuclear engineering education infrastructure in the U.S. has maintained its international leadership role. The U.S. universities are still the best place in the world to learn nuclear science and engineering. This educational leadership must be maintained as the necessary means for keeping all of the other sectors in the U.S. nuclear portfolio vital and vibrant.

Several possible steps have been taken to support and grow the university nuclear education and nuclear reactor infrastructure. Further steps are necessary. These include: steps which——

Chairman BIGGERT. Dr. Stubbins, if you could conclude, and we will——

Dr. STUBBINS. Yes.

Chairman BIGGERT. I am sure we will get to a lot of this in the questions.

Dr. STUBBINS. Okay. These steps include: full funding to 33 million for nuclear university programs; full funding for the INIE program; enhanced interaction between the labs and universities and industry; and continued support of the development of a new reactor system in the U.S.

Thank you.

[The prepared statement of Dr. Stubbins follows:]

PREPARED STATEMENT OF JAMES F. STUBBINS

Chairwoman Biggert, Mr. Lampson and Members of the Committee, thank you for the opportunity to provide your committee with some information and perspectives about *The Future of University Nuclear Science and Engineering Programs.* This topic is the central concern of the Nuclear Engineering Department Heads Organization (NEDHO), which I chaired until last week. This organization includes the Heads and Chairs of all of the nuclear engineering departments in the U.S., and broadly represents our common interests to see the nuclear engineering discipline flourish at universities. I am also speaking from my personal interests as the Head of the Department of Nuclear, Plasma and Radiological Engineering at the University of Illinois at Urbana Champaign. It is the single department of nuclear engineering in Illinois, the most highly nuclear state in the U.S., and the home of the first man-made reactor.

The timing of this hearing is particularly opportune since there are several forces interacting currently to focus attention on the need to support and grow university programs in nuclear science and engineering. These forces include several recent positive developments:

- The regrouping of nuclear power utilities under deregulation to provide a strong and sustainable nuclear power generation infrastructure;
- nuclear plant license extensions—several nuclear plants have or will apply for extension of up to 20 years in their operating license;
- power up-rates of several existing nuclear power reactors to increase overall nuclear generated electricity;
- new nuclear power reactor designs—both abroad and at home, new and future generations of nuclear plants are under active development. The long-term focus of the Generation IV (Gen IV) reactors is headed toward new, more efficient, more passively safe, and secure reactors;
- new waste-efficient and proliferation-resistant nuclear fuel cycles—developments are underway to support "high burn-up" fuels and the Advanced Fuel Cycle Initiative (AFCI) to develop new fuels and fuel cycles which reduce waste and deter the build up of undesirable side products;
- continuing and growing interest in nuclear fusion—the U.S. is now committed to a burning plasma experiment and is negotiating to rejoin ITER (one of the options for a burning plasma experiment);
- nuclear medicine—nuclear diagnostic techniques, radioisotopes, and a variety of nuclear-based imaging modalities are in increasing use to provide safe, effective medical procedures;
- movement forward with management of current nuclear waste at Yucca Mountain—the license process for Yucca Mountain is underway following the recommendation by the President and the assent of Congress last year;
- positive steps toward new civilian nuclear plant construction—the DOE and others are supporting an initiative for new nuclear plant construction in the "2010" Program. A few utilities have started inquiries for site approval as a first step toward new construction;
- Broad-based research initiatives for improving and advancing nuclear power facilities and operation for example through the Nuclear Energy Research Initiative (NERI) and the international version, INERI;
- increased awareness of the impact of carbon-containing emissions—the growing public awareness of the role nuclear power can play in reducing carbon-containing and other environmentally unfriendly gases;
- national and international security—the growing need for enhanced national and international security through the National Nuclear Security Administration (NNSA) and a broad range of activities to monitor and uncover dangerous nuclear agents;
- space nuclear power—the development of a nuclear power base for manned missions to Mars and beyond where nuclear-based propulsion is the only way to provide sufficient continuous power to keep flight times short and mission goals manageable;
- and the emergence of a balanced National Energy Policy—a balance approach to the development of a variety of energy resources in which nuclear power plays a central and long-term role. In addition, the trend toward a hydrogen-based fuel economy will certainly include nuclear power generation.

These positive trends have refocused the national outlook on the important and broad role nuclear technology and techniques can play in meeting our societal needs. The role of government has been critical in shaping and supporting many of these positive trends.

These positive dynamics are balance by several concerns which present major challenges to further development of nuclear power and technology. These include:

- an aging nuclear workforce;
- pressures on nuclear academic programs and university research reactors, pressures that are increasing now in times of tight university budgets;
- lingering public perception of nuclear power, nuclear waste and international nuclear security;
- and difficulties in the emergence of a competitive nuclear utility industry through deregulation.

In fact, both the positive aspects and the challenges have been helpful in bringing a new generation of students to study nuclear science and engineering. These students are buoyed by the positive trends in the nuclear industry and are willing to accept the challenges that lie ahead. These students see a meaningful and rewarding future in the nuclear engineering profession due to the expanding and long-term opportunities that the field now offers. This is a real turn around from the low enthusiasm and enrollments of the 1990's, a difficult period not only for the nuclear industry, but also for university degree programs and university reactors. This period saw the continued decline of several nuclear engineering departments and academic programs, and the loss of several critical university-based teaching, research and training reactors. This decline is still underway despite the current upward enrollment trends and increased research support for nuclear engineering programs. Two of the most recent serious concerns are the impending closing of the Ford Nuclear Reactor at the University of Michigan (the reactor I used in my undergraduate studies in Nuclear Engineering) and the moves to terminate my department at the University of Illinois and change its status to a program, or to disperse the faculty and program altogether. I will return to these points later, but it is important to note that these are major issues at two of the largest and best science and engineering universities in the country, and will have broad, negative impact.

There are currently 17 ABET accredited BS degrees in Nuclear Engineering, and one accredited MS degree program. This number has declined in recent years and can be contrasted to 295 BS degree programs in Electrical Engineering and 250 BS degree programs in Mechanical Engineering. Table 1 shows an indication of the engineering BS degree types at the top ten graduate colleges of engineering. Note that Nuclear Engineering is a prominent degree program at many top institutions. Nevertheless, at least two of the existing BS programs are under severe pressure and may not survive. These are the program at the University of Maryland and my program at the University of Illinois, as mentioned above. Several features of nuclear engineering educational programs are noteworthy and indicate the need for specific, focused attention to the well being of the discipline:

- Nuclear engineering is a unique discipline—it is not a sub-discipline of other traditional engineering fields, making it difficult to impossible to flourish as sub-discipline in another department.
- Many nuclear engineering programs which were merged into other engineering departments have dwindled or are completely gone.
- The nuclear discipline is new—the first reactor was assembled in Chicago just over 60 years ago, and many nuclear engineering programs were formed staring in the late 1950's to early 1960's to educate a new generation of students for a variety of nuclear applications.
- Nuclear is "high tech"—the discipline requires strong math, science and technical skills so nuclear engineering programs are found at the best universities and attract the best students, students who, on graduation, attract the best salaries in the short- and long-term and who have the highest average passing scores on the professional engineering exams.
- Nuclear programs are under pressure due to the low enrollments during the 1990's and needs to redistribute resources to other academic areas. This is exacerbated by current, severe university budget pressures.
- The resurgence of the nuclear engineering profession has prompted the formation of new programs and departments—the most recent are BS programs at South Carolina State and at the U.S. Military Academy, and MS programs at the University of South Carolina and at the University of Nevada at Los Vegas. The development of new programs requires extensive new resources to be successful. Thus these programs should be seen as complementary to the existing programs, and serve to further emphasize the value of the existing nuclear degree programs.

The situation for university research reactors is no better. The current number of university research reactors (URR) is 27, down from a high of 65. Furthermore, the losses of have not been orderly. Several of the largest, most well maintained reactors have closed due to local university pressures. My reactor at the University of Illinois is among this group. We closed in 1998 due to a local administrative decision not to relicense one of the top few reactors in the country, our Advanced TRIGA Reactor, the last research reactor in the State of Illinois. Nor have these closures been systematically planned since several of the best reactors have been shut down due to local pressures, rather than some view to national needs. The DOE recognized the need to better support these national assets and instituted a few directed studies which led to the development of the in Innovations in Nuclear Infrastructures and Education (INIE) Program last year. This program is aimed at providing the support base to maintain a national university research reactor program with coordination between participating universities, national laboratories and industry. In a highly competitive process, four reactor consortia were funded last year, and two more consortia will be added this year. This effort came too late to help reactors which closed in the 1990's, including mine, and could not influence more recent closures at Cornell and an impending closure at the University of Michigan. Other reactors, including some in existing consortia, are still at risk. Table 2 provides an indication of which of the current largest university research reactors are included in INIE consortia. (My reactor is in SAFSTOR, but its prominent position on the list indicates the magnitude of its loss to our program.) The INIE program, as the Table only partially indicates, has led to wide partnering between universities to share reactors, reactor technology and reactor resources. Partnering on this scale has not been seen before, and has broad benefits for sharing teaching and outreach resources which can only strengthen the nuclear discipline in general, while also supporting a diminished, but necessary, fleet of university reactors.

The DOE has taken several other critical steps to directly support university degree programs, including the Nuclear Engineering Education Research (NEER) Program, the DOE–Industry Matching Grant Program, and several Fellowship and Scholarship programs. These are in addition to university participation in other, broader research programs supported by DOE–NE and other DOE offices. Dr. Marcus will describe these in much more detail in her testimony, so I will not delineate them further here. These programs have been critical to the well being of university program. They have been offered on a competitive basis with highly focused peer review processes to determine and award only the very best proposals. Both the resources and the competitive nature of the award process have strengthened university degree programs. These programs have also been important in developing and strengthening ties between research programs at universities, national labs and with the nuclear industry. Nevertheless, these programs remain under-supported. For example, more than half of the NEER grant applications are worthy of funding. In a good year, less than 20 percent will receive funding, and this year less than 10 percent of the new grant applications were funded. In addition, only one new DOE–NE Fellowship will be awarded this year.

These efforts are critical for supporting nuclear programs, but challenges remain. For almost all university programs, resources are based on undergraduate enrollments. The decade of low undergraduate enrollments in the 1990's has compromised the position of many nuclear engineering departments. We need to continue to address the undergraduate enrollment issues for a number of reasons—the most important are the need to cultivate a highly-qualified and well-educated group of nuclear engineers to meet national manpower requirements. Increases in undergraduate student enrollments to meet this need will also restore the strength of the departments at universities. These manpower requirements are widespread—at national labs, at utilities, at nuclear vendors, and at nuclear utilities. The time line to the biggest impact differs between industry sectors, but it is clear that the future well-being of the industry rest entirely on attracting and educating new students. Even in sectors where the manpower needs are further in the future, for example, the nuclear utilities, they will need an extremely well educated workforce to provide them the edge they need for the competitive markets they are entering, and to maintain secure and safe operation. In the nuclear defense sector, international security issues demand a highly educated and highly dedicated workforce to replace the currently aging experts. The success in every sector of the nuclear enterprise will depend on the quality and education of the people they hire. This underlines the continuing, acute need to support the nuclear education infrastructure in the U.S.

In this regard, my situation at the University of Illinois is instructive, and foreboding. My Department is under pressure to be merged with another department or to be dispersed altogether. This is despite strong increases in research funding and moderate, but steady increases in undergraduate student numbers, and very high national ranking and reputation. This problem is exacerbated by the faculty age distribution—we, too, have a major issue with an aging work forces, common to many university nuclear programs. The average age of my faculty is over 56 years, with three of the nine faculty members at age 70 or more. The older faculty members represent a wealth of knowledge in the nuclear field dating back nearly to the beginning. In fact, one of these faculty members is the first Ph.D. in Nuclear Engineering awarded in the U.S. Nevertheless, my Dean is looking to redistributing resources in the College of Engineering and, in the process, to merge or disband my Department. This problem is related almost solely to our low undergraduate enrollment numbers. At a time when we should be building for the future with the rest of the country, we are fighting for existence. This is particularly alarming for us. We are the only nuclear engineering department in the State of Illinois, a state with 11 operating nuclear power reactors (and associated spent fuel), Argonne National Laboratory, and other nuclear facilities. Illinois residents have paid more than $2.4 billion into the federal Nuclear Waste Fund. Our program has contributed widely to the state and national nuclear infrastructure that supports nuclear power, technology and national security. It is hard to accept that a State with such a large stake in nuclear power and technology cannot support a Department of Nuclear Engineering and the necessary ten to twelve faculty members. This picture may be extreme compared to situations elsewhere where undergraduate enrollments have climbed more quickly than ours, but it is a warning about how fragile the nuclear engineering educational infrastructure remains in the U.S., particularly in times of tight state and university budgets. Action is required to support and maintain these valuable programs.

In conclusion, the government has played the key role in defining and supporting nuclear development in the U.S., an area which, in many aspects, the U.S. continues to lead. The globalization of much of the nuclear reactor design and support activities leaves the U.S. as a major player, at least. In other areas, which directly impact national and international security (both in defense and energy self-sufficiency), and in areas of advanced nuclear systems design, in nuclear fusion, in nuclear medicine, and in nuclear space applications, the U.S. maintains, and must protect, its leadership role. The nuclear educational infrastructure in the U.S. has maintained its international leadership role: the U.S. universities are still the best place in the world to learn nuclear science and engineering. This educational leadership must be maintained as *THE* necessary means for keeping all of the other sectors in the U.S. nuclear portfolio vital and vibrant.

Several positives steps have been taken to support and grow the university nuclear education and nuclear reactor infrastructure. Further steps are necessary. These include:

- Steps which lead to supporting the NERAC recommendation of a funding level of $33M for nuclear university programs;
- Full and continuous funding for the INIE program to support university research reactors;
- Support for enhanced interactions (intellectual and financial) among universities, national laboratories, and industry;
- Better national liaison with universities to underline the national, as well as local, importance of a strong nuclear education and reactor infrastructure, particularly to protect and enhance existing programs, and to provide opportunities for new programs; and
- Continued support of efforts to establish a new nuclear plant order in the U.S.—this is seen almost universally as a national commitment to nuclear power and is likely to attract many new students to the discipline.

Thank you for your attention and interest.

Answers to Specific Questions (in addition to comments in the body of the Statement)

- *What were the most important recommendations the Nuclear Engineering Department Heads Organization (NEDHO) recently made regarding DOE's university nuclear science and engineering programs? What are the implications for the health of university nuclear science and engineering programs and for the nuclear power industry if DOE were to fall short of implementing those recommendations?*

NEDHO has supported a request for increasing funds in the DOE–NE support for University Nuclear Science and Engineering Programs, designated in the DOE–NE budget as University Reactor Fuel Assistance Support (URFAS). We support a funding level of $26.5 for FY04, an increase from $18.5M, with priorities given to, in order, increase INIE to nearly full funding ($11M from 6.5M), increase NEER ($8M from $5M), and increase Fellowships ($1.9M from $1.5M). These increases will support the necessary growth of the university programs. In the longer-term, we support the recommendations of NERAC (Nuclear Energy Research Advisory Committee to DOE–NE) to increase URFAS to reach a level of $33M, with appropriate increases in several categories including those mentioned above. Without these resources, several programs would come under severe risk of merger or closure. Stability of research and infrastructure support, through DOE and others, remains a critical issue in the health of U.S. nuclear engineering programs. One only needs to reflect on the dire situation in the mid-1990's when the university support was zero, to see the lasting impact of funding shortfalls and instability of support.

A specific justification of the requested increases for FY04 are included here as an appendix.

- *To what extent is the existing university nuclear infrastructure, including nuclear research reactors, sufficient to maintain a vibrant nuclear research enterprise the United States? To what extent is it sufficient to provide the workforce training and research opportunities necessary to sustain the nuclear power industry and provide for other societal needs into the future?*

We feel that the nuclear infrastructure needs to grow to meet the increasing and lasting need for nuclear-educated professionals. However, first we need to commit to supporting the current number of excellent nuclear science and engineering educational programs, many of which are still struggling for resources in an increasing competitive atmosphere in under-funded university programs. This includes a commitment to replace aging faculty to maintain the important collective knowledge that will soon be gone. We also support the development of new programs, there are some recent examples, since the workforce issue will not diminish. Finally, almost all nuclear programs are increasingly using distance education techniques to reach wider audiences more quickly and efficiently. This technology can also be used to capture the wisdom of the more senior university faculty before they leave the system completely. In order to accomplish all of this, we require the substantial and continued support of the government.

- *To what extent does the quality of a university's nuclear science and engineering program depend upon the university having a nuclear reactor? To what extent can the national laboratories and industry support university programs?*

There are several aspects to maintaining high quality educational programs, and facilities, including university research reactors, are an important part of the picture. As indicated above, nuclear programs are found at the leading science and engineering universities. This is due in no small part to the high degree of science and mathematical skills required of student of the discipline. Our degree programs are able to maintain high academic standards in the absence of a reactor, but clearly reactor experience can be a defining event for student development. In the past year, the founding of the INIE program will provide for wider research reactor experience for students at universities without reactors (as well as many in other disciplines and other educational levels). We think this will have a very positive effect on maintaining the quality of nuclear engineering education. While remote access to reactor technology is helpful, the INIE, and earlier the "Reactor Sharing" Program, provide a mechanism for visits and research experiences on an existing reactor. National labs and industry have been supportive of reactor experiences for students when practicable. There are relatively few national lab reactors, and access to industry based power reactors is difficult. The nuclear industry has participated broadly in making their reactor simulators available for educational purposes. In addition, there is significant partnering with national labs and industry in the INIE program (as well as NERI, etc.) which support more expansive use of valuable reactor facilities.

National lab and industry interaction and support of university nuclear programs is critical in a very broad sense. There are many long-standing interactions of this sort which have resulted in graduate student experiences at national labs, and a variety of internships for undergraduate students at utilities and at national labs. In the research area, many of the most successful exchanges are done on an individual basis. Cooperative research through NERI, AFCI and partnerships within INIE have also been important in enhancing university-national lab-industry interactions. We support further considerations now underway at DOE–NE to provide better and more plentiful means of participating intellectually and financially in funded research at national labs, and with industry where appropriate. We feel that many of the current national nuclear initiatives will not succeed without strong university-national lab-industry cooperation.

Table 1. ABET Accredited BS Degree Programs at Top Ten Engineering Schools, USNWR 2003 and ABET

School	EE	ME	CE	ChE	CpE	IE	AE	MSE	AgE	Nucl	EM	GE	Eniv	Bio	Total
MIT	♦	♦	♦	♦	♦		♦	♦		♦			♦		14[a]
Stanford	♦	♦	♦	♦		♦									5
UC–Berkeley	♦	♦	♦	♦	♦	♦				♦					7
UIUC	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦			12[b]
Georgia Tech	♦	♦	♦	♦	♦	♦	♦	♦		♦			♦		11[c]
Michigan	♦	♦	♦	♦	♦	♦	♦	♦		♦					10[d]
Cal Tech	♦			♦											3[e]
USCal	♦	♦	♦	♦		♦	♦						♦		7
Purdue	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦			♦	*	13[f]
UT - Austin	♦	♦	♦	♦	♦		♦			†			♦		10[g]
Totals in top 10	10	9	9	10	7	7	7	5	2	6	1	1	4	0	
Totals in US	295	250	228	155	139	100	65	42	41	16	8	1	34	25	

* Purdue has an accredited BS degree in "Agricultural and Biological Engineering"

† U Texas – Austin has a Nuclear Engineering Option in its ME programs

Additional Degree Programs

[a] Ocean Engineering, variations on standard BS degree names

[b] EM – Engineering Mechanics, GE – General Engineering

[c] Textile and Fiber Engineering

[d] Naval Architecture and Marine Engineering

[e] Engineering and Applied Sciences

[f] Construction Engineering, Food Process Engineering, Land Surveying

[g] Architectural Engineering, Geosystems Engineering, Petroleum Engineering

Sources: http://www.abet.org/accredited_programs/EACWebsite.html
http://www.usnews.com/usnews/edu/grad/rankings/eng/brief/engrank_brief.php

Table 2
Status of the Largest University Research Reactors and INIE Funding
Shaded Facilities Are Included in an Existing or Likely INIE Consortium

Location	Type	Power -kW	Criticality Date	Status	Comments
U of Missouri-Columbia	Pool. LW mod	10,000	Oct-66	Operating	
MIT	Tank, LW mod, HW Refl	5,000	Jul-58	Operating	License renewed in 8/99
UC-Davis	TRIGA Mark II	2000		Operating	Acquired from McClellan AFB
U of Michigan (a)	Pool. LW mod	2,000	Sep-57	Operating	
U of Illinois (b)	*TRIGA*	*1,500*	*Jun-61/Jul-69*	***SAFSTOR***	*Operating License Expired 8/1998*
U Texas-Austin	TRIGA Mark II	1,100	Mar-92	Operating	
NC State	Pulsar	1,000	Jan-72	Operating	Received new license – 4/97 for 20y
Oregon State	TRIGA Mark II	1,000	Mar-67	Operating	License renew 2006
Penn State	TRIGA, Conversion Mark III	1,000	Aug-55	Operating	License renew 2005
Texas A & M	TRIGA Conversion	1,000	Jan-62	Operating	License renew-2003
U Mass-Lowell (c)	Pool, LW mod, Graphite refl.	1,000	Jan-75	Operating	License renew 2015
U of Wisconsin	TRIGA Conversion	1,000	Mar-61	Operating	License renewed - 2000
Washington State	TRIGA Conversion	1,000	Mar-61	Operating	License renewed - 2002

Notes:

(a) Scheduled to be shut down 3 July 2003
(b) Shut Down Aug 1998 – SAFSTOR with a possession only license, all facilities still on site
(c) Will likely join the MIT-based INIE consortium

Appendix

FY04 Funding Request for the University Nuclear Science and Engineering Programs

JAMES F. STUBBINS, JOHN C. LEE, ANDREW C. KLEIN, AND MICHAEL L. CORRADINI
NUCLEAR ENGINEERING DEPARTMENT HEADS ORGANIZATION

The FY04 Department of Energy funding for the University Reactor Fuel Assistance Support (URFAS) Program is inadequate to meet our nation's critical need for university-based nuclear education and research. The URFAS Program is the primary source of funding for the university nuclear science and engineering (NSE) educational programs and university research reactors (URRs). This testimony presents the unanimous position of both the Nuclear Engineering Department Heads Organization (NEDHO) and the National Organization of the Test, Research, and Training Reactors (TRTR).

Key Issues and the Request

The U.S. has become keenly aware of the importance of secure and affordable energy supply for the present and future well-being of the Nation. Nuclear energy can play a crucial role in stabilizing and reducing energy prices, and in meeting the energy needs of the country by the production of electricity as well as hydrogen for transportation. This has been emphasized in recent Congressional bills and in speeches by Secretary Abraham and President Bush. Significant concerns have been raised, however, regarding the maintenance of the workforce required to retain our nation's nuclear energy option. Grossly inadequate student enrollments in NSE programs, despite modest improvements over the past few years, and imminent threats to continued operation of URRs are primary concerns that need to be addressed immediately.

Despite these escalating problems, the FY04 DOE request of $18.5M remains flat at the FY03 appropriation and is significantly below the $33M recommended in the Energy Research, Development, Demonstration, and Commercial Application Act of 2003, H.R. 238. In light of the severe budgetary constraints anticipated for FY04, we respectfully request:

The House and Senate Energy and Water Appropriations Subcommittees appropriate for FY04 $26.5M for the University Reactor Fuel Assistance Support Program within DOE's Office of Nuclear Energy Science and Technology Programs.

This represents a modest increase of $8.0M from the FY03 appropriation and is required to prevent further declines in the URRs and university NSE programs. A detailed breakdown for the FY04 funding request for the university NSE programs is given in Table I below.

Table I. FY04 Funding Request for the University NSE Programs

Budget Category	FY02	FY03	FY04 (DOE request)	FY04 (needed)
Fellowship	1.4	1.4	1.4	1.9
Nuclear Engineering Education Research	5.0	5.0	5.0	8.0
Other academic programs	1.3	1.3	1.3	1.3
Reactor fuel, instrumentation, and sharing	4.3	4.3	4.3	4.3
Regional URR centers (INIE)	5.5	6.5	6.5	11.0
Total Funding ($M)	17.5	18.5	18.5	26.5

NEDHO and TRTR unanimously agree that the FY04 funding request should be, in order of priorities: (1) Innovations in Nuclear Infrastructure and Engineering (INIE) program increase of $4.5M to a total of $11.0M, (2) Nuclear Engineering Education Research (NEER) program increase of $3.0M to $8.0M, and (3) fellowship and scholarship program increase of $0.5M to $1.9M.

