WISE

Washington Internships for Students of Engineering

THE FUTURE OF THE NUCLEAR WORKFORCE: The Government's Role

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Washington Internships for Students of Engineering
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ABOUT THE AUTHOR

Laura Beth Bienhoff, a native of Kensington, Kansas, will be entering her senior year of studies at Kansas State University in Manhattan, Kansas in fall 2003. She will graduate in May 2005 with a bachelor's degree in chemical engineering and minor in business. At KSU she is actively involved with departmental events and the Society of Women Engineers. Prior to the WISE internship, she worked for the Dow Chemical Company in Freeport, Texas. Her interest in nuclear policy issues and the WISE program led to her participation as an American Nuclear Society sponsored WISE intern for summer 2003.

ABOUT THE WISE

The WISE program is the Washington Internships for Student of Engineering program. This internship is a unique experience for upper level undergraduate engineering students of all disciplines. The WISE program brings about 14 to 16 students to Washington, D.C. for 10 weeks during the summer to study how technical public policy is made. The entire group is supervised by a Faculty Member in Residence who arranges meetings with representatives from engineering, science, and technology organizations in D.C., such as the National Science Foundation and National Academy of Engineering. Technical societies sponsor each intern and provide mentors and resources for the summer. Each intern is also responsible for researching a public policy issue of interest to their sponsoring society and them. This paper is a product of that research.

Further information about WISE, as well as the research papers from this summer can be found on the WISE website at http://www.wise-intern.org.

ACKNOWLEDGEMENTS

First and foremost I would like to thank the American Nuclear Society for sponsoring me as a WISE intern and giving me this incredible