Justification for the Request

The Nuclear Energy Research Advisory Committee (NERAC) to the Secretary of Energy discussed in a recent report[1] the importance of academic NSE programs in meeting the infrastructure and workforce requirements for sustained nuclear technology development related to (a) current and future generations of nuclear power plants, (b) radiation sciences with industrial, medical, and biotechnology applications, (c) national security and weapons nonproliferation programs, and (d) nuclear propulsion in the U.S. Navy. This NERAC report highlights the near-crisis status of the country's NSE programs, noting that over the past two decades the number of academic nuclear engineering programs has halved to the current total of only 25, with a similar decrease in the number of URRs from 65 to 26.

In light of the decision by Cornell University in 2001 to decommission its campus reactor and the imminent risk to the URRs at the University of Michigan and Massachusetts Institute of Technology, DOE initiated in 2002 the INIE program to support regional URR centers. Seven regional URR consortia, distributed across the country, were selected through an independent peer review panel for funding. Due to the limited FY02 INIE appropriation of $5.5M, DOE was able to provide funding only for four consortia, with the three additional consortia to receive INIE grants as additional funding becomes available. In the FY03 omnibus appropriations bill, the INIE funding is increased only by $1M to a total of $6.5M, despite a funding request of $8.5M in the Senate appropriations bill. With this limited INIE FY03 appropriation, DOE would be unable to initiate funding for the remaining three URRs selected, but not funded to date. Without increased INIE funding the University of Michigan will shut down and decommission its reactor due to inadequate external financial support. The current INIE appropriation provides only partial funding even for the four URR consortia already funded. Our requested FY04 INIE funding of $11M provides the minimum support required to initiate funding for the three remaining consortia and sustain a total of seven URR regional centers distributed across the country. The lead institutions for the seven URR centers selected for funding are as follows:

1. Massachusetts Institute of Technology
2. Pennsylvania State University
3. Oregon State University and University of California, Davis
4. Texas A&M University
5. University of Missouri, Columbia
6. University of Michigan
7. North Carolina State University

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[1] M.L. Corradini, et al., "The Future of University Nuclear Engineering Programs and University Research and Training Reactors," Nuclear Energy Research Advisory Committee, U.S. Department of Energy (2000).

The seven consortia involve participation by at least 15 other universities and several national laboratories. Because these URRs belong to the group of best-utilized facilities, and are associated with the top nuclear engineering departments in the country, a premature demise of any of these leading URRs would be a major blow to the Nation's nuclear energy program and the loss of valuable national scientific research and training resources. This loss would be tragic particularly as the Nation begins to actively consider expanding nuclear electricity generating capacity to meet the increasing energy demand for the Nation. Because contributions of nuclear scientists and engineers extend well beyond traditional nuclear power, including national defense, homeland security, medical applications of radiation science, and industrial applications, the shortage of technically trained nuclear professionals is even more critical.

A recent NEDHO study[2] indicates that the annual demand for nuclear engineers is expected to exceed the supply by 400 in the immediate future. This shortage of nuclear engineers is due primarily to the retirement of the first generation of engineers engaged in the development, construction and operation of current generation of 105 nuclear power plants operating in the country. This shortage has resulted in a very tight job market for employers seeking nuclear engineers and a number of utilities are investigating programs to train non-nuclear engineers to work in the nuclear fields. With a number of U.S. utility companies establishing plans to order new nuclear power plants in the very near future, however, the demand for nuclear engineers will grow and the Nation's ability to expand nuclear electricity generating capacity may likely be limited by the trained workforce, not by the financial resources.

In addition to the urgent funding increase for the INIE program discussed above, we offer comments on various budget categories for the proposed university NSE funding:

- The NEER program, since its inception in the current form in FY98, has been a major source of research funding for the entire academic NSE community and has contributed significantly to our ability to attract quality graduate students into research programs. These research grants cover areas of basic nuclear science and engineering research and synergistically augment much more application-oriented programs funded through the Nuclear Energy Research Initiative (NERI). The NEER funding has been flat for the past five years at $5.0M, supporting only one out of every ten competitive proposals in a given year. Thus, the proposed increase of the NEER funding from $5.0M to $8.0M is very much needed, although still insufficient to fund many of the research proposals that are highly evaluated but not supported due to limited funding. The NEER grants have been and will continue to support research programs not only in nuclear science and engineering but also in related fields of health physics and radiation safety. An increased FY04 appropriation for the NEER program will be especially necessary for this purpose.
- Funds for undergraduate scholarships and graduate scholarships are essential in our effort to increase student enrollments in nuclear engineering and related programs. Although the DOE fellowship funding has been highly valuable, the funding level has remained flat for the six years and woefully inadequate. To simply illustrate the inadequacy of $1.4M fellowship support in the FY04 DOE request, we note that it requires up to $55,000 per year to support a graduate student at many research universities.
- The other academic programs for a total of $1.3M include the DOE/Industry Matching Grants, which leverage the DOE funding for broad-based support from the nuclear industry for the university NSE and URR programs. Many schools use the Matching Grants to augment the DOE fellowship funding for undergraduate scholarships and graduate student research support. The remainder of the $1.3M funding will support a modest program in radiochemistry and facilitate closer collaborations in research and instructional programs between DOE national laboratories and academic institutions. The funding will also promote community outreach effort including the training of high school teachers in nuclear science and technology.
- The remaining $4.3M funding for the URRs cover the costs for (1) supply of fresh reactor fuel and shipment of irradiated fuel, (2) refurbishment and upgrade of instrumentation primarily for URRs not included in the INIE con-

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[2] G.S. Was and W.R. Martin, Eds., "Manpower Supply and Demand in the Nuclear Industry," Nuclear Engineering Department Heads Organization (2000).

sortia, and (3) providing URR access to researchers at universities without a campus reactor.

- University research reactors provide essential support both for instructional and research programs on 26 university campuses. These campus reactors offer programs in (a) incore irradiations for materials science study, isotope production in medical and industrial applications, neutron activation analysis in manufacturing and environmental applications, and nuclear wasteform study, (b) neutron beam port applications for neutron scattering as a materials diagnostic tool, neutron radiography as a nondestructive testing tool, semiconductor processing, characterization of materials in nuclear and non-nuclear applications, and boron neutron capture therapy, (c) reactor control study involving digital instrumentation and control for advanced reactors as well as for the current generation of nuclear power plants, (d) neutron and reactor physics studies offering research in medical imaging, radiation detectors for homeland security, nuclear fuel development, and advanced reactor design and safety features. In addition, each URR serves as a magnet for recruiting students and is a focal point for community outreach.

Summary of the Request

We respectfully request that Congress provides in the FY04 budget *$26.5M for operations and research support for university research reactors and research and student support of the nuclear science and engineering departments.* This amount will fund the seven INIE regional reactor centers and strengthen academic programs in nuclear science and engineering. This funding level is required to guarantee the Nation secure energy sources for the future and enhance the scientific, medical, and industrial applications of radiation science and technology for the Nation.

BIOGRAPHY FOR JAMES F. STUBBINS

Dr. James F. Stubbins is a Professor and Head of the Nuclear, Plasma, and Radiological Engineering Department at the University of Illinois at Urbana-Champaign, Illinois (UIUC), where he has been a faculty member since 1980. His previous positions include Guest Scientist, Institute for Materials and Solid-State Research, Forschungszentrum (Research Center), Karlsruhe, Germany (1976–1977); Research Associate, Department of Metallurgy and Science of Materials, University of Oxford, Oxford, England (1977–1978); and Materials Engineer, Principal Investigator—Gas Cooled Reactor Materials Program, Energy Systems Programs Department, General Electric Co., Schenectady, NY (1978–1980).

He has extensive research and teaching experience related to issues surrounding the production, transport, and interactions of radiation with matter, irradiation damage and effects in materials, mechanical properties, high temperature corrosion, and electron microscopy.

Dr. Stubbins has enjoyed long-standing professional relationships with a number of national labs. He has maintained associations as a Faculty Appointee, Associated Western Universities (AWU) with Battelle Pacific Northwest National Laboratory, Richland, WA; a Faculty Appointee, Division of Educational Programs, Argonne National Laboratory; an Affiliate, Los Alamos National Laboratory, and a Visiting Scientist with Oak Ridge National Lab. He has a long-standing Visiting Scientist appointment in the Materials Science Department at the Riso National Laboratory, Roskilde, Denmark. He has written more than 75 technical articles and publications, and more than 40 conference proceeding.

Dr. Stubbins serves on several national boards and committees, such as Member of Department of Energy (DOE), Nuclear Engineering (NE) University Working Group, Program Reviewer DOE, and Program Advisory Committee Pacific Northwest National Lab (PNNL). He served as an ex-officio member of the Fusion Energy Scientific Advisory Committee (FESAC). He serves as chair of Materials Science and Technology Division, American Nuclear Society and is the immediate past Chair of the Fusion Energy Division, American Nuclear Society. He is also the current Chair of the Nuclear Engineering Department Heads Organization (NEDHO).

Dr. Stubbins earned his BS Degree in Nuclear Engineering at the University of Michigan, his MS degree in Nuclear Engineering and Ph.D. degree in Materials Science both from the University of Cincinnati.

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Department of Nuclear, Plasma, and Radiological Engineering

214 Nuclear Engineering Laboratory
103 South Goodwin Avenue
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10 June 2003

Congresswoman Judy Biggert
Chairwoman, Energy Subcommittee
House Committee on Science
Suite 2320 Rayburn House Office Building
Washington DC, 20515-6301

Dear Congresswoman Biggert:

This is to provide a record of financial disclosure according to the Rules of the House of Representatives for testimony at your Subcommittee's Hearing on *The Future of University Science and Engineering Programs*, June 10, 2003. My current federal funding contracts and obligations are provided in the following list:

Federal Contract Title	Period	Amount	Remarks
DE -FG07-02ID14337	6/1/02 - 5/31/05	$298,022	DOE NEER
LANL # 57384-001-02 8Y	8/26/02 - 5/31/04	$90,000	DOE Advanced Fuel Cycle Initiative
DOE PU 2406-UI-4423	9/27/02 - 9/26/07	$2,580,522	DOE INIE
DE-FG07-02ID14355	8/1/02 - 7/31/03	$58,000	DOE Industry Matching Grant
DE-FG07-01ID14164	8/20/01 - 2/19/03	$48,000	DOE Industry Matching Grant
DE-FG02-95NE38111	8/1/00 - 9/30/02	$50,000	DOE Industry Matching Grant

Please let me know if you require any further information regarding these federally funded contracts.

Sincerely yours,

James F. Stubbins
Professor and Head

Chairman BIGGERT. Thank you.

And Dr. Slaughter.

STATEMENT OF DR. DAVID M. "MIKE" SLAUGHTER, DIRECTOR, CENTER FOR EXCELLENCE IN NUCLEAR TECHNOLOGY, ENGINEERING, AND RESEARCH, CHAIR, NUCLEAR ENGINEERING PROGRAM, UNIVERSITY OF UTAH, SALT LAKE CITY

Dr. SLAUGHTER. Chairwoman Biggert, Mr. Lampson, and the other Members of the Committee, thank you for inviting me for this testimony.

We see growth and a need for different education research paradigms. During the decline over the past several decades of student enrollments in nuclear engineering and radiation science programs, many universities chose not to replace faculty who left, which has created a shortfall of qualified faculty at a time when student enrollments are increasing. In addition, infrastructure neglect has occurred during the past few decades due to a number of complex issues, which include restricted budgets, increased cost of operation, the necessary diversion of resource to meet increased regulatory demands, and faculty turnover that may have resulted in the change to program—changes to program directions.

These factors leave many colleges and universities ill-equipped to impart basic skills, interdisciplinary courses, industrial training, and relevant research needed to better serve the industrial and government sectors. Most research reactors were initially constructed for nuclear engineering and radiological science research and education. They were, and still remain, available for teaching, reactor design, core physics, nuclear safety, and radiological protection and support research in reactor physics, cross section measurements, and reactor component development.

Today's research reactors enjoy a broader academic and research mission that encompass a wide variety of disciplines: energy, medical, radiopharmaceuticals, physical science, engineering, and material sciences. As a result of these evolving and broadening missions, no one university is able to provide a comprehensive nuclear science engineering experience. And no one reactor program can provide the entire capabilities that education, research, and the industrial community demand.

Does an individual university have to own and operate a nuclear reactor to have a successful nuclear science and engineering program? Of course not. Does a university need reasonable access to such facilities? Yes, most likely, although it also depends on the institutional choices and directions, such as technical focus of an institution's departments, faculty, strategic plan, and the community needs. Are university nuclear reactors and the related highly specialized infrastructure required to maintain a vibrant nuclear research enterprise in the United States? Absolutely. While it is not known exactly how many university reactors are needed to fill the broad mission, it is clear from the demand that the current numbers may not be enough, although current numbers must suffice. One thing is certain: New research reactors will not be constructed on university campuses in the near future, in part due to the prohibitive costs associated with construction, the necessary and extensive compliance with regulatory restrictions, safety and security issues, and a general, although erroneous, negative public perception.

The most cost-effective and practical long-term strategy to maintaining the existing research reactors by strategic funding initiatives and an encouraged reactor program and university administrations to think beyond their institutional boundaries. We need to avoid duplication and share resources, when possible, with our counterparts at other educational institutions, in industry, and at government facilities.

We see research reactor education research activities expanding. Large companies and corporations that have historically maintained well-funded research and development components are now downsizing in order to better cope with competition. As an alternative to such onsite research facilities, many corporations are refreshing their links with universities that have reactor programs to help maintain an aggressive stance in technology development. Additionally, small companies without financial resources or reserves to support technology groups often seek to develop new products by teaming with universities to ensure their own competitiveness.

Reactors at universities have been successful in assisting a significant number of industrial clients in improving existing and creating new niche technologies. Most of the research reactors at universities maintain a strong and creative mix of faculty, staff, and students. Funds provided by industry heavily impact the development and movement of technologies, not to mention graduate students, who are the inventors of these technologies, into the mainstream of the industrial community.

We have seen a need for additional, stable funding from university, industry, and government. Engineering students are expensive to educate, with nuclear engineers and radiation scientists the most costly of this group. The high cost is due to the sensitive, unique, and highly regulative equipment that is required. If those greater educational costs can not be carried by state funding or by students themselves, such costs then must be covered by governmental grants and contracts with the industrial sector in resource-sharing strategies.

The health and vitality of an academic infrastructure in nuclear engineering reaches—depends on federal support, the same as any other vibrant science and engineering discipline.

While new funds must be made available that will adequately support the delivery of educational research missions, the effective administration of appropriate funds for distribution by the DOE needs equal attention. The key recommendations from the respective Corradini and Long Reports to Nuclear Energy Research Advisory Committee, NERAC, blue-ribbon panel suggests the most important role for the Department of Energy/Nuclear Energy, DOE/NE, is to assure significant numbers of nuclear science/engineering education programs and to maintain an effective research infrastructure.

Currently, the U.S. DOE has three priorities in the following order of importance, as provided: licensing issues for Yucca Mountain; transportation; and research and science. It is not clear how these DOE priorities will impact DOE/NE appropriations for nuclear education and research activities in 2003 and 2004 or in the future. The present DOE/NE administration, unfortunately, may be forced to reprogram critically important funds over to other areas of the DOE budget if significant budget cuts are undertaken. To protect, or buffer, vital program funds from reprogram, congressional appropriation bills should be well defined on disbursement and should clearly indicate what limits and justifications will be allowed for reprogramming.

The educational and research infrastructure needs to be funded at the $15 million-level recommended by the May 2000 Corradini Report to NERAC while increasing the current grant programs: Fuel Assistance, Reactor Sharing, and Instrumentation Upgrade. The current INIE program also needs to be revamped so it more closely resembles the April 2001 Long Report to NERAC, which recommended both regional research reactor consortia and regional education and training consortia.

It was presented in the Long Report, the INIE program was discussed at—as—excuse me, as was presented——

Chairman BIGGERT. Dr. Slaughter, if you could conclude. Thank you.

Dr. SLAUGHTER. It—in brief, equitable distribution of the new and existing DOE/NE funds is required for a healthy, effective, and fair delivery of federal support. Guidelines should be effectively presented at the time the solicitation is issued by the DOE, with an explanation of how funds are to be used and an outline of the reasonable performance criteria. It should be stated whether or not termination of fundings might occur if certain performance criteria are not met.

Thank you.

[The prepared statement of Dr. Slaughter follows:]

PREPARED STATEMENT OF DAVID M. SLAUGHTER

Developing New Paradigms to Improve Educational Experiences and Support Unique Infrastructure in Nuclear Engineering and Nuclear-Related Disciplines

New Paradigms

We in the academic community feel the classic and cyclic directive to: 1) generate as many graduates as possible; 2) publish the results of research in a timely manner; and 3) locate new sources of revenue through research contracts. It is mainly through Masters and Doctoral candidates that such research goals are pursued and met in the course of the students' education and their increasing proficiency. A sharp increase has occurred in student enrollments in most nuclear engineering programs (NEPs). Thus, faculty in nuclear engineering are even more highly motivated to encourage undergraduates to enroll in nuclear engineering courses and programs, and to continue to enthusiastically foster graduates in these programs. At times, it seems that typical NEP directors and faculty are struggling with the number of students we are able to graduate than uniting the quality and relevancy of their educational experience to contemporary industrial and commercial domains. We strongly believe it is time to establish better methods for resource sharing, information exchange, and general cooperation between universities and viable businesses in the nuclear engineering and radiation science industries as well as governmental agencies in the field.

During the decline over the past several decades of student enrollments in nuclear engineering and radiation science programs, many universities chose not replace faculty who left, which has created a shortfall of qualified faculty at a time when student enrollments are back on the rise. In addition, infrastructure neglect has occurred during the past few decades due to a number of complex issues, which include restricted budgets, increased costs of operation, the necessary diversion of resources to meet increased regulatory demands, and faculty turnover that may have resulted in changes to program directions. All of these factors and others combined with recent rapid technological and economic changes in nuclear engineering and radiation science leave many colleges and universities ill-equipped to impart the basic skills, interdisciplinary courses, industrial training, and modern and relevant research needed to better serve the industrial and government sectors. Universities should foster excellence and provide equal opportunity in the areas of Nuclear Engineering education, research, and public service. In order for us to succeed now and in the future, we must employ newly adopted educational paradigms that require continuous evaluation and advancement. Rigorous university reactor programs should:

- Deliver a "back-to-basics" educational program that encourages sound fundamentals, adapts new research and service strategies, and facilitates creative thinking.
- Develop performance-based and team-oriented faculty with diverse abilities and experiences, along with a credible background, who work together to deliver a broad and integrated laboratory experience with what is learned in the classroom.
- Incorporate innovative and legal budget strategies that tap into governmental, industrial, and other non-traditional sources to support educational activities and research combined with traditional federal and state funding.
- Foster an environment that provides good advising, frequent interaction, and practical and applied experiences for students that emphasize capability, mastery, self-motivation, and creativity in academic and research endeavors.
- Promote multi-tasking and multi-disciplinary experiences.

University Research Reactors (URRs) advance both research and education activities. University facilities have state-of-the-art experimental resources distributed within an appropriate educational environment, and students, especially at the graduate level, have access and opportunities for hands-on experiences using contemporary equipment. New concepts that require multiple trials are evaluated in a context where time pressures are not as competitively prohibitive, unlike research reactors available at national laboratories. Because of the university setting, activities at URRs are usually cross-disciplinary and use neutron science as a focal point. Results are most successful when faculty from several departments, educational institutions, and industry are able to input into the required experimental program outcomes, design, and implementation.

Most URRs were initially constructed for nuclear engineering and radiological science research and education. They were and still remain available for teaching reactor design, core physics, nuclear safety, and radiological protection, and support research in reactor physics, cross-section measurements, and reactor component development. Today's URRs (100 kW or higher) enjoy broad academic and research missions that encompass a wide variety of disciplines: energy, medical, radio pharmaceuticals, physical sciences, engineering, and material sciences. As a result of these evolving and broadening missions, no one university is able to provide a comprehensive nuclear science and engineering experience, and no one reactor program can provide the entire capabilities that education, research, and the industrial community demand.

Does an individual university have to own and operate a nuclear reactor to have a successful nuclear science and engineering program? Of course not. Does a university need reasonable access to such facilities? Yes, most likely, although it also depends on institutional choices and directions, such as the technical focus of a given institution's departments and faculty, strategic plan, and community needs. Are university nuclear reactors and the related highly specialized infrastructure required to maintain a vibrant nuclear research enterprise in the United States? Absolutely! While it is not known exactly how many university reactors are needed to fulfill the broad mission that these facilities serve, along with the ever-changing needs of government and industry, it is clear from demand that the current number may not be enough, although current numbers must suffice. One thing is certain: New research reactors will probably not be constructed on university campuses in the near future, in part due to prohibitive costs associated with construction, the necessary and extensive compliance with regulatory restrictions, safety and security issues and activities, and a general, although erroneous, public perception of danger that needs to be overcome because it is not warranted.

Some may cite the current low research/service activity at a few reactor facilities as proof that the United States already has an abundance of neutrons and the current levels aren't fully being utilized. As a professor of nuclear engineering and scientist, I could, in turn, argue that today's measured outcome actually represents the result of institutional, government, and industry neglect of programs. The most cost-effective and practical long-term strategy is to maintain existing URRs by strategic funding initiatives and to encourage reactor programs and university administrations to think beyond their own institutional boundaries. We need to avoid duplication and share resources whenever possible with our counterparts at other educational institutions, in industry, and at government facilities.

In present-day URR programs, faculty and students are involved in relevant technology advancement and research collaboration with industry and government to better understand practical and real-world issues. As an example, at the University of Utah's reactor program contains an NRC-licensed 100kW Modified TRIGA Mark I nuclear reactor with no operational beam ports except for vertical access through the pool. It is compact; we have limited space to conduct research. But it is versatile and well designed, containing radiochemistry, radiation detection, dosimetry, and computational capabilities. Our laboratory performs the duel function of research and education. Faculty, students, and our reactor participate with industrial and governmental agencies to solve unique challenges.

- We do not build the missiles that stand in the defense of this country, yet we test electronic components to assure they perform as designed under adverse conditions.
- We do not manufacture turbine blades, munitions, or detonators, yet we ensure their performance by developing increasingly advanced inspection techniques that use neutron, gamma, and x-ray radiography.
- We do not manufacture small remote nuclear power plants, yet we are in the process of designing a more advanced fuel that may one day be used in such a plant.
- We do not commercially dispose of radionuclides, yet we assist in understanding how radionuclides are transported through the environment (in both natural and human-engineered systems).
- We did not expose the Mayak workers who operated Russia's first weapons-grade plutonium manufacturing plant in the 1940s to radiation, yet we use dose reconstruction tools and modern techniques to better understand the long-term health impact of radiation exposure on living beings.
- We do not dig up archaeological artifacts or participate in art creation, yet we use non-destructive testing to explore where human eyes and hands cannot reach and verify the authenticity and integrity of priceless historic artifacts and artwork.

Expanding Roles for URRs

Large companies and corporations that have historically maintained well-funded and fruitful Research and Development (R&D) components are now downsizing in order to better cope with amplified competition and a bear market. The benefits of an in-house R&D are often eclipsed in a grim economic climate, and thus they tend to be a target for elimination of risk and reduced costs. As an alternative to such on-site research facilities, many corporations are refreshing their links with universities that have reactor programs to help maintain an aggressive stance in technology development. Additionally, small companies without the financial resources or reserves to support technology groups often seek to develop new products by teaming with universities to ensure their own competitiveness. In the face of their own budget cuts, universities are serendipitously capitalizing on these industry trends to diversify and strengthen their funding sources, and are turning to the private sector to participate in developing technologies that assist the private sector in boosting a community's economy.

Since universities are playing a larger role in technology development for businesses, we as educators are requiring that these businesses assist us in the education of their future employees. Potential employers seek students who have industrial experience as part of their academic program. Such experience gives the employer another way in which to measure the candidate's ability to successfully apply skills learned in the classroom and the university laboratory to the working world.

Reactors at universities have been successful in assisting a significant number of industrial clients in improving existing and creating new niche technologies. Most of the URRs at universities maintain a strong and creative mix of faculty, staff, and students. Funds provided by industry heavily impact the development and comprehensive movement of technologies-not to mention graduate students, who are the respective inventors of these technologies-into the mainstream industrial community.

Funding from University, Industry, and Government

Engineering students are expensive college students to educate, with nuclear engineers and radiation scientists the most costly of this aspiring group. The high cost is due to the sensitive, unique, and highly regulated equipment (i.e., nuclear reactors) required for use during students' educational tenure. If those greater educational costs cannot be carried by state funding or by students themselves, such costs then must be covered by both governmental grants and contracts with the industrial sector in resource-sharing strategies. Such collaboration enhances our ability to overcome the outstanding burden of educational costs, and provides internship and cooperative programs that allow students to explore and implement creative research innovations in an actual work environment. The benefits for industrial partners are that these cooperative research efforts provide relatively inexpensive access to bright minds and cutting-edge expertise in these fields and a conduit to future employees for the specific needs of their businesses. To make the most of all available resources, Nuclear Reactor programs such as ours must responsibly share resources with other academic programs in these fields as well as the industrial sector and with Federal and State governments in order to ensure the broadest and best training possible for students in nuclear engineering and radiation science.

The health and vitality of the academic infrastructure in nuclear engineering and radiation science depends on federal support, the same as any other vibrant science and engineering discipline. Historically, federal agencies have left the matter of research funding in nuclear engineering and radiation science to the Department of Energy (DOE); hence, programs like ours are discouraged from seeking funding from the National Science Foundation (NSF) or from other federal agencies. Nevertheless, the scarcity of funding available from the DOE and other beleaguered federal agencies has made it increasingly difficult for academic programs in these fields to provide and maintain top-quality professional training to students. Such training is essential for the future managers and leaders of these important and rapidly expanding technical spheres because the industrial sector requires expertly trained engineers and researchers to maintain growth, innovation, and a competitive edge regardless of economic factors and tenuous support.

The URR federal funding mechanisms that currently exist include:

- *Fuel Assistance to URRs.* These funds cover the entire fuel cycle (front and back end). It is essential for the continued uninterrupted operation of URRs (especially reactors >1 MW) that these funds remain distinct from other nuclear engineering appropriations. If these funds were merged with other programs, the possibility of their being diverted to another program would exist. Prolonged interruptions of these funds would force premature closure of selected URRs.
- *Reactor Sharing.* These funds are awarded on a peer-reviewed basis to URRs. They were originally obtained from the surplus in the fuel assistance budget (if any in a given year) and were provided to allow universities that lacked a URR to purchase services from a host URR. More recently, this program has become independent of the fuel assistance budget and a portion of the budget (35 percent of the awarded funds) now may be spent on the host university to reimburse it for real costs associated with off-campus users.
- *University Reactor Instrument Upgrade.* Funds from this program are awarded on a peer-reviewed basis to URRs. The funding was designed to allot specific funds to help maintain critical reactor safety and operations infrastructure.

Research URRs (100 kW and higher) offset their operating costs by charging users for neutrons. This revenue does not cover all operational needs. Faculty research grants typically provide little funding for reactor support. I do not advocate allowing university reactors that are currently subsidized with a combination of State, federal funds, and Nuclear Regulatory Commission (NRC) cost waivers to compete directly with their U.S. commercial counterparts. However, for areas where no U.S. commercial competitors exist for the product produced, university participation in delivering nuclear-related technologies should be allowed, and considered a community and industrial service.

While new funds must be created and made available that will adequately support the delivery of educational and research missions, the effective administration of appropriated funds for distribution by the DOE needs equal attention. The key recommendations from the respective Corradini and Long reports to the Nuclear Energy Research Advisory Committee (NERAC) blue-ribbon panel suggest that the most important role for the Department of Energy/Nuclear Energy (DOE/NE) is to assure a sufficient number of nuclear science/engineering education programs and to maintain an effective research infrastructure.

Currently, the U.S. DOE has three priorities in the following order of importance: 1) licensing issues for Yucca Mountain; 2) transportation; and 3) research and science. It is not clear how these DOE priorities will impact DOE/NE appropriations for nuclear education and research activities in 2003–2004 or in the future. No clear consensus is apparent among different DOE administrators regarding the value of nuclear R&D and the necessity and level required for funding URRs. The present DOE/NE administration unfortunately may be forced to reprogram critically important funds over to other areas of the DOE budget if significant budget cuts are undertaken. To protect or buffer vital program funds from reprogramming, congressional appropriation bills should be well defined on disbursement and should clearly indicate what limits and justifications will be allowed for reprogramming.

The educational and research infrastructure needs to be funded at the $15 million-level recommended in the May 2000 Corradini Report to NERAC while increasing the current grant programs (Fuel Assistance, Reactor Sharing and Instrument Upgrade). The current INIE program also needs to be revamped so it more closely resembles the April 2001 Long Report to NERAC, which recommended both regional research reactor consortia and regional education and training consortia.

As was presented in the Long Report, the INIE program was discussed at a DOE/NE-sponsored meeting held in Chicago, Illinois. Participants included university administrators, reactor directors, DOE/NE representatives, and others. The solicitation that was issued shortly afterward was confusing, incomplete, and contrary to recommendations contained in the Long report. In addition, the request did not reflect the understanding of university reactor directors and their administrations obtained at the Chicago meeting. The relatively short time frame to respond to the solicitation did not allow for extensive explanations and corrective actions. This inadvertentently disenfranchised a significant number of our URR constituencies. What opportunities still exist for reactors associated with those unsuccessful INIE proposals is unclear.

In brief, equitable distribution of new and existing DOE/NE funds is required for a healthy, effective, and fair delivery of federal support. Guidelines should be effectively presented at the time the solicitation is issued by the DOE, with an explanation of how funds are to be used and an outline of reasonable performance criteria. It should be stated whether or not termination of funding might occur if certain performance criteria are not met.

University administrations that do not see value in maintaining their reactor for either education and/or research should not be considered for DOE/NE financial programs. Federal funds would be better spent in support of nuclear reactor programs at institutions that perceive the education and research infrastructure as critical to the delivery of their institution's mission. For example, a stable education/research nuclear reactor (>100 kW) program should derive funding from university, industry, and government sources. Like a three-legged stool, if any one of the financial legs is eliminated, the reactor program fails to effectively serve its full purpose.

Educational facilities (such as University Research Reactors or URRs) are coming under increased scrutiny by the NRC in terms of security issues. Significant URR program funds along with general university resources are being tapped to address these new security obligations, yet limited funding has been made available from the DOE/NE to assist URRs in transition. Sufficient funds also should be provided to purchase new fuel for URRs as well as timely and appropriate removal when the fuel is spent.

In Summary

Present-day URR programs involve faculty and students in the development and advancement of relevant technology along with research collaboration with industry and government to better understand practical, real-world issues. Historically, URRs received federal assistance that shared costs associated with fuel, reactor sharing (host and receiver), and instrument upgrades. However, such funding only covers a portion of URR operating costs. Federal and State sources of funding can fluctuate dramatically depending on the economic climate and trends in agencies that sponsor research and education.

If the United States is going to remain competitive in nuclear power and nuclear-related technologies in the scientific and industrial world communities, a continued and dedicated investment nationwide in its URRs is vital. URRs need to be funded at the $15 million-level recommended in the May 2000 Corradini Report to NERAC, and current INIE programs revamped to ensure an adequate number and diversity of operational facilities nationwide. On its part, the DOE can assist most by showing continuous support of priorities that are in alignment with and fulfill the intentions of congressional appropriations bills by how equitably allocations are delivered.

BIOGRAPHY FOR DAVID M. SLAUGHTER

Dr. David M. Slaughter is currently the director of the Center for Excellence in Nuclear Technology, Engineering, & Research (the "CENTER") at the University of Utah in Salt Lake City, Utah, and has been the director of the CENTER for the past 10 years. He is the Reactor Administrator of the University's 100 kW TRIGA Nuclear Reactor and holds a Senior Reactor Operator's license. Dr. Slaughter chairs the Nuclear Engineering Program and is the graduate advisor. He holds faculty appointments in three departments within the College of Engineering: Civil and Environmental Engineering, Mechanical Engineering, and Chemical and Fuels Engineering. For three years, he led the Environmental Radiation Toxicology Laboratory at the University of Utah School of Medicine as its director. Dr. Slaughter has extensive experience in nuclear engineering, radioenvironmental sciences, radioassays, radiotoxicology, chemical engineering and radiation and materials interactions, and is familiar with environmental monitoring, dose reconstruction, and nuclear forensics techniques and analyses. He has participated in regulatory matters with the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), and the Occupational Safety and Health Administration (OSHA). Dr. Slaughter has either been the Principal Investigator or a Co-PI for over 50 contracts for government-sponsored research, has published over 20 journal articles, presented 30 technical papers at conferences, and authored 35 technical reports. He has supervised more than 15 Ph.D. and Masters graduate students, and has had more than 15 undergraduates perform research projects under his direction. He has been an enthusiastic and rigorous supervisory committee member for 25 students in a variety of engineering and science disciplines. Dr. Slaughter received his Ph.D. in Chemical Engineering from the University of Utah in December 1986.

A selected list of recent publications is appended to this short biography.

Selected Recent Journals Publications/Presentations:

Choe, Dong-Ok, Brenda N. Shelkey, Justin L. Wilde, Heidi A. Walk, and David M. Slaughter, "Calculated Organ Doses for Mayak production Association Central Hall Using ICRP and MCNP," *Health Physics Journal,* Vol. 84, No. 3, March 2003.

Slaughter, David M., Dong-Ok Choe, Melinda P. Krahenbuhl, Scott C. Miller, Evgenii Vasilenko, Michail Gorelov, "Reconstruction of Individual External Exposure Doses to the Mayak Production Association Workers: External Doses 2000," Submitted to *Health Physics Journal,* 2003.

Krahenbuhl M.P., Slaughter D.M., Wilde Bess J.D., Miller S.C., Khokhryakov V.F., Suslova K.G., Vostrotin V.V., Romonov S.A., Menshikh Z.S., Kudryavtseva T.I., "The historical and current application of the FIB–1 model to assess organ dose," *Health Physics* 82(4):445–454, 2002.

Choe, D.O., B.N. Shelkey, D.M. Slaughter, "An Investigation Comparing the Criticality of Stored DOE Waste Using MCNP with Previously Published Results Obtained with KENO," HPS Joint Midyear meeting, Anaheim, CA, Feb. 2001

Khokhryakov V.F., Suslova K.G., Aladova E.E., Vasilenko E., Miller S.C., Slaughter D.M., Krahenbuhl M.P., "Development of an Improved Dosimetry System for the Workers at the Mayak Production Association," *Health Physics,* Vol. 79, No. 1, 2000.

Choe, D.O., D.M. Slaughter, and K.D. Weaver, "Utilizing Distinct Neutron Spectra and a System of Equations to Differentiate Competing Reactions in Activation Analysis," *Journal of Radioanalytical and Nuclear Chemistry,* Volume 244, No. 3, 2000.

Krahenbuhl M.P., Wilde J.L., Slaughter D.M., "Using Plutonium Excretion Data to Predict Dose from Chronic and Acute Exposures," *Rad. Prot. Dos.,* Vol. 87, No. 3, 2000, 179–185.

Alexandrova O.N., E.K. Vasilenko, M.P. Krahenbuhl, D.M. Slaughter, "The Statistical Analysis of Occupational Radiation Dose Caused by Professional Exposure to External Gamma Radiation," International Data Analysis Conference, Innsbruck, Austria, Sept. 2000.

Choe, D.O., M.P. Krahenbuhl, and D.M. Slaughter, "Dose Reconstruction from Pu Exposure Using Fission Track Analysis (FTA) with Two Neutron Energy Spectra," Workshop on Standards, Intercomparison and Performance Evaluations of Low-Level Radionuclides by Mass Spectrometry and Atom Counting. Gaitherburg, Maryland, 1999.

Krahenbuhl M.P., and D.M. Slaughter, "Improving Process Methodology for Measuring Plutonium Burden in Human Urine Using Fission Track Analysis," *Journal of Radioanalytical and Nuclear Chemistry,* Volume 230, No. 1–2, 1998.

DISCUSSION

Chairman BIGGERT. Thank you, Dr. Slaughter. You can all rest assured that all of your written testimony will be included in the record. And so—and we will probably get to a lot of it in the question period, which is now.

We will now have—the Members of the Committee will have time to ask their questions within a five-minute period, also, so we have to adhere to that time. So I now recognize myself for five minutes.

And this is a question for the panel. Both Dr. Marcus and Dr. Kammen, in their testimony, stress the importance of cutting-edge research as a tool to drive the best of talent to the field of nuclear engineering. But Dr. Kammen points out that while most university programs are good, they are not truly innovative and do not attract the best students. So does the government have its priorities wrong? Should the government shift more of its resources into university research programs, like NERI or—and that has been cut in half by—the funding has been cut in half in the DOE's request for fiscal year 2004 instead of subsidizing the regulatory permitting process for nuclear plants? Would anyone like to start on that question?

Dr. Marcus.

Dr. MARCUS. Let me start by saying I think both tailored funding for university programs and funding for universities through R&D programs are needed. As I mentioned in my testimony, we hope to increase the funding through the latter mechanism.

While the NERI program may be reduced over prior year appropriation, what we see ahead are some larger programs arising out of the Generation IV activities. As such, I anticipate there would be a substantial amount of R&D funding and a substantial amount applied to universities.

Chairman BIGGERT. Thank you.

Dr. Kammen.

Dr. KAMMEN. I just wanted to clarify one of the points that you started with, but I agree with your—with the sentiment. And that was that I—what I did not mean to say was that the programs we have are not sufficiently innovative. I believe in the—many of the traditional areas, neutronics, heat transfer, they are doing a very impressive job. But in thinking about the longer-term future of the programs, that is where I see the disconnection between where we are training students and where we need to think about very different potential plants down the line.

So that is just the—let me just say one thing with the funding levels, and I would agree with Dr. Marcus on the need for some increased direct university support. In my testimony, I provided a graph that showed funding—federal funding levels in the United States, Japan, the UK. And it is dramatic that the United States, with the—this very large nuclear fleet, has a very low federal funding level relative to Japan, certainly, which actually has a nuclear energy R&D budget larger than, essentially, our entire energy

R&D budget. I would argue that, in fact, if you look at the importance of energy to national affairs, that increasing that number overall is one of the best things we could do.

But the other feature of it is that if you look at the amount of collaborative work between nuclear engineering companies and federal support programs, often at universities, what we have seen in many fields of energy work is an increase in these collaborative programs, linking, for example, the National Energy Lab with a number of private companies. And we have not seen that same level of increase of collaborative R&D, and I measured that in the testimony in terms of patents, in the nuclear area for a variety of reasons. So I would say it is not just a question of increased federal funding, which is the easy answer on some level, but that it is finding those ways to induce more industry money to support these programs that are now stressed.

Chairman BIGGERT. Ms. Howard.

Ms. HOWARD. Yes, if I may, please. To address and to pick up on what Dr. Kammen has said, as well as to your question on funding for R&D or funding for new plants, I think it is very important that we do have an infrastructure that will support a new generation of nuclear energy from the standpoint of providing energy to a direct generation of hydrogen or for the continuing non-emitting source of electricity production. And in order to do some of that, and also then to stimulate some of the collaborative research that Dr. Kammen has suggested, I think that it is an appropriate role for the initial few new nuclear units to come on line for government to provide some type of loan or loan guarantee, that would be repaid, perhaps from a loan guarantee standpoint, not even needing to be involving any federal funds, to start the program over again. And I think that is just one of the issues that, in fact, will be debated this afternoon in the Senate chambers on the energy bill.

So it is necessary as we re-look at a new generation of nuclear units to supply our vital energy for our economy going forward that we stimulate that. That, in turn, will stimulate the industry to move forward, make those necessary investments, and work through the universities and collaborative research through the Electric Power Research Institute and others to provide the overall type of environment that would encourage new students to come into the program as well.

Chairman BIGGERT. Well, I see that my time is up, so I will hopefully have an opportunity to come back to it.

And with that, I would recognize the Ranking Member, Mr. Lampson, for five minutes.

Mr. LAMPSON. Thank you, Madam Chairwoman.

Let me start with a question that my daughters would probably want me to ask first, both of whom are graduates of Texas A&M University. And I will ask it of Dr. Kammen. You cited that Texas A&M was a notable exception to the nationwide trend of declining nuclear engineering programs. How and why was the program at A&M in Texas able to expand so rapidly at a time when other nuclear programs were shrinking?

Dr. KAMMEN. I—that is, I believe, the first graph in my written testimony. And I watched the program at A&M with, sort of, delight, because I really thought that they took on this issue in the right way. The issues of declining enrollment, in my opinion, are not things to be met through programs designed to support more enrollment through just simply applying more funds.

In my opinion, you would get increased enrollment by having exciting programs. And what A&M did was to focus on the traditional areas but also look very hard at hydrogen, which is interesting to many students across the board: those who plan to go into nuclear engineering and those who want a very, very solid technical basis to think about new—hydrogen that might come from biological production, from wind, from solar. And I really think that that is the right approach. You do not guarantee a place of a certain number of spots, but you make the program cutting-edge and innovative. And I think that A&M did a dramatically quick, as you pointed out, job of getting on the map by saying, “We are going to take on a broader mission in nuclear engineering.” So that is how I think they did it so quickly.

Mr. LAMPSON. Is this being recognized by other universities, and are they trying to emulate it? Are they trying to do things that are going to attract the students in?

Dr. KAMMEN. Well, I think that we should also have Dr. Stubbins talk about it. But my view on this one is that A&M is—went from, essentially, off of the charts to certainly one of the programs knocking at the door to be in the top five with Berkeley, MIT, Wisconsin, Michigan, etcetera. So I think that they were able to make that jump very quickly by specifically taking on that exciting mandate.

Mr. LAMPSON. A comment, Dr. Stubbins?

Dr. STUBBINS. Yes, let me make a couple comments. I would agree that Texas A&M has been very proactive in developing programs. I am not sure how much of it is related to hydrogen. I think, in fact, they have spent a lot of money attracting students to the nuclear industry, in general, for a wide variety of things. My program, as another example where we have broadened our focus from nuclear power to other areas, as the title of my department indicates, we are a nuclear, plasma, and radiological engineering program. And many departments have done this, have broadened themselves in a very wide way to cover many of the basic areas that nuclear processes, nuclear reactions, and radiation can contribute substantially to.

I would also agree that there are many things in the cutting edge that most university programs are involved with, but this national vision of an energy policy and something in the future, I think, is an important attraction to students. Many of the most attractive things that students look at have, in the past 10 years, been small technology related things. If we are going to build a new series of reactors, public and government-based, those kinds of things are something that one person can contribute to substantially but cannot influence the overall outcome. So the government needs to support those kinds of activities, and this will attract students back in——

Mr. LAMPSON. Well——

Dr. STUBBINS [continuing]. To keep us at the cutting edge.

Mr. LAMPSON. To some extent—I wanted to make a comment earlier about the students who are here. I am not proud just to see you here because you are involved with studies in this particular.

I am proud to see that you draw a connection between the studies that you are involved with and government and learn to play a role in it and be active in what is happening within our government, because the—whether it is the policy that we are making or whether it is the regulation that is going to be—that will be effecting you or encouraging programs and projects.

But I remember once that Norman Vincent Peale said once that "if you want to know what we will look like in 20 years, tell me what we are thinking today." What are we doing, as a nation, to educate the public about the safety of nuclear reactors? I mean, if we do not get support from the public of this country, if there are not people that are—if we are going to get—to quit carrying the signs around and protesting doing this, then we are not going to win the support to make the programs that you are talking about happen. So what are we doing? And I would like for at least Dr. Marcus and Dr. Kammen to comment on that. And I have got to be quiet, because time is almost up.

Dr. MARCUS. Angie Howard might be the best person to answer this question in detail.

Mr. LAMPSON. Well, please.

Dr. MARCUS First, though, let me say briefly that my understanding is that the public is largely in favor of nuclear power and growing more favorable toward nuclear power. I think that recent events and growing concerns about global warming have contributed to that trend. But NEI operates specific programs to educate the public, so let me turn to Ms. Howard to respond to this.

Ms. HOWARD. Thank you, Dr. Marcus.

The public, from a public opinion polling standpoint, does support future nuclear, supports new nuclear——

Mr. LAMPSON. To what extent?

Ms. HOWARD. The neighborhood of 65 percent will support new nuclear being—nuclear being continued to be used for our future energy sources, as one of the future energy sources. And when they learned that 20 percent of our nation's electricity is generated by nuclear without emitting greenhouse gases or other controlled pollutants, that support goes up into the neighborhood of 70 to 75 percent.

What we have is a perception gap, though. When you ask them what their neighbors think, they think it is probably about 25 percent support nuclear. The same thing when we have polled some Members of Congress or their staff. It is sort of the same type of thing. I think what you find is that our public and our country do not support new industrial facilities being built in their neighborhoods. And that is where you get a dichotomy of between what do I support from a policy standpoint and what do I want that is generated in my backyard.

But we are trying to do a lot of public education work, both from a standpoint of media interactions, advertising, and web-based activities. We are also looking to work in our schools, both for the K through 12, particularly the secondary education activities, to encourage students to go into science and technology and also then to be able to attract it to these technical degrees. Because from an infrastructure standpoint, not just a nuclear energy standpoint but an overall infrastructure standpoint, we need students coming into these disciplines. But from a public communication standpoint, the industry is working hard to try to get those messages out.

Mr. LAMPSON. Maybe we can hear more of that when it comes back around.

Chairman BIGGERT. This is a quick follow-up. Dr. Marcus, what is DOE doing to broaden the programs, such has been suggested at the University of Illinois and Texas A&M that Dr. Stubbins and Dr. Kammen talked about?

Dr. MARCUS. Thank you for letting me comment, because I had wanted to get back to that.

We are broadening our programs in a number of ways, but particularly by collaborations among different groups. Probably almost all of our programs now are encouraging more than one organization to be involved. That alone broadens perspective and brings in other viewpoints. For instance, the INIE program includes collaborations with national laboratories and industrial research organizations. A majority of the grants under the NERI program involve collaborators from multiple organizations, often teaming universities, national laboratories, and industrial research organizations. You can go right down the line on all of our programs. We are trying to broaden our activities rather than narrow them, so I think we are moving very much in the direction that the other witnesses have mentioned.

Chairman BIGGERT. Thank you. And now our physicist of the panel and former nuclear physicist teacher has been waiting patiently, so I would yield five minutes to the gentleman from Michigan, Dr. Ehlers.

Mr. EHLERS. Thank you, Madam Chairwoman. And I would love to ask some physics questions, but I will not. I will talk to the panel about that later.

But I do want to point out, first of all, I thank the—thank you for holding this hearing. It is a very important issue. I have been fighting for years to maintain the funding for the nuclear reactor at the University of Michigan, without a great deal of success, frankly. There is just not a lot of public support.

But we have to continue the education efforts for the reasons you outlined in your opening statement, and one additional one, and that is, most of the world is using much more nuclear energy. We have a great opportunity for a major export business here, but if we are not training the nuclear engineers, we are going to say goodbye to all of the opportunities for export industry in nuclear power. So that is yet another reason to do this.

The nuclear power has fallen on bad times, and there are a lot of reasons for that. I think it will come back for reasons I do not want to use up my time on. But one major factor I will mention is the price and the cost of fossil fuel energy is going to go up dramatically. I just received last Friday notification from my gas company as to what my gas bill is going to be next year, what we pay on a monthly basis: 22 percent increase. Now I understand why, because we are—there are a lot of reasons, but a big one is that we are using a lot of the natural gas for—to produce electricity, which I think is horrible.

Natural gas is, simply, too good to burn. It is a beautiful feed stock for the petrochemical industry. It is great for home heating, and so forth, and nuclear energy would do the job much better.

My question is specifically to Dr. Marcus. You talked about the efforts DOE has been making to involve nuclear engineering departments throughout the country and the regional university research reactor consortia. And then you also expressed concern about the closing of two university research reactors at Cornell and Michigan. If DOE is supporting this regionalization effort, does it imply that you believe a smaller number of reactors would suffice? And why is the DOE concerned? Did you mention those two reactors for a reason? What role do you see the reactors playing in the educational programs? And are you advocating just regionalizing this or are you advocating that those departments that are strong, we make certain that they continue to be strong?

Dr. MARCUS. Let me respond to your questions with a couple of points. I mentioned Cornell and the University of Michigan because they are two very large reactors that are closed or are about to close. Cornell just closed last year, I believe, and University of Michigan will close next month. So they are the most recent closures. They occurred just when we saw the enrollments increasing. We saw the interest turning up, and we truly thought that the time was no longer right for closures. That is the reason I mentioned those two reactors.

We do see the INIE program promoting regional groupings of reactors. We do not at all see them, if I understand your question, as necessarily leading to closures of facilities that are now not in the INIE program. First, reactors at unaffiliated universities are not necessarily at risk. In addition, the existing consortia may well incorporate some of the unaffiliated programs in the future.

Mr. EHLERS. Let me ask the university personnel here. How important is it to maintain a reactor in the university campuses where you have nuclear engineering programs, for two reasons: one, for research; and secondly, for training of students? Do you believe that it is essential or it is something you can get along without?

Dr. Kammen.

Dr. KAMMEN. Well, certainly at—Berkeley is in an unusual spot, because we also have a strong fusion program that is linked with the national labs. And students pick and choose between the programs based on some of those features. There is no question, though, that in terms of the—some of the staffing levels that Ms. Howard talked about with the support issues, that having access to a facility is critical.

So I am not as clear that having it on campus is the thing as long as there is a very strong relationship to get students placed, because there is certainly no substitute for actual reactor time. We bring our students from Nuclear Engineering at Berkeley down to Diablo Canyon where we do a very intensive course where they do a series of scram drills. They do a whole variety of real management issues. They go back to the classroom and they do more on the theory of heat transfer and neutronics, and they go back down again to Diablo Canyon.

So there are a variety of ways you can do that, but there is no question that access to real facilities much more so than, say, the book-based and a lot of remote stuff is very critical to supporting that long-term.

Mr. EHLERS. Dr. Stubbins and then Dr. Slaughter.

Dr. STUBBINS. No, I would agree that they are critical for programs. I think some of the growth, including the ones at Texas A&M, where there are two actual research reactors, have been critical in reestablishing the undergraduate enrollments. This is an exciting area for undergraduate students. We lost our reactor three or four years ago, and I think this has impeded our growth of undergraduate enrollment. We do not see it as the critical thing to keep the department alive, but access certainly is important. And we are one of the INIE participants. We are one of the group in the big ten consortium, so we do have access, and this has provided us an avenue that we did not have a year ago.

Mr. EHLERS. Dr. Slaughter.

Dr. SLAUGHTER. Well, I think the—having reactors on campuses and involving the research is extremely important. It does give the—their hands-on experience where they are not going to be able to get it from the book. There is also an ability for multi-disciplinary type of operations in a time-reflective way in educational institutions that are not really there at national labs where you can take time on national lab reactors. I think universities provide that unique opportunity.

But I also caution that university reactors can only survive at a university if, in fact, you have full support of their academic administrations. That is extremely key, because then you will find those administrative—those reactor facilities fighting their own administration. So I think one of the things we have to also do is not only fund university reactors, but we also have to make sure that university administrations are friendly to these type of experimental facilities. But I see them extremely important, and they really are urgent and needed for educational and research.

Mr. EHLERS. I see my time has evaporated, and I yield back.

Chairman BIGGERT. Thank you.

We will next have as our participant is Dr. Bartlett from Maryland, who is also in this field. He is a physiologist and an inventor, so I know he knows a lot about innovation. So Dr. Bartlett is recognized for five minutes.

Mr. BARTLETT. Thank you very much.

Several of you have mentioned the need for increased federal dollars. There are some things that only the Federal Government can support, and we need to be supporting those things. But many other activities, including yours, might be better supported by the private sector.

I would just like to note that there is no such thing as the "federal dollar." Every dollar we spend either comes from the paycheck of some hardworking American or increasingly we are borrowing it from our children and our grandchildren. In a very real sense, you can not tax a business, because that simply becomes a—part of the cost of doing business, and they pass that cost on to their consumers. So in reality, either we pay for it, as working Americans, or we pass that debt on, for which I am very sorry, to our children and our grandchildren. So I think that we might all be better off if we left more of the money in the private sector so that you could then get the money directly from the people in the private sector, rather than through a government, which can be very arbitrary and capricious. And you should not have to come on bended knee to get your money from the government.

I am concerned, for two reasons, with the decrease in enrollment and funding in our nuclear programs. One is that basic research, obviously, is hurt. I do not have the foggiest idea what societal payoffs for basic research may be in the future, but I do know that history tells us that whenever we have had adequate basic research that there have been societal payoffs and that I am sure that that will be true in the future. So I have no idea of what societal benefits we will not have, because we do not have adequate support of basic research today.

But I am also very concerned because of the engineering decrease. As you know, we have only two percent of the known reserves of oil in the world. We use 25 percent of the world's oil. We import 57 percent of what we use. In the last Congress, I had the privilege of chairing this subcommittee, and one of the first things we wanted to do is to determine the dimensions to the problems. We held hearings on the availability of oil. General agreement across the spectrum, roughly 1,000 gigabarrels of known reserves. Now we will find more, but we shall also like to use more, and we will be lucky, I think, if the more we would like to use is matched by the more we find.

So all you need to do is to divide roughly 80 million barrels a day, 20 for us, 60 for all of the rest of the world. One person out of 22 uses 25 percent of all of the world's oil. Divide that 80 million barrels a day into 1,000 gigabarrels. That is one trillion barrels. You come up with about 40 years of known reserves. Now we will find more, but we would sure like to use more, and I think that the more we would like to use, it will probably exceed the more that we are going to find.

Who do you think ought to have the responsibility of looking down the road? Very difficult for government to do that. We—it is hard for us to see beyond our next election. It is very tough for industry to do that. They have great difficulty seeing beyond the next quota report or the next Board of Directors meeting. Who needs to be looking down the road?

Today—as you drive tonight, as you have mentioned, every fifth house and every fifth business would be dark if it were not for nuclear. And since our fossil fuels are not inexhaustible, who, in your judgment, should be looking down the road and making the kind of decisions that we need to make today so that we are not going to come to grief tomorrow?

Dr. Kammen.

Dr. KAMMEN. Well, I have to admit, I love the question, because the calculation that you have preceded is exactly what our energy society course for beginning grad students aims to get the students to work on it. That is the perspective that I am pleased to hear.

In my view, and I have worked on a range of energy technologies and policy at the federal and national level, the critical mechanism that, I think, echoes what you are saying is we need to make the process of using energy wisely and innovating to find new energy supplies in the best interest of business. I—we need to align the best interest

—the interest of business with our—of our society. And right now, I would argue that our fossil fuel policy is one that has the interest of business misaligned with that of civilians, meaning that we are interested in low-cost energy now but none of the long-term planning that you have described.

There are a variety of mechanisms, however, that can be used to help industry align those interests more along the national directions that you are mentioning. I mentioned briefly in my comments mechanism for carbon trading. If we truly value the environment and we truly believe in global warming, as does now the majority of scientists agree, mechanisms to allow businesses to profit from making these wise energy decisions make sense. Carbon trading would be one way to do that, as would be renewables portfolio standards, as would be a variety of mechanisms to allow us to use our fossil fuels more wisely. I am a great fan of fossil fuels, but I also agree with Congressman Ehlers that they are too valuable to burn in applications where we have other technologies.

Those are the sorts of things that we could do to make that sort of alignment one where businesses saw the types of policies that you described in their best interest. And right now, I believe we are sending mixed signals, at best, to companies as to how to make those decisions.

Mr. BARTLETT. Thank you very much. And I hope we will have a second round that we can come back for further discussion. Thank you.

Chairman BIGGERT. Thank you.

Mr. Bonner from Alabama.

Mr. BONNER. Thank you, Madam Chair. I am one of 54 new Members of Congress, and yet I worked on the Hill for 18 years. And so I come to this seat predisposed to being a supporter of nuclear energy.

But Ms. Howard, I would like to ask you a question specifically, because I have also had an opportunity, during my years as a Chief of Staff to my predecessor, to travel on two NEI trips to Yucca Mountain and to see what the industry is doing to take the lead in the development of Yucca. My question, though, is based on the figures in your testimony, if the nuclear energy industry sold 780 billion kilowatt hours last year, and assuming the very conservative estimate of two cents of revenue per kilowatt hour, the industry, as a whole, has earned over $15 billion in revenue. But the industry's share funding for education in this area has amounted to just $19 million since 1980, a tenth of a percent of revenue in the year 2002 alone. So expressing my strong advocacy for nuclear energy, but coming from an area where fiscal conservatism is something that we practice as well as preach, I would wonder is the industry contributing its fair share to nuclear education?

Ms. HOWARD. Thank you for your question, and I was not trying to be comprehensive in the testimony. I was giving one example of a concerted effort on some fellowships. The industry itself is doing quite a bit more across the board on—by individuals. Many companies and Southern Nuclear in your service territory is a prime example of a tremendous presence on campus, internship programs that they sponsor, like many of our companies do, as well as a strong advocacy program for the university programs. Auburn University gets a tremendous amount of resource from that particular company as well. So there is a broad base there and as well as the suppliers.

I think where our gross revenue is an important measure, it is not the measure, though, that is currently the measure of industry performance, and particularly utility performance. And unfortunately, that is earnings per share. And if we look at some of those earnings per shares from a down market over the last few years, the industry has had some significant financial impact across the board. But if we can have government policies to address the other question that encourage the longer-term investment and capital infrastructure, then I think you will see the industry stepping up to the plate for new nuclear, for new clean coal technologies, and other long-term, energy-intensive, and capital-intensive activities.

Mr. BONNER. Would you care to propose a ratio of federal support to that of industry?

Ms. HOWARD. I would be glad to give some thought to that and respond back to you, certainly. Yes.

Mr. BONNER. Madam Chair, if I could ask one final question, and this is for the entire panel. I think the Administration deserves great credit for pushing forward with Yucca Mountain. And I think the actions of Congress in recent months certainly send a positive signal. But in the event this facility is blocked by some court or some other proceeding, what is plan B? What would plan B be if you looked into your proverbial crystal balls and came up with an alternative, given the discussions that we have had today?

And that is open to any of the academics or others.

Dr. STUBBINS. Let me start. I am not sure there is an easy alternative, but there are—there is a major initiative underway to look at alternate fuel cycles and ways of burning fuels, burning waste in innovative ways that would reduce the waste burden. This is, of course, something looking into the future, but if there has to be a plan B, maybe it is something that we could do retrospectively. And there is a lot of activity nationally, internationally in this area. The U.S. is not the only problem—the only country with waste issues—nuclear waste issues. So there is a lot of innovative thinking about how to take care of nuclear waste and reduce its burden overall, which could be applied to existing waste.

Mr. BONNER. Madam Chair, thank you.

Chairman BIGGERT. Thank you.

I am just listening to the bells to see if we are going to have a vote. All right. We are not.

A number of you—I think we will begin a second round. If we can move quickly and answer quickly, then we will be in good shape.

A number of you testified to the fact that existing university research reactors remain underutilized. And will programs like INIE maximize utilization of these reactors, or will more reactors need to shut down to maximize the use of those that remain? Dr. Slaughter, could you give us an insight on that?

Dr. SLAUGHTER. I—actually, I am concerned. The fact is that when people indicate that there is an under-utilization—and part of the reason for, I believe, under-utilization is that for the last two decades, we have been in a survival mode, and we have lost a considerable amount of faculty, students—or faculty and staff on this. And it is—goes back to the idea of being creative. Think of yourselves, for example. I use this as if you were doing your job completely without your staffs. The multitasking that you do, and now have budget cuts go across the line in a heavily regulated environment and see how well utilized you are in the completion of tasks.

Unfortunately, what we need to see actually is not a reduction in reactors, but an increase in creative people utilizing them. That means we are going to see an increase in faculty. That means we are going to see an increase of technical staff. And then I believe you will see a surge in new creative ideas that, in fact, will deliver the B part of that, aspects of "if we can not get Yucca Mountain." Or we will have, certainly, other solutions and, more importantly, new technologies in the other areas in which these reactors perform.

Thank you.

Chairman BIGGERT. I think you have given us a great visual picture of—comparing our staff and—thank you for that. We will remember that.

Dr. Stubbins.

Dr. STUBBINS. Yes, let me say a word about this, which I think impacts on some of the issues that Mr. Bartlett and Mr. Bonner raised. I think there does need to be a national focus on these things. One of the major difficulties that we, as universities, have is that a lot of the decisions are made based on local pressures. There is an effort, but I think a small relative effort to look at a national picture when we decide whether this reactor should close or whether this program should go away. These are done based on pressures that have to do with where the other university—local university issues have to apply resources.

And so I think having a national view—and I would include what NEI has done in terms of giving a national focus to the nuclear utilities, and certainly what DOE has done through the INIE program and many other programs to provide a better connected national infrastructure to look at the future of nuclear engineering, nuclear reactors has been a very critical thing to keep our universities focused on the bigger picture.

Chairman BIGGERT. Thank you.

Anyone else? Dr. Marcus.

Dr. MARCUS. I would just agree with both Dr. Slaughter and Dr. Stubbins.

I see a number of trends coming together that will, I think, improve the utilization of the reactors. The INIE program is one. I think the anticipated increased research programs are another. A good fraction of funding in those programs will be directed to the universities and will involve the university faculty, students, and facilities. While I can not predict what every university administration will do—as Dr. Stubbins said, there is still a problem at some schools—I see a lot of promising activities underway today to address the issue.

Chairman BIGGERT. Just another one quick question for Dr. Stubbins. In your testimony, it was unfortunately kind of a gloomy scenario for university nuclear engineering in Illinois, and it is—nuclear is so important, to what extent do you think that Illinois companies might partner with the state programs like yours to a greater degree?

Dr. STUBBINS. Well, we have been getting support from Exelon, which is the big nuclear utility in Illinois. And also on—nationally, the Argon National Lab is there, and we have had a tremendous amount of interaction over the years, both ways, including supplying people for Argon and for Exelon. So I think there is a strong sentiment for supporting the program at Illinois. I think it is difficult for these external forces to put enough pressure locally on my university administration, to me.

Chairman BIGGERT. Well, assuming that Congress was able to fund the university nuclear science and engineering programs at the levels recommended here today, would that be enough to sustain the Illinois program or are there other pressures that——

Dr. STUBBINS. There are still other pressures. The University of Illinois programs have been growing—expanding. The number of students are up. The research support is up. We lost our reactor, but we are now part of one of the INIE programs. We are a major partner in one of the INIE programs, and this has been very supportive. So I, quite honestly, do not understand the point of view of my administration vis-á-vis the current positive trends in the industry in our local situation.

Chairman BIGGERT. Thank you.

Mr. Lampson, you are recognized for five minutes.

Mr. LAMPSON. Thank you.

I think it is important to note in my own mind a comment that we heard a few minutes back that—about putting private money in. Obviously we want private dollars involved in all aspects of our lives, but I have always been taught that community does what we, as individuals, can not do. And so I hope that the government would continue to look for ways to fund programs like this and make them happy, because if individuals either will not or cannot, and it appears to be, for the collective good of all of us, to me, that is what our government is all about. And I do not mind spending money when it is well spent in those regards.

I was also considering the cost of—when we were talking about a couple cents per kilowatt-hour, the cost of generating electricity from fission-generated—from fission generation. In relation to other fuels, can you give me some comments? And Dr. Kammen particularly, on page six of your testimony, there is one paragraph that was somewhat confusing to me where you talk about electricity being at two cents per kilowatt-hour, but then you go down and say that the Nuclear Energy Institute lists power cost at 3.8 to 4.8. The Rocky Mountain Institute cites cost of eight to 12 cents per kilowatt-hour. And also throw in some kind of a comment about the cost of protecting, not just this, but also access to fossil fuels.

Dr. KAMMEN. Well, I apologize that the paragraph was confusing. This may mean that I did not do my academic job as clearly as I should have. What I tried to raise in that paragraph, in contrasting the cost figures presented by the Nuclear Energy Institute and by the Rocky Mountain Institute, an anti-nuclear organization, I mean let us be clear on who is what, is that the cost of nuclear power, in my opinion, is much more determined by ideology than it is by straight financial energy economics that I would practice in my course.

I do not say that—what I mean by that is that the things that you include in the cost are taken very differently by different sectors of the community. If Yucca Mountain, for example, is not put in the cost, which is a valid calculation, then you get the numbers that NEI listed. But as we heard before from Congressman Ehlers, those monies that come from the Federal Government come from somewhere. If you include the cost of Yucca Mountain, and critically, for example, in California, the very large bailout for some unfortunate nuclear investments that were made in California previously, then you get these much higher numbers.

So while everyone can claim that their number—2 cents, 2.13 cents is the generating cost, not necessarily the sales cost, but the generating cost for nuclear, that is a valid statement. But you can also get people to tell you a very different one. And in my opinion, all of this leads back to your question in the first round, and that is: what is the perception of nuclear power? Where your ideology is dictates which of these economics that you choose to highlight. And I guess I am much less optimistic than Ms. Howard is about the public perception of nuclear power. I believe that the public gets used to things. And I am an author of a book on risks where I document some of this. But the public gets used to things. And we get used to 20 percent of our power from nuclear. Those plants have not had a major accident recently, therefore that is taken as part of our given.

But talking about expanding those facilities, either increasing the power at those plants or new plants, I believe that the public perception, certainly in my State of California, which admittedly is far from Washington right now, shall we say, certainly indicates that new construction is not likely to be part of what would be—would prove concerning my part of the country. So the answer to your question, which I hope is not too roundabout, is that I really do not think that the—you are not going to get agreement on the cost of these technologies. But what you will get, I believe, is an opportunity to more fully integrate nuclear into the overall energy planning.

If we really did sit down and have this national nuclear energy policy debate where we looked at what the cost of fuel production—of energy production at the—I mean, right—immediate production, plus the life cycle cost across clean coal, oil, gas, nuclear, solar, wind, biomass, then I think we could get to what you are getting at, and that is we could discover where those dollars are going to spend. But right now, the energy debate is largely disparate arguments from the different technology sectors. So that is my concern in answering your question.

Ms. HOWARD. May I make just one clarification?

Mr. LAMPSON. Go ahead.

Ms. HOWARD. The cost for Yucca Mountain is contributed—the utilities through the cost of nuclear energy at a kilowatt hour or generation, and so roughly $700 million a year are going into the Federal Government through the nuclear waste fund. There is roughly now close to $20 billion in that fund, about seven of which have been spent on Yucca Mountain. So I would like to point out that that is a part of the operating and maintenance cost of the existing nuclear fleet today. And so the money has been contributed. It is—we hope will be—the waste fund will be addressed as we go forward so the corporates of that waste fund can be spent on Yucca Mountain as the intent was when the electricity customers paid that in through their rates.

Mr. LAMPSON. I want to thank the panel and the Chairwoman for an interesting hearing.

Chairman BIGGERT. Thank you.

Dr. Bartlett of Maryland is recognized for five minutes.

Mr. BARTLETT. Thank you very much.

I would just like to note that maybe one of the reasons the private sector does not have more money to help you is because we take too much from them. You know, we do not—the town dollars when they come into our Congress. As a matter of fact, we shrink them, because we have got a big bureaucracy that has to be fed down here.

The nuclear activities in our country—universities have been decreasing over a number of years. I remember when I first came here about a decade ago, I was—voted with a minority, unfortunately, to keep the super-conducting super collider in Texas open. I was concerned for two reasons. One, we desperately need something that captures the imagination of our people, inspires our young people to go into careers in science, math, and engineering. I hope that might do that. Further, I thought that it was very exciting that the particles we produce with energy are roughly ten times of those we produce other places might provide, just the missing information that Steven Hawking needs to complete his mathematical synthesis of the mysteries of the universe. And I thought how exciting that maybe he may have the best mind in a millennium trapped in a body that will not endure forever. And I thought it might be exciting if we could do that, but alas, he did not.

I would just like to come back to the energy power. I am opposed to drilling into Lake Michigan and off the coast of Florida, not for any environmental reasons. I have been to Anne Noire. I—that may be, to some, a pristine wilderness. It looked more like a wasteland to me, but my concern is that if we have only two percent of the known reserves of oil in the world, I am having trouble understanding how it is to our national security and benefit to rush around and pump that. I asked the Vice President, “If you could pump that oil tomorrow, what will you do the day after tomorrow?” And the—and his response was, “Roscoe, as long as I can remember, they have been telling me there are 30 years of oil left in the world.” What that means is, I think, that he generally believes that there is a whole bunch of oil out there. It is kind of a cosmic hide and go seek. God knew how profligate we would be in our use of energy, so he hid a lot of oil out there and our only challenge is to go find it.

But the reality, as I mentioned, is that the best estimate is that there is about 1,000 gigabarrels remaining. That is not forever. That will not last forever. And our use of fossil fuels is so enormous that we are going to have to be very clever if we are going to find enough energy from other sources, and nuclear, obviously, is one of those. How—where do we go from here? I do not see us as a society really understanding that there is a problem out there or doing anything meaningful to address that problem.

I am 77 years old, and I will not live forever, and I want to pass on to my children and my grandkids a country better than when I came here. And in terms of energy, we are not about to do that unless something changes. How do we educate and how do we make it change?

Dr. Kammen.

Dr. KAMMEN. Well, I certainly agree with that completely, on a whole variety of levels. I mean, one of the statements about our use of oil is not that in the very short-term we are running out of oil. We are running out in long-term, but what we are running out of in the short-term is atmosphere. We are running out of places to put the waste products, and it does not make sense, on a whole variety of levels, to continue on this sort of path, which seems to be wasteful locally and wasteful in the long-term.

I hope that—well, let me start—one of the mechanisms that seems to be what you are talking about and that is what would wake up this process. In American history, that item that has woken us up regularly, unfortunately, has been crises. Americans often talk about the "sleeping giant" approach to all variety of problems. We began that with the Japanese bombing of war—of Pearl Harbor as an example. The scientific community right now believes that that current "sleeping giant" is climate change. And that climate change has been debated, and it is easy to take sides, because we do not have glaciers melting in our backyard, although now we, in fact, do.

The issue is what level of crisis environmentally or through some Middle East or politically is enough to wake us up to develop this broader energy policy and not so large that we are killed off in the process. And so along your lines, I hope for a small crisis, but not a large one. Now that is a pretty—as a physicist, that is a dangerous thing to be hoping for, just enough but not too much of a problem. But I have not seen, with all of the various energy things going on in the world, us taking the steps that you describe as so important, and I agree with, with the crises that I already think have been big enough.

Ms. HOWARD. Well, I just might say that what I think we need to have is the statesmen decision like—and involving a consortium of business and non-governmental organizations as well as government to come together and put aside some of the special interests. We seem to be run by special interests and wait for the crisis to happen. And perhaps this has to start over a long-term generational process with the education in the schools and addressing the curriculums that educate our young people and then bring that forth through a national policy on energy and economic coordination. Our economy runs on available, affordable, and environmentally available and environmentally compatible energy. And so we do need to make some very difficult decisions, and it has to be communicated as a statesmen level as a national policy and that be driven by looking at all of our energy sources.

I do not think there is a debate about should we have fossil energy or should we have nuclear or should we have renewables or should we have conservation and efficiencies. We need them all, absolutely, and it has to be the kind of national policy but also the economic policies that reward the tough long-term decisions.

Mr. BARTLETT. Thank you, Madam Chair. Thank you for a good hearing.

Chairman BIGGERT. Thank you.

And just in time is Dr. Ehlers, if you have any—another question.

Mr. EHLERS. Thank you. I am sorry I am bouncing between two Committees that are going on simultaneously.

The two general questions—well, actually one general and one specific. First of all, do you think any corporation is likely to invest $2 billion or more in the nuclear power plant today, given the uncertainties of nuclear power? We will just go down the line on that.

Dr. Marcus.

Dr. MARCUS. I think a lot more active consideration is being given to building new reactors than there has been in the past. Senator Domenici has introduced some legislation that we are looking at with great interest. Ms. Howard can probably comment on that legislation in more detail. I don't think a decision on a new plant is going to be made next week or next month, but it appears that the prospects are more positive than they have been in the past.

Dr. KAMMEN. I would argue that, in fact, I do not think it is likely right now. I think we just had an experiment with Exelon and they went through a thought process and were intimately involved with DOE in thinking about the near-term deployment plan. And for a variety of reasons, they pulled out. So I would argue that right now, without a change, I do not think it is likely.

Ms. HOWARD. It depends on what you mean by "right now." There are three companies that are investing in early site permitting to test the new energy policy on early site approval. There are three companies who have design certifications approved and ready to go with the nuclear regulatory commission. There are additional companies that are going forward with design certification, investing hundreds of millions of dollars into—both from a standpoint of the utility site work as well as the design certification.

Will some assurances that the—will—combined operating—construction permit and operating license can go forward as has been approved by the 1992 Energy Policy Act. I think you will see these same companies being willing to invest their money. At this stage, we would like to see a government partnership on some of the early units going forward, a sharing of some of that investment risk to be assured that the policies in place can actually be implemented. And then after that, if that is successful, I seek—think you will see those same companies and others coming forward to build a new generation of reactors in this country.

Mr. EHLERS. Dr. Stubbins.

Dr. STUBBINS. I think it is likely. There are some impediments, and I think the gas cold reactor issue is one that is kind of off the map because of its very advanced technology. The next step probably will be a reactor like the ones that we are currently building around the world, other places, that is consistent with the current fleet.

But I think the other real impediment is that the nuclear utility industry has two problems. First of all, they really have not made the transition yet to be completely competitive. They need to align themselves better to do that. The market will become very competitive, I think. And part of the difficulty is that since they have consolidated in some ways, they are competing, in a sense, against themselves to build a new plant. They have existing plants that operate well where they are increasing capacity. And so building a new plant is not, maybe the nearest-term thing they are thinking about, but I agree that in the short-term, there will be a new order.

Mr. EHLERS. Dr. Slaughter.

Dr. SLAUGHTER. I think the question here is—I think there are technology issues, but I think those can be overcome. I think what the critical question will be if a company will put some kind of financials of that nature to this is where will they site it, and will the community support it. I think the fact is that is the key question. And that has to be answered.

Mr. EHLERS. I think another question is now with deregulation, they do not have an assured customer base. And can they—will they be able to sell the electricity at a price commensurate with the cost of the reactor? And that is another issue to face.

One last quick one. Dr. Kammen, you were the first to mention using reactors to produce hydrogen. What process is that, and how do you expect it to compete with preparing hydrogen from fossil fuels?

Dr. KAMMEN. Is—I think the main issue here is actually the amount of research that we need to do. The temperature regime in which hydrogen is most efficiently produced from nuclear reactors is actually somewhat different than what we operate reactors at today. That might—that does not need to be the case in the future necessarily. But it does mean that if you want to think about a future reactor that is an electricity-only machine or a hydrogen-only machine or a hybrid machine that would do both in a, sort of, more free wheeling market where you produce electricity one day and hydrogen the next, that with the exception of this research of Dr. Forrestburg at Oak Ridge, we have very little long-term thinking about that. And so I actually think before an answer can be given to that very good question, we need to diversify the advanced innovative research activities in this area, because I do think it is very much understudied right now.

Mr. EHLERS. Well, the other factor is you have to—when you compare costs, you have to decide whether you are going to sequester the carbon from the fossil fuel process or not——

Dr. SLAUGHTER. Correct.

Mr. EHLERS [continuing]. Because that can make a huge difference in the cost of hydrogen using fossil fuels.

Dr. SLAUGHTER. That is right. And this is exactly why I am most interested in these carbon taxes and ways to think about those economics that would favor this sort of fossil fuel conserving, environment conserving process.

Mr. EHLERS. All right. I note my time has expired, but it is up to the——

Dr. KAMMEN. Let me make a quick—one more comment. I think one of the issues is that I think the Department of Energy has been looking at this fairly carefully. One of the NERI programs that just finished has looked at carbon cycles

—or hydrogen cycles. There are 200-plus cycles. And there are some that are very workable with nuclear power that would be much more efficient than electrolysis, which you could do by generating electricity in any one of these means, and would be a—have possibly the added bonus that they could be used as hybrid plants. But this is under very active consideration. It is also one of the things that DOE is looking forward at in terms of developing a new reactor, at least a new experimental test reactor.

Mr. EHLERS. And Dr. Marcus, last word.

Dr. MARCUS. I had wanted to note that the Department is looking at some advanced reactor designs that would be higher temperature and thus more conducive to hydrogen production, which was mentioned earlier. Some of these designs are part of the Generation IV program that was described previously as being pursued with international partnership. Ultimately, there will also be strong participation from industry. The question of industry involvement was mentioned previously, including the problems that may arise when the government selects technologies. We hope to avoid those problems by involving industry in making sure that the result will be a product industry will want when it is developed.

Mr. EHLERS. Generation Y may build Generation IV reactors.

Dr. MARCUS. I will keep that in mind. Thank you.

Chairman BIGGERT. Before we bring this hearing to a close, I want to thank our panelists for testifying before the Subcommittee for their excellent testimony and their insight. And I would also like to thank the students that are here for attending the hearing and staying through the whole thing. So I appreciate it.

If there is no objection, the record will remain open for additional statements from Members and for answers to any follow-up questions the Subcommittee may ask of the panelists. Without objection, so ordered.

The hearing is now adjourned.

[Whereupon, at 11:50 a.m., the Subcommittee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Gail H. Marcus, Principal Deputy Director, Office of Nuclear Energy, Science, and Technology, U.S. Department of Energy

Questions submitted by the Majority

Q1. What percentage of the Advanced Fuel Cycle Initiative's (AFCI) funding has gone to universities in fiscal years 2001 and 2002? How will the nature of the university research funded by the new mechanism—the fixed 5 to 10 percent of all nuclear R&D funding that you announced at the hearing—differ from the university research conducted under the Nuclear Engineering Research Initiative (NERI)?

A1. The AFCI program dedicated 11.7 percent of its FY 2001 budget to university directed research programs and fellowships ($3.98 million out of $34 million). In FY 2002, AFCI dedicated 14 percent of its budget to university programs ($7.1 million out of $50 million). The majority of these funds supported the University of Nevada at Las Vegas and the Idaho Accelerator Center at Idaho State University in Congressionally directed research. The funds also supported ten Masters Degree student fellowships and over one hundred students in national laboratory directed research at nine universities.

The new mechanism being developed for funding university research results from the refocusing of our program from general research to research specifically related to the advanced reactor system concepts which have now been identified for international collaborative research through the Generation IV International Forum. We would expect the total funding available to universities under the anticipated research projects to be greater than the funding that was available under the NERI program. In addition, since this research will be tied to significant on-going programs, universities participating in research related to these reactor designs will be able to work with a larger national and international research community.

Q2. At the hearing, Ms. Howard of the Nuclear Energy Institute (NEI) testified that the nuclear industry's goal is to increase its share of the electricity market to one third. At the hearing, Dr. Kammen suggested instead that it was likely to maintain a 20 percent share, while the Energy Information Administration (EIA) has projected that industry capacity is likely to expand by less than one percent.

Q2a. How does DOE project the future size of the nuclear power industry when designing its programs, and how do its methods differ from those of NEI and EIA?

A2a. The Department of Energy has not made projections on the expected size of the commercial nuclear power industry. The design of our programs is based on optimizing current nuclear power generating capability and on enabling an increase in total nuclear generating capability through the construction and operation of new nuclear power plants in the future. Therefore, the programs of the Department may alter the premises behind some of the projections of the future size of the nuclear power industry by removing barriers and opening new possibilities.

Q2b. How do you ensure that DOE's programs are best able to cope with the uncertainty in such projections, which historically have been quite large?

A2b. As DOE programs relating to nuclear capacity optimization in the United States are not based specifically on projections, the large uncertainties in projections have not impacted their need or direction.

Q2c. Given the long lead times that are required to build nuclear plants, what are your estimates of the most likely and the most optimistic number of new nuclear power plants that could be operating or under construction by 2011?

A2c. It is possible that an order for a new nuclear power plant could be placed around the year 2005. New orders are based on evaluations of the energy market by the power generation industry, and therefore will depend on a variety of economic factors. It is impossible, at this point in time, to make a valid projection regarding the number of new plants that might be built over the next decade.

Q3. In Ms. Howard's testimony, she stated that the nuclear industry would require 90,000 new workers over the next 10 years.

Q3a. What is your best estimate for the total number of new nuclear workers (including replacements for retirees) needed in the next 10 years? How many of those would be nuclear engineers?

A3a. DOE participated in that NEI Task Force and has no reason to disagree with the conclusions. The Task Force estimated that about 800 nuclear engineers would be required over the period 2002–2011.

Q3b. In developing your estimate, how many commercial reactors do you assume will be running in 2013? How many would be needed to employ 90,000?

A3b. The assumption was that the 103 plants operating today would continue to operate and no new plants were projected.

Q3c. How large is the current nuclear workforce, including all workers from maintenance workers to engineers? What fraction of the current workforce is nuclear engineers?

A3c. Citing again the NEI Task Force in which DOE participated, the aggregate estimate of the total number of workers in the entire industry, including the national laboratories, industry and universities, is 90,000. The NEI study did not collect data on the current number of nuclear engineers in the workforce.

Q3d. What is the uncertainty associated with your estimated total number of workers needed?

A3d. This study was based on direct solicitation of data from the industry, and is therefore considered to have a high degree of certainty.

Q3e. What are the key determinants of the demand for nuclear engineers and other nuclear workers?

A3e. The key determinants of the demand for nuclear engineers and other nuclear workers are the state of the nuclear infrastructure in the country (for example, number of nuclear power plants) and the demographics of the existing workforce.

Q3f. How large do you believe DOE's university programs must become (and how quickly) to allow the Nation to produce the new graduates you estimate are needed?

A3f. While there is no exact correlation between the size of DOE's University Programs and the number of nuclear engineering graduates, the program is clearly having a positive impact as more nuclear engineers are graduating from the Nation's universities today than a decade ago. Additional funding would enable the Department to fund more Nuclear Engineering Education Research, more fellowships and scholarships, and to better meet the projected contractual needs of the Innovations in Nuclear Infrastructure and Education initiative. Even if the number of graduates remains fairly constant, maintaining current educational levels requires new faculty to replace those retiring, improved equipment, modernized research reactors and challenging research.

Q4. A number of studies suggest that the number of nuclear workers per power plant is declining. What is the average number of college-trained (at each level) personnel employed at a typical reactor today and how many do you expect a typical reactor to employ in 2013?

A4. The Department does not maintain this kind of data or make these kinds of projections.

Q5. In the 1990, the American Society for Electrical Engineering (ASEE) released a study entitled, "Manpower Supply and Demand in the Nuclear Industry," that found that 35004500 "BS and MS graduates" would be required by the nuclear power industry and that the workforce "supply" would fall short of that number by 400 nuclear engineers by 2000 and 2001. Did the predicted shortfall occur and, if so, how was the shortage handled?

A5. It is difficult to measure such shortfalls directly, as shortages of personnel are often filled, albeit with greater difficulty, by engineers from other disciplines. However, anecdotal evidence, such as continuing increases in salary levels for nuclear engineers, and numbers of job offers per graduate, suggest that the demand for nuclear engineers has continued to exceed the supply. The Nuclear Energy Institute's *Nuclear Industry Staffing Pipeline Survey* (December 2001) indicates that there is a shortfall that is essentially being handled by retraining. When employers cannot recruit sufficient numbers of degreed nuclear engineers, they hire engineers from other disciplines and train them in the nuclear applications that are needed for a particular job. However, retraining has its limitations in those instances when highly specialized nuclear engineering expertise is needed.

Q6. Your testimony implies a bright future for nuclear power, yet EIA and others argue that the current state-of-the-art nuclear plant is as much as 20 percent too expensive to complete with fossil-fueled plant. Given that the first new plants of any new or innovated design are likely to be more expensive, what is the per kilowatt capital cost of a new nuclear plant? How does this translate into levelized cost per kilowatt-hour? When do you see the price of nuclear plants being competitive, and how do DOE's programs contribute to the decline? What role do the DOE university programs play in these cost reductions?

A6. There are wide variations in the estimates of construction costs for new plants to be built in the United States. Industry estimates for new nuclear plants range between $1,100 and $1,400 per kilowatt. These estimates are significantly lower than EIA projections and represent the latest industry experience abroad. The cost of the first nuclear plant is about 25 percent above what is economical in today's deregulated market. A significant portion of this above market cost is related to regulatory risk surrounding the construction and commissioning of a new plant, first of a kind engineering cost and learning how to build plants efficiently, but after such issues are addressed for the first few plants, subsequent plants should be more economical.

Projected electricity generation costs for new nuclear plants costing between $1,100 to $1,400 per kilowatt-electric translate to a levelized cost of 3.6 to 4.3 cents per kilowatt-hour. This levelized cost range includes capital, operating and financing costs.

Under the Department's Nuclear Power 2010 initiative, DOE matches industry investments over the next several years to address first of a kind technology costs and demonstrate key regulatory processes designed to make new plants more efficient, effective and predictable. The Department is currently working with three U.S. nuclear generating companies to obtain permits for sites at which new plants could be built. Additionally, this year the Department will issue a solicitation seeking industry participation in projects to develop and implement plans to license and build new plants.

Currently, efforts aimed at cost reduction for new nuclear power plants do not involve technological research, and therefore, the DOE university program is not involved in this area.

Q7. What evidence, if any, do you have that university programs contribute to increasing nuclear capacity factors and other increases in industry productivity? How can this construction be measured?

A7. As funding for University Programs increased in the late 1990s and early 2000s enrollments increased in a similar fashion. The effect of our University Programs on capacity factors or productivity is difficult to measure since it is impossible to isolate their impact from the many other factors impacting these two variables, but the skill level of the workforce certainly contributes to the ability to develop new methods and technologies to improve productivity.

Questions submitted by the Minority

Q1. How does DOE project the future size of the nuclear power industry when designing its programs and how do its methods differ from those of NEI?

A1. The Department of Energy has not made projections on the expected size of the commercial nuclear power industry. The design of our programs is based on optimizing current nuclear power generating capability and on enabling an increase in total nuclear generating capability through the construction and operation of new nuclear power plants in the future. Therefore, the programs of the Department may alter the premises behind some of the projections of the future size of the nuclear power industry by removing barriers and opening new possibilities.

Q2. We've been hearing about impending shortages in the nuclear workforce for a while. In your written testimony you concede that the nuclear workforce shortage predicted in the late 1980s failed to materialize in the 1990s. In 1999, a study by the American Society for Electrical Engineering also predicted a shortage of 400 nuclear engineers by 2000 or 2001. This time, however, you seem to be arguing, there really will be a shortage and that the situation is even more dire than in the early '90s. Is this a correct interpretation, is a shortage more likely now and if so why?

A2. The main reason that a shortage of trained nuclear engineers is more likely now than it was a decade or so ago is that the nuclear workforce is older and there are insufficient numbers of trained nuclear engineers graduating from our colleges to replace retirees on a one-for-one basis. The earlier predictions of shortages may not have come to pass in part because some nuclear personnel may have deferred their retirements. But, as we learned in the Nuclear Energy Institute report completed in the year 2000, *Nuclear Education and Training: Cause for Concern,* industry, government, universities and national laboratories are all confronting this unbalanced manpower demographic and the number of graduating nuclear engineering students is just now beginning to increase. While manpower retirement extensions of current personnel are unlikely to occur in large numbers as they have in the recent past, increasing numbers of graduates, retraining of engineers from other disciplines, and other public-private sector initiatives such as our university partnership program with minority serving instructions should help mitigate the shortage.

Q3. In your written testimony you highlight new DOE efforts with the first Historical Black College or University (HBCU) to offer a degree in nuclear engineering. To what degree are minorities and women under represented in the workforce? As the first woman doctorate in the field of nuclear engineering, how do you believe greater workforce diversity might affect the future vitality of the nuclear engineering field? What policy changes you would recommend for universities, laboratories, industry and government to increase diversity?

A3. The Department has not done a study to quantify the degree of under-representation of women and minorities in the nuclear engineering workforce. However, numerous reports on engineering in general indicate that this under-representation exists, and there is no evidence to suggest that nuclear engineering differs significantly from other engineering disciplines in this regard. Greater workforce diversity will be critical to meeting future demands for nuclear-trained professionals, and therefore, to the ultimate vitality of the field. The government, universities, laboratories and industry already recognize the potential workforce deficiencies, and have established programs and policies designed to help address the problems. For example, DOE is working with universities and industry to help increase minority and female enrollments. In 2000, we began our University Partnership program. It is designed to match a nuclear engineering school with a Minority Serving Institution (MSI). To date, we have four partnerships involving five minority and four nuclear engineering schools. Student interest and enrollment in this program is high and will yield new minority and women nuclear engineers in the near future to help meet the Nation's nuclear manpower requirements. Further, Exelon Corporation provided significant funding to South Carolina State University (SCSU) under the Department's matching grant program. SCSU is the first historically black college to begin a nuclear engineering degree program. Such policies need to be continued, and, where possible, increased, to help expand the pool of nuclear engineering students.

Q4. Dr. Kammen suggests that the current production rate of 500-700 new nuclear engineers over ten years is sufficient for the nuclear power industry while Ms. Howard's testimony suggests we need 90,000 new workers over the coming decade, of which it seems that over 20,000 would go to the power industry. Do each of you agree with these estimates? If not, what do each of you think is the right number of nuclear engineering graduates the Nation will need? Do you have a sense of how many commercial reactors would be required to employ your estimated number of future employees?

A4. The NEI study, in which DOE was a participant, stated that 800 nuclear engineers would be needed from 2002–2011. Dr. Kammen's upper range is not far removed from the NEI projection. The NEI projection was based on the Nation having 103 operating nuclear power plants. In addition, it is important to note that additional demands for nuclear manpower will derive from government, universities and national laboratories where a significant percentage of the current workforce is already at or past average retirement age.

Q5. You discuss the efforts DOE has been making to involve nuclear engineering departments throughout the country in the regional university research reactor consortia. Then, on page 4 of your testimony, you express "concern" about the closing of two university research reactors—one at Cornell and one at Michigan. If DOE supports the regionalization effort, it implies that a smaller number of reactors could suffice. Why is DOE concerned about these particular reactors? Who will decide and what criteria will be used to select the surviving regional reactors? What is DOE's role in this selection process? You mentioned that those few universities with nuclear programs not affiliated with any consortia, "are being encouraged to affiliate." Is DOE trying to reduce the number of research reactors, or just trying to get all the programs to work as affiliates?

A5. Both the Michigan and Cornell reactors represented strengths in the U.S. nuclear engineering community that cannot be replaced. DOE is not involved in a selection process to determine which nuclear reactors continue to operate. That is decided by each university. DOE, over the past decade, has improved its programs, such as reactor upgrades and reactor sharing, and this has helped the reactors to better serve students and faculty researchers. Based upon reports of the Nuclear Energy Research Advisory Committee, a regional reactor consortium was determined to be the best way to ensure that these reactors, and their associated nuclear engineering programs, could best serve their constituent population. The more affiliation, the better the cooperation among the universities and their national laboratory, utility industry and private sector partners. Becoming affiliated with Innovations in Nuclear Infrastructure and Education not only strengthens each individual reactor program, it strengthens the nuclear reactor community as a whole.

Q6. What fraction of the total cost of educating a nuclear engineer does DOE provide? Does DOE have a model of the cost of educating a nuclear engineer (i.e., student stipend, faculty, nuclear reactor and equipment, and overhead) and the sources of the funds provided to cover costs (i.e., student tuition, DOE, university support, industry support)?

A6. DOE does not have a model for the cost of educating a student in nuclear engineering. There are many options to support the cost of educating a nuclear engineer. DOE has a fellowship program for graduate students, and a scholarship program for undergraduates. The fellowship program provides full tuition and a monthly stipend plus a one-time summer practicum at a national laboratory with full stipend. Fellowship costs range between $30,000 and $45,000 per student per year, depending on the university the student is attending. The scholarships are for a flat $2,000 per year to help cover tuition. This amount is usually adequate since most nuclear engineering programs are located at state universities where the tuition is relatively modest. Both of these awards are highly competitive and there are many more applicants than there are funds to pay for them. Other organizations outside the government also offer assistance to students. In addition, the universities have the flexibility within the DOE-funded matching grant initiative to provide funds to students in the form of fellowships and scholarships. DOE also provides summer internships for students at DOE's national laboratories. Those students are paid for their travel expenses and receive a stipend. Therefore, most students, especially graduate students, can receive financial assistance to enable them to become nuclear engineers. Financial aid is very much a recruiting tool used by the universities to entice students to study nuclear engineering and science.

Q7. The NNSA recently announced a $9M award in its Stewardship Science Academic Alliances program to, in part, involve the universities in stockpile stewardship, train scientists, and promote scientific interactions between universities and laboratories. To what extent will this funding help satisfy the demand for nuclear engineers? Are there other DOE, DOD, or government programs to help support the education and training of nuclear engineers?

A7. There are several programs that provide funding that supports the training of nuclear engineers. These all can help contribute to meeting the demand for nuclear engineers. However, each is designed with specific objectives in mind, so they cannot readily directly substitute for each other. The NNSA Stewardship Science Academic Alliances program provides research grants relevant to stockpile stewardship. In addition, the Office of Naval Reactors has a fellowship program for nuclear engineers that is modeled, primarily, on the Office of Nuclear Energy fellowship program. Naval Reactors started its program about two years ago. It has some specific requirements that NE programs do not have, including one that obligates the student to a certain number of years in their program at one of the Naval Reactors laboratories—Bettis or Knolls Atomic Power Laboratory.

According to NASA's Project Prometheus, its nuclear systems program to develop advanced radioisotope and fission power technologies for space exploration is in the process of establishing a comprehensive education program that will include a university component to strengthen the pipeline of engineers in relevant disciplines of nuclear and aerospace engineering.

Q8. The DOE FY2004 Congressional Budget Request (DOE/ME–0018) indicates that the NERI budget for FY 2004 is $7.4M down from $17.5M in FY 2003 and $22.0M in FY 2002. In view of this trend and the putative value of the program in your written testimony, what plans are there to reverse this trend or establish a follow-on program?

A8. The reductions in the NERI program represent the programmatic re-focusing of the program from general research to research specifically related to the advanced reactor system concepts which have now been identified for international collaborative research through the Generation IV International Forum. We would expect the total funding available to universities under the anticipated research projects to be greater than the funding that was available under the NERI program. In addition, since this research will be tied to significant on-going programs, universities participating in research related to these reactor designs will be able to work with a larger national and international research community.

Q9. How should the government determine how many research reactors the country needs, if the idea of regional reactors is to save money and eliminate duplication?

A9. The government should not make the determination of how many research reactors are needed; this is a decision that must be made by the universities themselves. DOE's Innovations in Nuclear Infrastructure and Education (INIE) is a competitive program designed to improve the use and availability of regionally located reactors for research by a wider audience of students and faculty and is not designed to limit or reduce the overall number of university research or training reactors. Ultimately, if a university does not believe its reactor benefits the students and faculty or that its liabilities exceed its usefulness, then it can decide to shut it down.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Daniel M. Kammen, Professor, Energy and Resources Group, Goldman School of Public Policy; Department of Nuclear Engineering, University of California–Berkeley

Questions submitted by the Majority

Q1. Ms. Howard from the Nuclear Energy Institute (NEI) testified at the hearing that the nuclear industry will require 90,000 new workers over the next 10 years.

Q1a. What is your best estimate for the total numbers of new nuclear workers (including replacements for retirees) needed in the next 10 years? How many of these would be nuclear engineers?

A1a. As described below, my estimate for the number of new engineers needed is under 1,000. At present 20 percent of nuclear engineering graduates enter the commercial nuclear energy work force. If this attrition factor is applied, my estimate would rise to closer to 5,000.

The estimate provided by Ms. Howard of the NEI is a vision of 50,000 MW of *new* nuclear capacity by 2020, and 10,000 of additional capacity through the enhancement of operations at existing plants. The 50,000 MW of new capacity can be roughly translated to be 50 new reactors over the next 15 years. The 10,000 MW of additional capacity is possible, but will be challenging because the capacity factor of the U.S. reactor fleet is already very high (over 90 percent), so these gains would likely have to come from core upgrades, which would require new certification.

In my view, the probability of building 50 new reactors over the next 10–15 years is low. Industry plans for these new reactors are largely dependent on efforts by the Near Term Deployment Study that took place from 2000–2002 as part of the Generation IV (Gen IV) process. Those plans were dealt a significant setback when Excelon Corporation cancelled their Pebble Bed Reactor program. Other designs are, of course, possible, and the DOE is working hard to streamline the certification and approval process for new plants. There have been some significant advances in PBMR technology (larger core sizes and higher potential efficiencies), and the recent inclusion of very large (estimated $13 billion) loan guarantees for the nuclear industry in the recent U.S. Senate Energy Bill.

Even taking these changes into account, I do not consider the construction of the new plants in the NEI plans to be likely. There may be some construction of new/replacement reactors at current nuclear power plants, but my best estimates place these new facilities at a level that would sustain, *but not significantly increase* the U.S. nuclear fleet beyond its current level of 103 reactors.

In this scenario, the total number of new nuclear workers (new workers + retirement replacements) over the next decade is essentially only the retirement replacement number. Thus, assuming a retirement rate of three percent/year, 50–60 new engineers are needed each year, or under 1,000 over the next decade. This is very far from the 90,000 in the NEI forecast. Even if some number of new reactors are built, I would not consider it to be more than 5–10, for which the current production rate of engineers is likely to be sufficient. My estimates here are, in fact, below the number of nuclear engineers that are currently produced at the undergraduate and graduate levels (345 in 2003). Even with the current yield of only 20 percent of nuclear graduates taking jobs in the commercial nuclear power sector, the current rate of graduates appears to be sufficient to meet the needs of the industry.

Note: One important issue not addressed directly by this question is that as the training of these engineers may likely need to change, which would require some significant new types of training for the engineers that are produced.

Q1b. In developing your estimate, how many commercial reactors do you assume will be running by 2013? How many would be needed to employ 90,000?

A1b. As discussed above, my belief is that in the next decade there will not be a net increase in the number of commercial reactors. Current reactors employ roughly 20 engineers per reactor. With the general employee/plant engineer ratio at 20:1 (which is meant to roughly include both on-site employees and those at nuclear parts fabrication and storage facilities), to employ 90,000 new workers would require over 200 new power plants. This is not even faintly realistic or warranted.

Q1c. How large is the current nuclear workforce, including all workers from maintenance workers to engineers? What fraction of the current workforce are nuclear engineers?

A1c. The current workforce supports roughly 100 reactors, with almost 20 nuclear engineers/plant and roughly 10 employees/engineer, the total workforce is roughly 2,000 engineers, and 20,000 workers total, in all upstream and downstream jobs.

Q1d. What is the uncertainty associated with your estimated total number of workers needed?

A1d. Clearly the largest uncertainly is in the number of new plants. At 20 engineers per plant, and roughly 20 x (10 to 20) = 200–400 total workers per plant, this uncertainty can be significant.

Q1e. What are the key determinants of the demand for nuclear engineers and other nuclear workers?

A1e. The key determinants are the types of nuclear plants that might be built. New, advanced, designs, will require significantly more engineers compared to the potential construction of additional numbers of current generation plants.

Q1f. How large do you believe DOE's university programs must become (and how quickly) to allow the Nation to produce the new graduates you estimate are needed?

A1f. In my view, no increase in the total number of graduates is needed. What may be needed, however, is a significant alteration in the type of training that the next generation of nuclear engineers receive.

Q2. A number of studies suggest that the number of nuclear workers per plant is declining. What is the average number of college trained (at each level) personnel employed at a typical reactor today and how many do you expect a typical reactor to employ in 2013?

A2. The number of workers per plant is declining for this current generation of nuclear plants. By 2013 I do not expect a new generation of plants to be deployed, so the current number of engineers per reactor, 16–18, is a good guide for plants by 2013. When Gen IV or other advanced designs are introduced, this number will likely change.

Q3. What factors determine the size of university departments and programs? To what extent do you consider the future demand for graduates by the industry in determining the appropriate number of students to enroll and graduate at your university's programs?

A3. Industry demand *per se* is not an immediate driver of the number of students we enroll and graduate in the Department of Nuclear Engineering at the University of California, Berkeley. This is true because as one of the top nuclear engineering programs, there is a larger demand for UC–Berkeley graduates than would be the case if the industry hired from each program proportionally. As a result, federal grants and student awards are a larger, or at least more immediate, determinant of the size of our program. Note that only 20 percent of graduates from nuclear engineering programs go into the commercial nuclear energy field. This is both a testament to the quality and rigor of the training in nuclear engineering, and a strong warning that employment in commercial power production from nuclear reactors is not likely to be the overwhelming driver of university program size.

Q4. In our opinion, to what extent should nuclear engineering be forced to compete with other disciplines for funding through the National Science Foundation or other multi-discipline funding agencies, rather than be allowed to rely on programs dedicated solely to nuclear disciplines?

A4. This is a critical question, and gets to the very heart of the way that we operate our nuclear power industry in the United States. At present nuclear power is managed as a *discipline apart* from the rest of the energy sector. The Price Anderson act, the Yucca Mountain repository (and the process that lead to it), and the recent push for massive loan guarantees for the industry are all examples of this special status that nuclear power enjoys. Paradoxical as it may seem, in my view, this treatment has not served the development of nuclear power well. The industry has become insular, isolated from important discussions and forces that can spur true innovation (as opposed to incrementalism, or what has been called 'technological involution').

It is important for each technology to have a fairly secure *core* funding and support network, such as already exist for nuclear power within the Department of Energy, and within engineering directorates in the NSF. It would be far more productive for the nuclear energy industry, and for energy field generally, to get more cross-technology discussions and exchanges. This can only be accomplished by placing all technologies on a more even playing field.

Q5. Your written testimony ends with a quote from the head of your nuclear engineering department saying that most department heads believe that the best approach to reinvigorating nuclear engineering education—even over providing direct funding for universities—would be for the government to commit to create "incentives" to build a small number of additional commercial nuclear plants, allowing those incentives to decrease over time.

Q5a. What are the incentives these department heads have in mind?

A5a. The incentives of special interest to my colleagues include the loan guarantees that are included in the Senate Energy bill. Other incentives that have been discussed include a variety of mechanisms to encourage or facilitate the commercial construction of even small additional reactors at existing nuclear facilities.

Q5b. Do you think that their analysis is correct? How would expansion in the number of plants increase the vitality of nuclear research? For example, how could it fix the problem you describe in your testimony that half of the scientific papers published on the production of hydrogen from nuclear energy are written by a single researcher?

A5b. There is no question that the construction of even a small number—even one—of new reactors in the U.S. would send a powerful signal to the industry. Without the opportunity for new facilities and new reactor designs to be moved from theory to practice it is difficult to maintain interest in any technological field.

The problem of the lack of researchers in areas like the connection between nuclear power and hydrogen—as discussed in my testimony—is one that requires two related approaches. First, construction of even a small number of new reactors would alter the industry in fundamental ways—bringing new purpose and vitality to many areas of investigation. The specific problem of nuclear hydrogen is one that related back to my response to Question #4. If nuclear power is more fully connected to the wider set of energy issues and infrastructure, then discussions between different disciplines—between the nuclear and the renewables community over the best ways to produce hydrogen for example—can bring new forces of innovation and investigation to the entire energy field. This sort of debate, discussion, and cross-fertilization of ideas has been retarded by the balkanization of energy research. One mechanism to begin this integration is to encourage or require life-cycle cost benefit, and risk/benefit analyses for *all* energy technologies, and to make federal decisions on energy systems cognizant of these results.

Q5c. How would you prevent rent-seeking behavior, where recipients seek to perpetuate subsidies rather than allow them to decrease?

A5c. Several approaches exist:

i) Policies that specifically mandate a sunset are difficult to circumvent;
ii) Open competition across technologies (as advocated above) reduce the opportunity for the special status and rent-seeking behavior that you highlight. Nuclear energy has arguably already been the recipient of significant resources that have already led to significant patronage and rent-seeking.

Q5d. What is the appropriate industry share for these incentives initially?

A5d. The nuclear energy industry is already the recipient of *massive* financial and political subsidies, and despite this has contributed relatively little in direct support for university research. Congressman Bartlett made this point very clearly during the June 10 hearing. If the construction of a new nuclear power facility were to take place, the nuclear power industry would benefit immeasurably. As a result, the industry should contribute significantly, in fact should arguably lead the development of these new facilities.

Questions submitted by the Minority

Q1. As director of a university program, how do you determine the appropriate number of students to enroll and to graduate? To what extent do you consider the future demand for graduates by the nuclear power industry? How do you determine what the demand will be? What methodology would you suggest to identify the required number of university reactors, where they should be located, and the appropriate level of federal support?

A1. Industry demand *per se* is not an immediate driver of the number of students we enroll and graduate in the Department of Nuclear Engineering at the University of California, Berkeley. This is true because as one of the top nuclear engineering programs, there is a larger demand for UC–Berkeley graduates than would be the case if the industry hired from each program proportionally, as a result, federal grants and student awards are a larger, or at least more immediate, determinant of the size of our program. Note that only 20 percent of graduates from nuclear engineering programs go into the commercial nuclear energy field. This is both a testament to the quality and rigor of the training in nuclear engineering, and a strong warning that employment in commercial power production from nuclear reactors is not likely to be the overwhelming driver of university program size.

Analysis of future demand can be accomplished by the sort of scaling factors that can be determined from the current industry, such as nuclear engineers/reactor, and total employees/engineer.

The number of research reactors needs to be sufficiently large so that all graduates who have a reasonable chance of working in the industry are well trained in actual operation of nuclear facilities. The location of these facilities is far less important than the amount of hands-on time that each student can be afforded through the university consortia that have developed around the existing research reactors.

Q2. In your testimony you cite a colleague as saying that department saying that most department heads believe that the best approach to reinvigorating nuclear engineering education—even over providing direct funding for universities—would be for the government to commit to create "incentives" to build a small number of additional commercial nuclear plants. What kind of incentives do you think these department heads have in mind? How will adding a few plants this way increase the demand for nuclear engineers, if, according to the GAO report you cite in your testimony, the current number of annual nuclear engineering graduates could probably meet the demand of an even of an expanded nuclear power industry? How will the expansion in the number of plants increase the vitality of nuclear research? For example, how could it fix the problem you describe in your testimony that half of the scientific papers published on the production of hydrogen from nuclear energy are written by a single researcher?

A2. The incentives that my colleagues envision include the loan guarantees that are included in the Senate Energy bill. Other incentives that have been discussed include a variety of mechanisms to encourage or facilitate the commercial construction of even small additional reactors at existing nuclear facilities.

There is no question that the construction of even a small number—even one—new reactor in the U.S. would send a more powerful signal to the industry than would any amount of continued 'business as usual' research. Without the opportunity for new facilities and new reactor designs, it is difficult to maintain interest in any technological field.

The problem of the lack of researchers in areas like the connection between nuclear power and hydrogen—as discussed in my testimony—is one that requires two related approaches. First, construction of even a small number of new reactors would alter the industry in fundamental ways—bringing new purpose and vitality to many areas of investigation. The specific problem of nuclear hydrogen is one that related back to my response to Question #4. If nuclear power is more fully connected to the wider set of energy issues and infrastructure, then discussions between different disciplines—between the nuclear and the renewables community over the best ways to produce hydrogen for example—can bring new forces of innovation and investigation to the entire energy field. This sort of debate, discussion, and cross-fertilization of ideas has been retarded by the balkanization of energy research.

Several approaches exist:

- Policies that specifically mandate a sunset are difficult to circumvent;
- Open competition across technologies (as advocated above) reduce the opportunity for the special status and rent-seeking behavior that you highlight. Nuclear energy has arguably already been the recipient of significant resources that have already led to this dynamic.

The nuclear energy industry is already the recipient of *massive* financial and political subsidies, and despite this has contributed relatively little in direct support for university research. Congressman Bartlett made this point very clearly during the June 10 hearing. If the construction of a new nuclear power facility were to take place, the nuclear power industry would benefit immeasurably. As a result, the industry should contribute significantly, in fact should arguably lead the development of these new facilities.

Q3. In Figure 1 of your testimony, Texas A&M shows a dramatic increase in enrollment, nearly quadrupling in five years while other university programs showed little or no growth. Can you tell us more about what happened at A&M? Is this growth just a blip, or can it be sustained? Are there lessons that should be applied to other programs?

A3. The Texas A&M story is important in several respects. The university made a commitment to grow the department, and did so with a long-term plan that involved new research areas in traditional (e.g., neutronics, heat transfer, waste management) and in new areas (e.g., hydrogen production, nuclear energy security). This diversity provides the A&M department with significant funding options, and security against down turns in specific disciplines. The growth of the A&M program is certainly not a 'blip', nor is it a growth we can expect many other programs to follow. University programs arguably already over-produce nuclear engineers, and competition for federal funds is fierce. What A&M has done is to build a top-ranked department, and done so in a way that should provide stability in their program for many years.

The most important lesson for other departments is that non-traditional areas of nuclear and more generally energy systems engineering can become core areas of a vibrant nuclear engineering program.

Q4. In view of the potential terrorist threat to the safety of university nuclear reactors, how can the security of those reactor be assured? What would be the costs of security measures? What degree of these costs should be borne by the Federal Government? Are there any legislative measures that Congress should take to assure university reactor security?

A4. I do not consider myself an expert on the *management* of university reactors, so will defer to Professors Stubbins and Slaughter on this question.

Q5. How should the government determine how many research reactors the country needs, if the idea of regional reactors is to save money and eliminate duplication?

A5. The number of research reactors needs to be sufficiently large so that all graduates who have a reasonable chance of working in the industry are well trained in actual operation of nuclear facilities. The location of these facilities is far less important than the amount of hands-on time that each student can be afforded through the university consortia that have developed around the existing research reactors.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Angelina S. Howard, Executive Vice President of Policy, Planning, and External Affairs, Nuclear Energy Institute

Questions submitted by the Majority

Q1. At the hearing you promised to provide for the record NEI's estimate of the proper ratio of federal to industry support for university nuclear science and engineering education programs. In general, what does the nuclear industry view as its role in assuring an adequate supply of nuclear science and engineering graduates?

A1. NEI does not feel it is appropriate to make an estimate of a correct ratio of industry vs. government funding for university programs. The nuclear industry provides a substantial amount of funding for education programs, from roughly one million dollars per year in scholarships and fellowships provide by the Institute of Nuclear Power Operators through their National Academy Program to myriad paid summer internship and cooperative education programs, scholarships, grants and fellowships offered by individual private firms. In addition to funds which directly support students at universities, industry also funds research studies through the Electric Power Research Institute.

In the past, where industry participates in matching programs, government often does not contribute their promised share. For example, in the 1990s the industry agreed to support a fifty-fifty cost sharing program with the DOE Office of Nuclear Energy for the Advanced Light Water Reactor Program. The industry shouldered nearly seventy percent of the funding when reduced appropriations threatened the success of the program.

Another example of this, specific to education programs, is the Government Industry Matching Grants Program. Although this program is based on a fifty-fifty cost share model, for FY03 industry is expected to contribute $1.2 million, while government will only contribute $800,000 due to another appropriations shortfall.

Finally, we feel that as a future employer of nuclear engineers, the nuclear industry is already filling a very appropriate role: reaching out through deans and college placement personnel to ensure that students have viable job opportunities upon graduation.

Q2. In your testimony, you stated that the nuclear industry would require 90,000 new workers over the next 10 years.

A2. In my testimony, I made several statements about the future need for workers in the nuclear industry. In 2001, NEI conducted a comprehensive study on the future need for workers in the nuclear industry called the *Nuclear Workforce Pipeline Study*. The nuclear industry referred to in this study is broadly defined as the nuclear components of power operations; plant refueling and maintenance outages; government; the national labs; government contractors; universities; front and back end fuel cycle; and engineering, design, services and construction firms.

a) *Does this figure include all workers, from maintenance workers to engineers? How many engineers, including nuclear engineers, are included in the total figure?*

The *Nuclear Workforce Pipeline Study* looked at all workers in the nuclear industry and the 90,000 new workers discussed included 13 categories of nuclear specific workers representing the vast majority of workers in the industry.

b) *In developing your estimate, how many commercial reactors do you assume will be running in 2013?*

In developing these estimates, we used a "business as usual" scenario. This assumed that over the ten years, 2001–2011, the 103 operating reactors would continue to operate and there would be no new plant construction.

c) *How many workers would the industry require over the next decade in the "business as usual" scenario—if the number of commercial reactors did not increase?*

The study used a "business as usual" assumption of 103 operating reactors that would require 90,000 new nuclear workers over the study period.

d) *What is the uncertainty associated with your estimated total number of workers needed?*

The study was produced from direct industry input describing their projected needs for new employees. There was a high level of industry response to the survey and thus we have a high degree of confidence in the study findings.

e) *What are the key determinants of the demand for nuclear engineers and other nuclear workers?*

The key determinants of worker demand in the study were retirements and attrition to other industries. There were a small number of new workers required due to new job creation.

f) *How large do you believe DOE's university programs must become (and how quickly) to allow the Nation to produce the new graduates you estimate are needed?*

We believe that DOE is on the right track in supporting university programs as evidenced by the improvement in enrollment during the past two years. We suggest that DOE University Programs be funded at the $26.5 million dollar level. Further, we recommend that DOE follow the guidance provided by the analysis and conclusions of the of *The Future of University Nuclear Engineering Programs and University Research & Training Reactors,* authored by Dr. Michael Corridini et. al. provided to the DOE Secretary's Nuclear Energy Research Advisory Committee.

Q3. How would you respond to the assertion by Dr. Kammen that the industry would likely require no more engineers than universities are currently expected to produce? How do you believe DOE should design its programs to best cope with the inherent difficulty in predicting future workforce demand and the large differences in such predictions offered by the industry?

A3. We are not familiar with the data upon which Dr. Kammen has based his assertion regarding nuclear engineers. In fact, the data from our 2001 study and other evidence we are familiar with contradicts the testimony submitted by Dr. Kammen. One could of course assume that only nuclear power plants will require nuclear engineers in the future and plant refueling and maintenance outages; government; the national labs; government contractors; universities; front and back end fuel cycle; and engineering, design, services and construction firms would no longer have such a requirement. We know, however, from our research and experience in the industry, that these organizations will continue their operations in the future and as such, require employees to replace retirees and others leaving the industry.

Dr. Kammen may have been referring to the total numbers of engineers of all disciplines graduating from engineering programs. If this was his assumption, than of course there will be enough engineering graduates to meet the nuclear industries need. However, many other industries will need new engineers to replace their retiring or departing workforce. From our analysis, we will need to increase the share of engineers hired into the nuclear industry form the current level of two percent to six percent (a substantial increase.)

Q4. A number of studies suggest that the number of nuclear workers per plant is declining. What is the average number of college trained (at each level) personnel employed at a typical reactor today and how many do you expect a typical reactor to employ in 2013?

A4. It is true that the number of workers at nuclear power plants has declined since the mid-1990s. Since 1996, we have seen a 15 percent reduction in staffing headcounts; however we do not expect to see future reductions in staff at rates we observed in the mid-1990s. Staffing levels in 2001 and 2002 remained relatively stable.

NEI does not keep statistics on the numbers of college trained workers at the sites since there may be no correlation between the degree an individual holds and their employment at a plant, e.g., an individual with a Master's Degree in English Literature may work in Personnel. There are however, positions which require a specific degree, such as a systems engineer or reactor core designer. Further, many of the firms who support plant operations or national labs require specific degrees to fill their positions.

Q5. In 1990, the American Society for Electrical Engineering (ASEE) released a study entitled Manpower Supply and Demand in the Nuclear Industry, that found that 3500–4500 BS and MS graduates would be required by the nuclear power industry, and that the workforce supply would fall short of that number *by 400 nuclear engineers by 2000 and 2001. Did the predicted shortfall occur and, if so, how was the shortage handled?*

A5. While we are not familiar with the assumptions of the ASEE study with regard to new plant construction, the number of operating plants and other factors that could affect demand for nuclear engineers, we have noticed a number of factors which could serve to clarify this issue. We have been informed by members of the university community that many of their nuclear engineering graduates have two or three firm job offers in hand upon graduation. This anecdotal evidence serves to support the issue of shortage. Your fourth question noted that the staffing levels have fallen on the plant level. Since the mid-1990s plant staffing was reduced by roughly 15 percent. While we do expect some decreases in plant staffing levels in the future, we do not expect to see equivalent staffing level decreases in the next few years.

This 15 percent staffing decrease could more than account for reducing the supply shortage in the ASEE report. Additionally, many of our member companies have invested in programs to train non-nuclear engineers for employment at nuclear power plants. Finally, our 2001 report indicates that the power sector of the nuclear industry is not expected to see significant attrition due to retirement until the second half of the study period (2001–2011) and beyond.

Q6. What are the primary reasons that nuclear capacity factors and generation have increased over the past decade? What impact did electric industry restructuring and other economic factors have on motivating these improvements? To what extent are these improvements related to changes in management focus?

A6. The nuclear power industry has enjoyed improving performance, while maintaining an excellent safety record for over a decade due to a number of factors. Since 1990, capacity improvements have added the equivalent of 24 new 1000 megawatt generating plants without building a single new unit. The factors that have lead to this improved performance include, but are not limited to a decrease in the time that units are off-line for refueling outages, better management, more effective predictive and preventative maintenance, and improved on-line maintenance programs. Generally, the industry has sought to optimize performance with the recognition that there is a positive correlation between safety and reliability. This positive correlation translates to greater capacity factors and an improved bottom line.

Q7. What metrics should Congress use to determine whether DOE is doing the right things to ensure that sufficient nuclear professionals are available to meet the needs of the U.S. nuclear power industry in the coming decade?

A7. NEI shares this concern. As such, we are currently working on updating our 2001 survey and would welcome the opportunity to share our results and recommendations with this committee. In addition, we support the analysis and conclusions of *The Future of University Nuclear Engineering Programs and University Research & Training Reactors,* authored by Dr. Michael Corridini et. al. provided to the DOE Secretary's Nuclear Energy Research Advisory Committee.

Questions submitted by the Minority

Q1. In your testimony, you state that NEI's goal is for nuclear power to increase its share to one third of all electricity produced in the U.S. This projection differs greatly from that of the Energy Information Administration, which essentially projects no growth in capacity. How do you account for these differences?

A1. The main factor which accounts for the differences in projections is the assumed capital costs for new plant construction. NEI feels that the EIA cost estimates grossly over estimate capital costs. If EIA were to use reasonable cost estimates as a basis for their forecasts (estimates supported by current technological and design improvements), the forecast would indicate substantial new capacity in nuclear. NEI is constructively engaging EIA on this issue and we hope that by working together, inaccuracies in the EIA model can be corrected.

Q2. Why do natural market forces, like starting salaries and employment incentives, appear to be ineffectual in satisfying the demand/supply for nuclear engineers? What changes would be required to have market forces be the dominant mechanism controlling the supply of nuclear engineers?

A2. The median salary for nuclear engineers, according to the Bureau of Labor Statistics is $79,360 per year in 2000. This is the highest median salary of the 14 engineering specialties that BLS studied in its 2002–2003 occupational outlook hand-book. Further industry surveys have found that compensation in the nuclear industry is very competitive with other industries such as IT.

We believe that market forces alone are not enough to drive students into careers in nuclear engineering. We believe that three factors are affecting student selection of nuclear engineering as a field of study. The first factor is the perception of nuclear engineering as a dying field. With role models like "Homer Simpson" and an industry that has not constructed a new plant since the 1980s, prospective students may not see that there are indeed very lucrative employment opportunities in the industry.

Second, due to the rigorous academic nature of a nuclear engineering degree, many students who consider such a major may not have the basic math and science background to fulfill their academic pursuit. Many studies have indicated that student interest in science technology, engineering and math has dropped steadily since the mid-1980s.

Finally, the lack of funding available in the form of research grants may also deter some students from pursuing this field. Many students who have a thesis or research requirement as a component of their degree, seek fields in which they can work on a funded research projects as a research assistant. While exposing the student to the leading edge in their chosen field, this also helps them pay for their education and related expenses. Further, it may form the foundation of a Master's Degree or Ph.D. thesis. NEI commends DOE on their plan to use universities to conduct a portion of their R&D.

Q3. How should the government determine how many research reactors the country needs, if the idea of regional reactors is to save money and eliminate duplication?

A3. NEI is supportive of DOE's program called Innovations in Nuclear Infrastructure and Education or INIE. The program was established last year and it encourages partnerships between universities, national laboratories, and industry to share facilities. As this program progresses, there will be ample opportunity to determine how many research reactors are needed. In addition, with the advance in bio-medical applications for reactors, the question of the required number of research reactors may be broader than the energy sector.

NEI urges this committee to take a careful and deliberate approach to determining the optimal number of operating test reactors. We are particularly concerned that if this committee is too aggressive in reducing the number of operating test reactors through a decrease in program funding or other mechanism, it may be impossible to restart an existing facility or to site a new reactor due to regulatory requirements, infrastructure or negative community perception.

Q4. Using the figures you gave in your testimony, if the nuclear industry sold 780 billion kilowatt-hours last year (and we assume a very conservative estimate of two cents of revenue per kilowatt-hour) the industry as a whole earned over $15 billion in revenue. But industry share of funding for education amounted to just $19 million since 1980—a tenth of a percent of your revenue in 2002 alone. As a strong advocate for nuclear energy, is industry contributing its fair share to nuclear education? Why has it not contributed more? What do you think is the proper ratio of federal support to that of industry?

A4. In response to this question, I'd like to make two points. First, that total revenues should not be used in this type of analysis. They do not take into account the costs of doing business, such as plant operation, fuel, capital and user fees. The business of owning and operating a nuclear power plant is capital and resource intensive. In addition, it may be impossible to calculate the exact revenue generated by a plant since they are often owned and or operated by a firm which has vast holdings and may not account for revenue on a per unit basis.

Second, I would like to reiterate my answer to the first question from the majority. NEI does not feel it is appropriate to make an estimate of a correct ratio of industry vs. government funding for university programs. We have found in the past that where industry participates in matching programs, government often does not contribute their promised share. The commercial nuclear industry does provide a substantial amount of funding to nuclear engineering university programs as detailed previously.

Additionally, power plant operators are not the only employer of nuclear engineers. A large number of nuclear engineers are employed by government at the Department of Energy, Department of Defense, the National Aviation and Space Administration, the Nuclear Regulatory Commission, and through the National Laboratories. We have been informed by several Nuclear Engineering Department Heads that in recent years their students are most often recruited into the National

Labs and government. It would seem unfair for industry to be on the hook for funding university nuclear engineering programs if a preponderance of current grads are being hired by government.

This is not to say that commercial components of the nuclear industry do not have a strong demand for nuclear engineering grads, just that the most pressing needs are in other segments of the nuclear industry. This is consistent with the overall findings of our 2001 study.

ANSWERS TO POST-HEARING QUESTIONS

Responses by James F. Stubbins, Head of the Nuclear, Plasma, and Radiological Engineering Department, University of Illinois–Urbana-Champaign (UIUC)

Questions submitted by the Majority

Q1. What do you see as the most effective uses of federal funds to develop and sustain an adequate nuclear engineering workforce?

A1. The use of federally supported programs is critical to the future of the nuclear engineering workforce. The current efforts are aimed in the right direction. These efforts are primarily focused on providing research funds, through competitive proposal processes, to advance the fields of nuclear science and engineering. While this funding effort is directed primarily at research and development activities, these activities provide a mechanism not only to create new knowledge and technology, but also to educate and develop new generations of nuclear engineers. This funding is critically important in several venues which include funding to competitive programs at universities, national laboratories, and industry. These sectors have found ways to increase cooperative programs to maximize their impact on maintaining a robust nuclear workforce.

Federal funding to universities to support nuclear science and engineering programs has grown steadily in the past several years from non-existent levels in the mid-1990s. The increases in the DOE–NE university programs budget have been aimed primarily at graduate level research and support of the facilities (i.e., university research reactor) infrastructure. Universities have also participated widely in competitive research support from various other programs in the DOE–NE portfolio (i.e., NERI, AAA now AFCI), the DOE–Office of Science through Basic Energy Science programs and the Office of Fusion Energy Science, other DOE directed efforts, and through cooperative research programs with national laboratories. These efforts need to grow beyond current levels to be an effective force in rebuilding the nuclear workforce in the U.S.

Q2. Ms. Howard from the Nuclear Energy Institute (NEI) testified at the hearing that the nuclear industry would require 90,000 new workers over the next 10 years.

Q2a. What is your best estimate for the total numbers of new nuclear workers (including replacements for retirees) needed in the next 10 years? How many of those would be nuclear engineers?

A2a. My estimate for total new nuclear workers would be close to those projected by Ms. Howard from the NEI surveys. This number reflects the total numbers of people who will be needed to replace all retiring or departing nuclear plant and nuclear power industry workers. I would estimate that only about 10 percent of this number would be degreed nuclear engineers since many of the current plant personnel are technical staff or technicians, but not BS degreed engineers. The number should become much higher than 10 percent as utilities transition to a somewhat smaller, but better educated workforce. This will require strong nuclear engineering degree programs.

Q2b. In developing your estimate, how many commercial reactors do you assume will be running 2013? How many would be needed to employ 90,000?

A2b. I would estimate that there would be between 90 and 100 commercial reactors running in the U.S. in 2013 from the existing fleet of currently operating reactors. I would also estimate that there will be new plant construction underway in the timeframe of the next 10 years, but that any new plant would, at best, be just beginning operation in a 10-year timeframe. Nevertheless, new engineering, including nuclear engineering, expertise will be required for plant design and construction.

Q2c. How large is the current nuclear workforce, including all workers from maintenance workers to engineers? What fraction of the current workforce are nuclear engineers?

A2c. The workforce associated with nuclear power generation can be roughly estimated from the numbers of units, about 100, and the average staff per unit, about 750. This would suggest that about 75,000 people directly associate with nuclear power plants. In addition, there are a number of people associated with nuclear fuel management, nuclear fuel production, nuclear operations and maintenance, and a variety of other nuclear power-related services that would add about 10,000 to the numbers. There are a number of other nuclear-related workers at national laboratories and a variety of industries in the health, food irradiation, plasma processing, non-destructive testing, etc., fields that would add several thousands more to the total numbers. Of this large group, which would easily range above 100,000, only about 10 percent would be nuclear engineering professionals. This relatively small fraction, however is the driving force behind all of the rest of the activities. The current workforce has the additional problem that many of the most highly skilled and experienced technical people are in the late stages of their careers and replacing the knowledge base is even more challenging than the raw headcounts would indicate.

Q2d. What is the uncertainty associated with your estimated total number of workers needed?

A2d. There is a relatively large uncertainty for the numbers of workers needed on the upside, and relatively small uncertainties on the downside. With the reliance on the currently existing nuclear energy infrastructure, we will need a large number of new nuclear-educated workers to replace those currently in the workforce, thus it is unlikely that we will need many fewer new people than those projected in current studies. On the other hand, new innovations in nuclear technology, particularly to support several current national initiatives such as the move toward a hydrogen economy, nuclear based deep space exploration, the development of nuclear fusion, the development of advanced fission reactor designs, advances in nuclear medicine, and nuclear arms and security issues, could result in a significant increase, above the current estimates, in the numbers of nuclear engineers we will need.

Q2e. What are the key determinants of the demand for nuclear engineers and other nuclear workers?

A2e. Nuclear energy and nuclear science and engineering are "high tech" fields and require a highly educated workforce. The nuclear power industry has held a key role in defining the numbers of nuclear engineers in the workforce. The nuclear power industry will continue to need significant numbers of nuclear engineers. Other nuclear-related fields in national defense, security, fusion, medicine, accelerator applications, etc. will need significant new nuclear engineers.

Q2f. How large do you believe DOE's university programs must become (and how quickly) to allow the Nation to produce the new graduates you estimate are needed?

A2f. Studies by the DOE–NE Nuclear Energy Research Advisory Committee (NERAC), supported by interactions with representatives from all universities, indicate that a funding level of at least $33M per year is necessary to maintain and build a strong nuclear engineering educational infrastructure in the U.S. This number includes funds for expanded research at universities, expanded use of existing university research reactors, new initiatives to support nuclear engineering faculty and students.

These funds could be used right away. This is necessary to stem the decline in nuclear engineering programs which has already seen a number of nuclear engineering degree programs and university research reactors vanish over the past twenty years.

Q3. A number of studies suggest that the number of nuclear workers per plant is declining. What is the average number of college trained (at each level) personnel employed at a typical reactor today and how many do you expect a typical reactor to employ in 2013?

A3. For some time, U.S. utilities have looked toward the European model for reactor operations management where similar size plants are run with about 500 workers compared to about 800 per plant in the U.S. This decline in personnel would result in a major cost savings. It should be noted, however, that the ability to run a plant with fewer workers is highly dependent on having extremely well trained and experienced personnel. So while the number of workers per plant may decline, the need for better-educated personnel becomes increasingly important. This, in fact, provides more incentive for maintaining a healthy group of nuclear engineering degree programs at universities.

Cutbacks in personnel numbers without sufficient emphasis on experience and skills could be disastrous. If cutbacks in reactor operating staff are accompanied by less oversight and a smaller commitment to maintenance and safety, plant operations could be severely compromised. This again argues for a strong nuclear education program and the need for well-educated staff.

Q4. What factors determine the size of university departments and programs? To what extent do you consider the future demand for graduates by the industry *in determining the appropriate number of students to enroll and graduate at your university's programs?*

A4. In most cases, the faculty size in a given university nuclear engineering program is determined by undergraduate enrollment numbers, usually about 5 to 10 undergraduate students per faculty member. The undergraduate enrollments are controlled by the college of university and by student interest. The undergraduate enrollments are usually out of the control of the department, other than through information and incentive programs. The faculty numbers, in turn, determine the size of the graduate program since the numbers of graduate students are determined directly by the research funding and other departmental resources. For a program our size, we would expect to have about 30 or more students graduate with BS degrees each year. Our program is typical of many, so the total numbers of BS nuclear engineers would range upward from about 500 graduating each year.

Q5. You suggest that nuclear engineering be treated more as a discipline, like chemical engineering. In your opinion, to what extent should nuclear engineering be forced to compete with other disciplines through the National Science Foundation or other multi-discipline funding agencies, rather than be allowed to rely on programs dedicated directly to nuclear disciplines?

A5. Nuclear engineering is a unique discipline, based on uses and applications of nuclear processes such as nuclear fission, nuclear fusion, nuclear magnetic resonance, nuclear spallation, radiation transport, etc. This is comparable to chemical engineering which is based on the use and application of chemical processes.

The nuclear engineering community feels that funding opportunities should be made available through NSF and other federal funding avenues. We see this not so much as a competition with other disciplines, but rather as establishing a meaningful presence for nuclear-related activities in those agencies. For example, NSF has a number of divisions each of which is responsible for funding a specific discipline. It would be appropriate to add a division which covers nuclear engineering. [The attached Appendix includes a draft position statement from the Nuclear Engineering Department Heads Organization (NEDHO) and the National Organization of Test, Research and Training Reactors (TRTR) regarding the development of a nuclear radiation and sciences effort at the National Science Foundation.]

We should also note that some nuclear-related funding is already covered through federal agencies other than DOE. For example, NSF and the Department of Commerce (through NIST) fund neutron scattering work associated with materials characterization, in addition to similar efforts funded through DOE. NIH has programs in the nuclear medicine area. These types of programs are important to expanding and broadening the nuclear field.

Questions submitted by the Minority

Q1. As director of a university program, how do you determine the appropriate number of students to enroll and graduate? To what extent do you consider the future demand for graduates by the nuclear power industry? How do you determine what the demand will be? What methodology would you suggest to identify the required number of university reactors, where they should be located and the appropriate level of Federal Government support?

A1. University programs will need to produce perhaps several hundreds of BS graduates per year in nuclear engineering to meet current and future needs. These needs are based not only on the nuclear power industry, but also on other nuclear-related fields in security, defense, advanced systems, medicine, fusion where graduates are needed. It is hard to determine the exact numbers, but they should be two to four times the current enrollments to start to meet our national needs. This is based only on the continuation of nuclear power efforts at current levels. At the undergraduate level, the numbers of students that enroll in nuclear engineering is due to student selection, and is not directly controlled by the various nuclear engineering departments. BS students will select nuclear engineering based on their perceptions about the challenges and career opportunities the field will provide. Roughly half of the BS students will eventually end up in the nuclear power industry. The other half will pursue of the career paths in related areas and many will attend graduate school to pursue advanced degrees.

Q2. Dr. Kammen suggests that the current production rate of 500–700 new nuclear engineers over ten years is sufficient for the nuclear power industry while Ms. Howard's testimony suggest we need 90,000 new workers of the coming decade, of which over 20,000 would go to the power industry. Do you agree with these *estimates? If not, what do you think is the right number of nuclear engineering graduates the Nation will need? Do you have a sense of how many commercial reactors would be required to employ your estimated number of future employees?*

A2. First let me clarify the large differences in the numbers projected by Ms. Howard and Dr. Kammen. The need for a large number of well educated and trained nuclear workers by Ms. Howard includes a large number of technicians and technically trained staff who don't necessarily need to be degreed nuclear engineers. The rather low number indicated by Dr. Kammen is from a scenario which would deemphasize nuclear power in the U.S. and reduce the numbers of operating nuclear plants. We are already producing nuclear engineers at the rate Dr. Kammen suggests and this is clearly insufficient to support a variety of needs, particularly those in the nuclear power arena.

Nuclear engineering is a high tech field but educates engineers much more broadly as engineers than is typically perceived. It turns out that nuclear engineers are equal to many types of engineering jobs, and have the added bonus that they understand radiation transport, nuclear criticality and several other areas that are not covered by other engineering disciplines. This means that nuclear engineers, if there were sufficient numbers available, could take on many of the positions that are currently held by other engineering disciplines (EE, ME, . . .) with the added advantage that they could also cover all of the nuclear aspects. This means that the nuclear engineering workforce should expand to provide even better coverage of nuclear power operations.

Q3. You suggest that nuclear engineering be treated more as a discipline, like chemical engineering. Why should nuclear engineering have funding programs dedicated to it? Should nuclear science and engineering compete with other disciplines for funding from NSF and other funding agencies?

A3. I have answered this question in the response to the majority questions #5, and respectfully request that you refer to that response.

Q4. In view of the potential terrorist threat to the safety of university nuclear reactors, how can the security of those reactors be assured? What would be the costs of security measures? What degree of these costs should be borne by the Federal Government? Are there any legislative measures that Congress should take to assure university reactor security?

A4. Nuclear reactors at universities are secure. They may provide attractive targets for terrorists, but they could cause much less real harm than many other civilian targets. Campuses, in concert with NRC guidelines, have stepped up security measures for university research reactors following 9–11. The costs include, one-time cost items, such as more secure perimeters and monitoring devices, and continuing items such as more security personnel. It is not clear to me to what extent the Federal Government should cover these costs, though they may substantial. It is my opinion that the oversight and guidelines provided by the NRC for university research reactor security are sufficient, thus no new legislation is necessary or needed.

Q5. How should the government determine how many research reactors the country needs, if the idea of regional reactors is to save money and eliminate duplication?

A5. University research reactors are multi-functional facilities. They perform important roles for teaching, research and applied radiation services. In their capacity as research facilities, they can be regionally located and shared by a variety of users. Specialty research facilities can be located at individual facilities, and shared by the appropriate research communities. Researchers from other locations would travel to the facilities for extended periods to utilize specific experimental facilities and capabilities.

In their other functions, the concept or regional reactors is more difficult to justify. As teaching tools, it is important that students have access to reactor facilities without detracting from other necessary academic pursuits. In this sense, regional reactors are not nearly as effective as reactors located where there are strong nuclear oriented academic programs, or academic programs that rely strongly on reactor facilities (i.e., radiochemistry, nuclear medicine, nuclear biomedical research, etc.). This argues for more university research reactors than are currently available. Reactors would be co-located with the appropriate educational programs and be equipped to handle their teaching, outreach and service functions. More specialized equipment would be added as appropriate to serve various research needs, and to avoid duplication for more advanced, research level facilities.

Appendix

A Draft Position Statement regarding NSF Support for Nuclear Science and Engineering

(MAY 2003)

NUCLEAR ENGINEERING DEPARTMENT HEADS ORGANIZATION (NEDHO)
NATIONAL ORGANIZATION OF TEST, RESEARCH, AND TRAINING REACTORS (TRTR)

Research in Nuclear and Radiation Science

The NEDHO and TRTR recognize an urgent need for support from the National Science Foundation for the fields of nuclear and radiation science (NRS), outside the nuclear engineering areas traditionally focused on nuclear energy research and development. Over the past decade, nuclear science and engineering (NSE) departments in U.S. universities have significantly broadened and diversified their instructional and research programs into various NRS fields, covering scientific, medical, and industrial applications of ionizing radiation. Thus, NSF support of basic NRS programs will significantly enhance the ability of the academic NSE programs and university research reactors (URRs) to contribute to the society.

For more than two decades, NSF has taken the position that support for the NSE programs is the responsibility of the Department of Energy. The DOE support of the NSE programs through the Office of Nuclear Energy, Science and Technology has, however, been limited primarily to the support of nuclear engineering research, student fellowships, and the Innovations in Nuclear Infrastructure and Engineering (INIE) program initiated in 2002, which will provide limited facility upgrade and operating support for a few URRs. The NSF response of 23 May 2001 to Senator C. Bond focuses mainly on the student fellowship programs available as part of the nuclear physics program, and does not address the important need for NSF funding to support and promote basic NRS research. In light of the broadened scope of the NSE programs and URRs in recent years and the importance of NRS research programs to the Nation, NEDHO and TRTR request that NSF initiate a separate program to fund NRS research activities in broad disciplines including engineering, physics, chemistry, geology, and environmental sciences. We request an initial funding level of $20M/year for the Nuclear and Radiation Science Program in the Division of Chemical and Transport Systems, Directorate for Engineering. In light of the modest funding level, we further request that the NRS Program be restricted to the research and instructional activities of U.S. academic institutions.

There are many programs within the National Science Foundation that would benefit from the application of radiation either as a diagnostic tool or for material modification processes. Achieving full benefits of these applications will require significant research in NRS, which we believe is best addressed via a focused program within NSF. A focused NRS Program would provide for much better coordination of research activities across various science and engineering disciplines that would benefit from this core research.

Potential NRS Areas for NSF Support

The focus of NRS programs lies in the study of mechanisms of interaction of ionizing radiation of various types with matter and in scientific applications of radiation. In addition to the enhanced applications of ionizing radiation in physical sciences and engineering, there has been increased interest in recent years in applying radiation science to medical diagnosis and therapy and to radiation safety. There is an urgent need identified for the development of accurate and efficient surveillance systems and assaying devices for special nuclear material in homeland security.

The core of NRS can be subdivided into several sub-topics. Radiation transport analysis and simulation is necessary to design and interpret results from diagnostic tools, detection devices, and material modification processes. Modeling of radiation transport still represents a very challenging computational problem where the merging of computer science, applied mathematics and physics is very much needed. A focused program within NSF would build upon the substantial investments that the Department of Energy is making in developing radiation transport modeling capabilities in support of national defense.

Instrumentation development is of great importance in support of developing diagnostic tools and material modification processes. With the rapid development of advanced materials for non-nuclear applications, there has been demonstrated a great potential for spin-offs in the development of radiation detection instruments, which would play an important role in homeland security. In conjunction with instrumentation development is the required research on signal processing from both a hardware and software viewpoint.

None of the above activities would be possible without research on enhanced radiation sources. There are substantial opportunities in developing radiation sources of the desired type, intensity, energy, coherence and polarity, customized to the specific diagnostic tool or material modification process. In addition, specialized radiation sources are required to support fundamental nuclear research, such as is possible with ultra-cold neutron sources.

Finally, it is readily recognized that engineers and scientists trained in NRS will be required to support a number of key scientific programs, including the Spallation Neutron Source under construction at Oak Ridge. In this regard, training of graduate students in neutron scattering, neutron activation analysis, neutron radiography, and related fields would make effective use of URRs and should be considered as an integral part of the NRS program.

Thus, the proposed NRS Program would provide natural and synergistic collaboration with a number of existing NSF Divisions:

- Radiation transport analysis: Bioengineering and Environmental Systems, Atmospheric Sciences, Astronomical Sciences, Environmental Biology, Mathematical Sciences, and Physics.
- Radiation detection and diagnostics: Astronomical Sciences, Materials Research, and Physics.
- Advanced radiation sources and URRs: Materials Research, Earth Sciences, Ocean Sciences, Design, Manufacture, and Industrial Innovation, Environmental Biology, and Physics.

In the following sections of this white paper are presented specific areas of research that would benefit from a core research program focused on nuclear and radiation science.

1. Radiation Transport Analysis

(a) Radiation Transport Computational Methods

- Starting from the Manhattan Project, obtaining accurate solutions to radiation transport equation has been a challenge.
- Fast and accurate methods are important especially for real-time transport analysis for clinical applications and the design of the future generation of nuclear power plants.

(b) Health Effects of Ionizing Radiation

- Linear No-Threshold regulations rely on data of Japanese bomb survivors and radiation accident victims, and may entail waste of financial resources.
- Further study will be necessary to determine if repair mechanisms inherent in biological cells could provide a threshold for deleterious effects of ionizing radiation.

2. Radiation Detection and Diagnostics

(a) Radiation Detection and Measurements

- Fundamental to safe and effective uses of ionizing radiation for medical, scientific, and industrial applications is the ability to identify minute quantities of radiation.
- Development of miniaturized, robust radiation detectors would contribute significantly to medical therapy, space physics, and astrophysics as well as homeland security.

(b) Radiation Imaging and Therapy

- Significant enhancements are necessary in imaging tools and associated software for accurate delivery of radiation doses, to make full use of portable radiation detectors.
- Alternate radiation treatment modalities, including proton beam, neutron capture, and heavy ion therapies, offer large potential benefits.

(c) Radiation Safety

- Protection of the public and radiation workers from deleterious effects of radiation requires further study to accurately determine internal and external radiation doses.
- Advanced radiation facilities rendering minimum doses to patients and operators should implement risk-based control and regulation of radiological procedures.

(d) Non-destructive Testing

- Neutron activation analysis (NAA) identifies trace quantities of impurities or special-purpose materials in scientific, industrial, and environmental applications.
- Prompt gamma (PG) NAA enhances discrimination against background and identifies light elements, for medical, industrial, and homeland security applications.

3. Advanced Radiation Sources and University Research Reactors

(a) Ar/Ar Geochronology

- Measurement of ^{39}Ar, produced through neutron irradiation of ^{39}K, and of ^{40}Ar, formed through natural decay of ^{40}K, yields the age of geological samples.
- The technique enables geologists to study volcanic eruptions, geological faults, glacial and ocean plate movements, and oil and gas deposits dating back a billion years.

(b) Radiochemical and Tracer Study

- URRs have active programs to produce radioisotope tracers for scientific, medical and industrial applications.
- Significant funding will be required to develop fully functional radioisotope production facilities at select URRs for clinical trials of radiopharmaceuticals.

(c) Neutron Scattering

- Neutron powder diffraction instruments and cold neutron sources at URRs offer significant potential in condensed matter physics and materials science.
- Such facilities offer opportunities to perform campus-based research in material structure studies and train undergraduate and graduate students in multiple disciplines.

(d) Boron Neutron Capture Therapy

- Neutron beams at URRs have been used in clinical trials to study the efficacy of boron neutron capture therapy for the treatment of brain tumors.
- Significant research will be required to determine the proper modalities of this cancer therapy, including the utilization of epithermal neutrons.

(e) Neutron Radiography and Radioscopy

- Neutron radiography uses a beam of neutrons to image light materials, particularly hydrogenous fluids, contained within metallic structures.
- Significant research will be required to obtain quantitative imaging capability for neutron radiography, especially for real-time applications.

(f) Positron Beam

- Positrons are produced by neutron capture and subsequent photon annihilations, and used as sensitive probes to investigate the structure and defects in heavy materials.
- Low-energy positrons are easily trapped in vacancy-type defects of atomic dimensions, providing accurate information on the near-surface structure.

ANSWERS TO POST-HEARING QUESTIONS

Responses by David M. "Mike" Slaughter, Director, Center for Excellence in Nuclear Technology, Engineering, and Research; Chair, Nuclear Engineering Program, University of Utah, Salt Lake City

Introduction

The statements herein respond to individual questions, both Majority and Minority, received from Congress, and are intended to provide a more comprehensive and integrated understanding of issues that surround those questions. Each section identifies in brackets the specific questions that are addressed by the response.

University Role in Education/Technology Creation [Majority 2, 3, 4; Minority 1, 2]:

A public-supported university operates on a limited budget from its state legislature. Upper level administrators at universities and colleges are challenged by the reality that their educational institution must deliver a quality educational experience with limited resources. No single institution can offer every academic and professional program. Thus, university stakeholders focus support on programs that best enhance the success of the students, faculty, academic institution, State, and industries within their geographic area.

Local, national, and international needs, as well as our nation's chosen role in the international community, influence the number of nuclear engineering and University Research Reactor (URR) programs that exist in the United States. The continuation and maintenance of existing technology is closely tied to the number of students who enroll in Nuclear Engineering or other nuclear-related disciplines, successfully graduate with a Bachelor of Science degree, and immediately enter the workforce. It is the students who go on to graduate school to earn Master of Science (MS) and Doctor of Philosophy (Ph.D.) degrees that become the creators of innovative future technologies. They are also the engineers and scientists who teach at universities, perform basic and applied research at national laboratories, operate and manage nuclear facilities, enter government service, and start up and lead commercial businesses. It takes a minimum of 8 to 10 years to develop an advanced degree nuclear engineer and scientist. Yet our current education and research infrastructure at universities is grossly lacking for this latter group when you consider the importance and extent of their roles.

If we desire only to *maintain* current U.S. nuclear technologies as a nation and with respect to our international community (running in place, if you will), then we must now encourage and optimize the use of limited education resources for students who choose to enter the workforce with a BS degree in nuclear engineering or in a nuclear-related field. Such support is felt broadly across all engineering and science programs. The academic laboratory and research facilities and the educational curriculum associated with nuclear engineering and research reactor programs are also used by students earning other engineering and science degrees. However, the choice to simply *maintain* technologies comes at a high price: It means that the United States would and could no longer be a world leader in technological advancements and such role would fall on other nations to provide guidance and breakthroughs for future technologies. The United States would not reap the full economic benefit of new technologies. In addition, our nation would clearly be hampered in its ability to improve all aspects of the fuel cycle (fuel manufacture, power generation, fuel recycle/disposal) associated with nuclear power applications. It would soon be beyond our capability to design the next generation of nuclear power technology that will require advanced fuels for remote locations (such as for exploration of the ocean floor and space travel).

From an energy perspective only, this may not be perceived as a major concern if the United States chooses to significantly reduce or eliminate the generation of electricity via nuclear power. However, the technical understanding and development capabilities of the U.S. would be reduced in many other strategically important applications: nuclear weapons, nuclear medicine, radiopharmaceuticals, material science, radiation detection and protection, nuclear material diagnostics, and neutron transport—to name just a few in nuclear-related fields. The truth is the impact would be felt on downstream industries in energy, transportation, environment and national resources, and future industries that we cannot conceive of because they have not yet come into being.

Our graduate-degree recipients are most likely to advance our national understanding and capabilities. An investment now in programs for these graduate students allows the United States to continue to play a predominate role in the international community. Their sustained role as nuclear technology creators and leaders assures a secure and technologically balanced future for the United States, in spite of dramatic global shifts in political, social, and economic arenas.

At the University of Utah, we restrict admission in the Nuclear Engineering Program to a maximum of 12 graduate students at any given time who are pursuing either an MS or Ph.D. Our educational program consists of an intensive and broad study of nuclear phenomena and engineering. The restriction on the number of students allowed into the graduate program ensures sufficient time for students and faculty to interact on a variety of levels, allows students to gain access and utilize limited yet extremely sophisticated equipment and resources, and provides a quality educational experience overall. University of Utah MS and Ph.D. candidates are required to participate in academic classes and laboratories, research reactor operations, and compliance activities associated with our Nuclear Regulatory Commission (NRC) regulatory program; to serve on multi-disciplinary national and international research teams with industrial/government partners; and, of course, to pursue their independent research in partial fulfillment of their degree.

The conclusions of Dr. Kammen and Ms. Howard concerning projected numbers of required trained nuclear workers over the next ten years significantly differ because of their critically different perspectives. This is not a surprise given that these colleagues have opposing views regarding the future of the nuclear power industry. In my opinion as a nuclear engineering professional and scientist, the conservative figure of "500–700" that Dr. Kammen estimates is indicative of a profoundly declining industry rather than one that is attempting to maintain its technical expertise. Ms. Howard's estimate of "20,000" represents a significant growth that does not reflect the current political/social limitations that will temper that forecast. Unfortunately, both estimates at opposite ends of the spectrum not only arise from greatly diverse perspectives, but also incorporate widely differing uncertainties. It is not *how many* we educate that is the core question, but what our engineers and scientists will *do* with their education that determines our future needs.

Technical Alliances and INIE [Majority 5, 6; Minority 4]:

Developing special education and technical alliances allows curriculum and special research facilities to be shared by a number of university nuclear engineering and research reactor programs, and the idea of equitably sharing resources is both positive and practical. If properly implemented, the potential benefits for education and research are far greater than the sum of technical accomplishments achieved by individual and separate institutions.

Partnership with other educational and research programs potentially results in an integration of expensive instrumentation along with the complex activities required for experimental studies (for example, using BNCT and neutron diffractometers or creating radiopharmaceuticals), and enlarges creativity within the available pool of experienced faculty and graduate students. Proper teaming of equipment and investigators is essential to avoid duplication or excessive overlap of tasks and program elements.

The Innovations in Nuclear Infrastructure Education (INIE) program was not conceived or intended to include all university research reactor programs. It was designed with competitive solicitation in mind, based on finite resources, as are all our other funding opportunities. INIE enabled the development of innovative educational and research tools to be used in university programs, which allowed university faculty and students with industry involvement to evolve our educational infrastructure to a new level. In the beginning, the program was structured to fund innovative and regionalized education/ research/facility concepts in the field of nuclear engineering and research reactor programs. Proposed INIE Centers that had made an initial unsuccessful attempt could refine their innovative concepts for later submission as additional funds became available. The INIE program was not an entitlement nor did it seek a preconceived number of INIE Centers.

While participating INIE Centers are required to track their progress toward proposal goal(s), it is not clear in practice that INIE funds will be reduced or eliminated when a center's progress is deemed insufficient or unsatisfactory. By choice, a number of universities that had research reactor programs did not participate in the program or did not follow-through with a proposal. Unfortunately, in addition, some promising proposals were ill-fated due to confusing changes in the solicitation requirements. Ultimately, this *process*—not the INIE program itself—resembled no other Request for Proposal (RFP) that participants had ever been involved in. The evolution of the INIE Centers program heavily underscores how much implementation, positively or negatively, impacts the actual delivery of an innovative program far beyond its original conception.

Lead universities may find it difficult in the current economic climate to embrace other research reactor programs into their own existing facilities without sufficient seed funds to make the transition. A reallocation of the current level of funds may endanger the ability of INIE Centers to effectively fulfill existing grant obligations. If other university research reactor programs are assigned without an increase in financial support, affected INIE Centers should be allowed to amend their grant objectives and schedules to accommodate the burden.

Reprogramming dollars and shifting solicitation parameters after proposals have already been approved for funding have grave consequences on the short- and long-term financial stability of research reactor programs, most of which are already operating on extremely lean resources and staff to vie competitively for solicitations. As a program administrator and scientist, I work tightly within the given restrictions when I am fully aware of the available funds and the process in which I will be judged. I ensure that our budget is appropriate for the proposed tasks and the proposal closely matches the solicitation so that our program is more often successful in gaining approval and awards. We obviously cannot and do not submit for every possible Request For Proposal (RFP); for example, the University of Utah has not submitted a proposal for a NERI grant as it is not applicable, at least to our program. Other nuclear engineering departments and programs may have faculty and/or an infrastructure more capable or more attuned to contribute effectively to that grant's objectives. When awarded funding is suddenly reduced or solicitation parameters altered post-submission, or changes occur in the review process and merit criteria, the award/submission ratio also drops, and the result is higher risk to the program attempting to secure financial strength and constancy.

NRC Security Obligations [Majority 0; Minority 3]:

The University of Utah has always taken its security obligations seriously; we have an Emergency Plan and Security Plan that cover any existing risks, just as all other universities with research reactors do. Research reactors at most universities pose a far lower risk in reality than is perhaps perceived by a community at large, in main part because the public lacks understanding of the differences between reactors and their purposes and any potential risks. Nevertheless, in the post-9/11 environment, existing Security Plans at universities underwent extensive review with revisions as necessary, security measures were fine-tuned, monitoring facilities were expanded, and increased personnel training was implemented. The University of Utah and other universities with research reactors are concerned that the Nuclear Regulatory Commission (NRC) may require additional security measures that provide no substantially increased security benefit (such as when a legitimate risk factor is reduced or eliminated). Costs associated with existing new security requirements, along with potential new requirements, ultimately will be borne by the university and its research reactor program unless Congress appropriates sufficient funds to upgrade facilities to properly implement new security measures required by the NRC.

Available University Reactors and Funding Paradigm [Majority 1; Minority 1, 4, 5]:

The determination of the number of research reactor facilities in the United States should never fall solely on our Federal Government, in part due to the nature and complexity of the facilities themselves. The small and finite number of university research reactors currently operating in the United States vary in power and possess diverse technical capabilities—capabilities that are best assessed by the nuclear engineers and scientists who comprise teaching faculty at our universities. Universities have knowledge of various research efforts, trends, and advances; are aware of where students are enrolling and focusing their studies; and support the directions their faculty are taking in programs to ensure not only well trained graduates but graduates who have fostered their imaginations and have vision. Universities perceive research reactors as fundamental resources to be cultivated over time, decade after decade, so that they will be readily available to stimulate future minds and, ultimately, solutions. Finally, universities already seek input from both industry and government in estimating national need. In addition to self-regulation by universities, the NRC regulates licenses and monitors the vitality of university research reactors. Thus, the current system combines a diverse cross-section of different research and teaching interests with practical perspective derived from industry and government and has built-in federal NRC safeguards. Universities remain the best organizations to gauge current and future needs.

Federal resources are limited and shrinking. The challenge is to use these valuable and finite financial resources to ensure that educational and research capabilities at universities across the Nation are not inadvertently lost. Federal funds should be used to offset costs associated with NRC regulatory activities, to maintain state-of-the-art instrumentation for research reactor operation, and to promote more effective use of facilities. Federal matching programs to universities that encourage industry involvement with students in university research reactor programs have a three-fold effect: Such funds stimulate U.S. industry in developing new nuclear applications and technologies, allow access to cutting-edge research and development from universities, and reciprocally provide students superior hands-on educational experiences in real-world industries, contributing to their future success.

Although instrumentation and reactor-sharing programs currently exist, they are funded at conservatively low levels. Support needs to be increased to $1M each. An innovative industrial matching program could mirror and expand the existing structure of university matching fund grants available to many nuclear engineering departments or programs. The DOE would provide a financial match when an industry donates funds for unrestricted use in maintaining and advancing the research reactor capabilities, up to a specified limit (for example, $50,000). Thus, a $50,000 donation from industry would result in a $50,000 match from the DOE. If the donation was of a lesser amount, say $5,000 from the industrial contributor, then the DOE obligation would only be for that amount. An industry matching funds program would provide an incentive for industry to participate in developing and enhancing educational and research facilities.

Funds are needed from the DOE (approximately $10M) for universities with research reactors to reimburse costs associated with complex activities that comply with NRC regulations. Such reimbursement lowers the costs of operation of university research reactors to levels competitive with the operational costs of other educational, engineering, and science laboratories. It also allows education and research costs to be reimbursed at equivalent levels. Federal agencies have had no hindrance in compensating direct costs due to activities on grants and cooperative agreements. However, the costs associated with NRC regulatory activities are independent of specific educational and research tasks, and are required to be performed regardless of value as an educational or research task. Currently, the costs associated with NRC activities are not accounted for in negotiated and accepted institutional Facilities and Administration (F&A) overhead rates.

Universities should continue to cover the costs associated with performing educational lecture and laboratory classes, faculty, and teaching assistants. When appropriate, governmental agencies (such as DOE, NIH, NSF, DOD, etc.) that outsource research opportunities (for example, NERI, NEER, and INIE) to universities with research reactors should cover allowable direct costs (use of facilities, supplies, graduate students and faculty). The INIE program should be refocused, and its scope and cost scaled to its original intent to develop curriculum and special research facilities for regional use. In no circumstance should federal funds displace university and industry contributions.

Industries should be encouraged to fairly compensate universities for technology development, service activities, and use of university resources (both research reactors and brainpower). A matching funds program for industries would provide an alternative source of funding that advances university research and educational capabilities. Industry participation, with its focus and perspective on cost effectiveness, timeliness, and ergonomic design, enhances university programs and provides greater educational breadth and depth for students.

Appendix 2:

ADDITIONAL MATERIAL FOR THE RECORD

STATEMENT OF HAROLD L. DODDS

PH.D., P.E., IBM PROFESSOR OF ENGINEERING AND DEPARTMENT HEAD, NUCLEAR ENGINEERING DEPARTMENT, UNIVERSITY OF TENNESSEE-KNOXVILLE

Introduction

Chairman Biggert, Mr. Lampson, and Members of the Subcommittee, it is indeed an honor and a pleasure to provide written testimony on the capability of university nuclear engineering programs to produce graduates to help meet energy, environmental, economic, human health, and security needs of the United States. My initial comments will address the importance of nuclear energy and nuclear technology to society, and the current status of nuclear engineering workforce supply and demand in the United States. I will then describe what The University of Tennessee Nuclear Engineering Department is doing to affect the supply side of the nuclear engineering workforce issue while, at the same time, maintaining high quality standards for its graduates. Finally, I will conclude with some suggestions on what the Federal Government should be doing, in my opinion, to address the nuclear workforce issue.

Importance of Nuclear Energy and Technology

Nuclear generated electricity constitutes 20 percent of the total amount of electricity generated in the United States and is currently our least expensive major source of electricity according to the Utility Data Institute. It is also the most environmentally benign of the major energy sources in that it produces essentially no air pollution including no greenhouse gases that can lead to global climate change. Coupled with hydrogen production for transportation and other end-use energy needs, nuclear energy has the potential to be the "savior of our planet" from an environmental point of view. Further, major improvements in human health have been made possible by nuclear technology via improved diagnostic and therapeutic medical procedures, and by making food safer for human consumption. Also, many commercial industries rely on nuclear techniques for monitoring and quality control in manufacturing and for increased productivity (e.g., nuclear instruments are used in oil well logging). Finally, and most importantly, nuclear energy has the potential to greatly reduce and eventually eliminate our dependence on foreign energy sources (e.g., foreign oil), which is vitally important to the energy and economic security of our nation. In short, nuclear energy and technology is a commodity-type resource that has become indispensable to our standard of living and our way of life, and therefore must be sustained.

Role of University Nuclear Engineering Programs

Nuclear engineering and health physics programs at universities in the United States have the responsibility and the commitment to supply graduates who satisfy workforce needs in these strategically important nuclear areas. Up to now the workforce supply has, for the most part, met demand thanks to support from the United States Department of Energy (DOE) Office of Nuclear Energy, Science and Technology, which has provided critically needed financial support for student scholarships, fellowships, and infrastructure improvements in university nuclear engineering programs. Similar financial support has also been provided by several nuclear power utilities. The financial support provided by DOE and nuclear utilities is responsible for many students entering the nuclear engineering field, which is the main precursor that enables workforce supply to meet demand. However, the current "graying" of the nuclear workforce in the United States (i.e., 30 percent can retire within five years) indicates there will be a shortage of nuclear engineering graduates in the near future. An increased level of financial support from DOE and the commercial nuclear industry for additional scholarships, fellowships, and infrastructure improvements would help to mitigate the shortage. Even greater DOE support as recommended by the May 2000 NERAC report (Nuclear Energy Research Advisory Committee), also called the Corradini report, would be an even better approach to mitigate the shortage.

University of Tennessee Nuclear Engineering Distance Education Programs

To address the impending shortage and also to respond to the needs of a significant segment of society, the University of Tennessee Nuclear Engineering (UTNE) Department has implemented four new distance education programs, which are delivered live and interactive over the INTERNET in real time to the student's computer. These four programs are the Master of Science Degree in Nuclear Engineering; a Graduate Certificate in Maintenance and Reliability Engineering; a Graduate Certificate in Nuclear Criticality Safety; and a Colloquium Program that is free and open to the public as well as to students and faculty. The Colloquium Program consists of weekly presentations by experts from industry, academia, and government laboratories, and is a major outreach activity for our department. The Colloquium presentations are also archived on our website for posterity (see *http://www.engr.utk.edu/nuclear/colloquia/*. UTNE is the only nuclear engineering program in the United States with a weekly Colloquium Program that is delivered live and interactive over the INTERNET (i.e., webcast).

These four new distance programs augment the traditional model of students coming to campus to pursue an education with a new paradigm that "takes the university to the students." Thus, students who want to study nuclear engineering, but do not live or work close to a university with a nuclear engineering program, can pursue their educational goals from their home or office (or on the side of a mountain in Nepal) provided they have a computer connected to the INTERNET (for the student vacationing in Nepal, his laptop was connected to the INTERNET via satellite). In other words, UTNE distance education programs have opened the door of nuclear engineering education to a huge market of people who would otherwise pursue a different educational objective because of convenience, or pursue no educational objective at all. To illustrate, our distance programs have led to an almost 50 percent increase in UTNE graduate enrollment over the past two years with distance students from New York to Brazil and from Chicago to Birmingham, Alabama. The increase in our graduate enrollment combined with the increase in our undergraduate enrollment due to aggressive undergraduate recruiting has resulted in UTNE becoming the second largest nuclear engineering program in the United States based on total student enrollment.

More importantly, the quality of our distance programs is the same as our local on-campus programs in that the distance students take the same courses simultaneously with local students. Concurrent course delivery is accomplished by using a big-screen, touch sensitive Smart Board in the local classroom, which permits the same information to be presented to local students (both audio and video) that is presented to distance students via the INTERNET. Distance students can ask questions vocally in real time just like local students, and vocal answers by the instructor are available to both local and distance students in real time. In addition, distance students can collaborate on projects with local students and make presentations that are available to all students, both local and distance, and to the instructor in real time. Although the quality of our distance programs has not been compromised relative to our local on-campus programs, attending class in person is still probably the first choice of most people. But this first choice is not an option for many who have families and hold full-time jobs (e.g., employees at remote nuclear power plants and other remote locations). Thus, UTNE distance education programs enhance the supply side of the nuclear engineering workforce by providing the only alternative available to many people.

Conclusions and Recommendations

While increased financial support from DOE as indicated above is certainly a move in the right direction in addressing the nuclear workforce issue, what is needed even more is strong leadership from the highest levels of government to advocate and promote nuclear energy and technology. Government advocacy should be accompanied by meaningful actions such as loan guarantees to industry, and/or partnership with industry, for construction of a first-of-a-kind, next generation nuclear power plant. More importantly, recent polls (conducted after 9/11) indicate that two-thirds of the American public support the expanded use of nuclear power. However, many of our government leaders still consider the "nuclear" word as something to be avoided politically (e.g., President Bush did not mention nuclear power in his 2003 State of the Union Address). It appears that our leaders either do not know about the recent polls or do not believe their results.

In summary, it is time for our government leaders to join with the American public in endorsing the expansion of nuclear energy and technology in the United States so that its many benefits to the environment, human health, national security, and our economy can be realized.

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Closing the Nuclear Fuel Cycle for Current and Advanced Energy Production
Actinide Chemistry for Radioactive Waste Disposal, Partitioning, and Transmutation

Washington State University
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I. Summary

The demand for energy worldwide is exceeding supply, even with improvements in efficiency and conservation. Fossil fuel consumption is growing to meet this demand, while global warming resulting from carbon dioxide emissions is one of the biggest long-term threats to our environment. These and other factors make a renewal of nuclear energy in the United States likely. However, ***growth of nuclear power remains limited in the US until the nuclear fuel cycle is closed.*** For example, no existing spent nuclear fuel has yet been placed in a geologic repository. Also, little emphasis currently exists for development of technologies for advanced fuel cycles that could lead to significant waste volume reduction.

Many of the technical challenges that limit closure of the nuclear fuel cycle and development of advanced fuel cycles & fourth generation reactors are ***chemical challenges*** that are not effectively addressed by the discipline of nuclear engineering alone. These challenges, described in more detail below, include our limited understanding of the chemistry of plutonium (Pu) in the environment, and the development of processing technologies that minimize the amount of Pu and other actinides in radioactive waste disposal streams. In the subdiscipline of ***radiochemistry***, these challenges are the focus of research efforts. At Washington State University (WSU), radiochemistry is an essential component of the Chemistry Department. ***Establishment of an Institute for Actinide Environmental and Separations Chemistry at WSU would be a strategic investment in the closure of the nuclear fuel cycle for current and future energy production.***

II. Technical Issues

The US currently uses a "once through fuel cycle" (OTFC) that sends all actinides and fission products produced during fuel irradiation to a geologic repository, although U and Pu could be recycled for addition power production. This approach generates the largest volume of waste, and ***continued practice of the OTFC will require many additional waste repositories if nuclear power production continues beyond today.*** The "reprocessing fuel cycle" (RFC) is used by nations such as France, Japan, and the United Kingdom, and recycles U and Pu back into the fuel for additional energy production. This approach reduces waste volumes by as much as five times.

The "advanced fuel cycle" (AFC) is an improvement in the RFC. U and Pu are recycled for additional energy production, and other radionuclides are consumed by nuclear transmutation via reactor or accelerator system. Transmutation uses nuclear reactions to alter the most hazardous radionuclides (other than U and Pu) into less hazardous, short-lived ones. This fuel cycle provides significant reduction in waste volumes, although a geologic repository is still necessary. ***Development of an AFC for the nuclear energy program in the US would extend the life of its existing geologic repository significantly.***

In addition to consideration of wastes from our current generation of reactors and fuel cycle, attention must also be given to the entire fuel cycles for fourth generation nuclear reactors. For example, pebble bed reactors being developed in South Africa allow for continuous refueling via partial replacement of fuel pebbles. ***The impact of such a spent fuel waste stream on these fuel cycles must be considered.***

OTFC, AFC, and spent fuel from fourth generation reactors present significant technical challenges that must be addressed for the US to close its nuclear fuel cycle, and to maintain or increase its current nuclear energy production capacity. These technical challenges include:

- ***Improved predictive capabilities for modeling the performance of waste repositories for the isolation of radioactive wastes on a geologic timescale.*** Predictive capabilities must be developed from improved knowledge of actinide chemistry in the environment.
- ***Development of improved chemical separations technologies that optimize the partitioning of U, Pu, and other actinides for industrial scale processing.*** New approaches to chemical separations that are highly selective and that consider approaches such as aqueous, nonaqueous, bio-, and/or supercritical processing must be developed.
- ***Development of chemical processing technologies to support incorporation of new fuel forms for fourth generation reactors and transmutation processes.*** The impact of higher

burn-up fuels and alternative fuel forms such as fuel pebbles on the closure of the fuel cycle must be considered.

These technology needs to support the renewal of nuclear energy in the US coincide with erosion in the academic infrastructure that provides training in these areas. During the last US growth period for nuclear energy, e.g. the late 1960's and early 1970's, many academic chemistry departments provided undergraduate and graduate training in radiochemistry. At that time, US colleges and universities produced about 24 chemistry PhD's annually who had training in radiochemistry. This was accomplished in Chemistry Departments that had 2-3 faculty members in this subdiscipline. Today, only about five US academic Chemistry departments provide any graduate level training in radiochemistry, generating about 6 PhD's annually. Very few of these Chemistry Departments have more than one radiochemistry faculty member, and many of these faculty members will retire in the next decade.

III. An Investment in Washington State University

Washington State University (WSU) is one academic program that has maintained its training capabilities in radiochemistry in its Chemistry Department. ***WSU has two tenured Professors who are actinide radiochemists, and both are less than 50 years old.*** These two faculty members are producing PhD radiochemists who are highly sought after by DOE site contractors and national laboratories. In addition, WSU has unique radiochemical laboratory facilities and a Nuclear Radiation Center that houses a 1 MW research reactor.

If additional resources are provided, the Chemistry Department at WSU is capable of addressing the technical challenges outlined above, and producing more PhD students in radiochemistry for the nuclear workforce. Prof. Sue Clark is an internationally recognized expert in actinide environmental chemistry, and conducts research in the areas of Pu chemistry in high-level radioactive waste, and actinide fate and transport in repository and far-field environments. Prof. Ken Nash is also internationally recognized, particularly for his extensive work in actinide radiochemical separations. Both Profs. Clark and Nash have developed strong collaborative ties with various DOE sites and national laboratories, including Pacific Northwest National Laboratory, Idaho National Laboratory, Lawrence Berkeley Laboratory, Oak Ridge National Laboratory, and Westinghouse Savannah River Company. ***With additional support for their research efforts, the radiochemistry program in the Department of Chemistry at WSU can grow*** to address the chemical challenges described above, and produce more students who will enter the DOE work force to face these challenges and help carry the US into a safe, clean, and productive nuclear future.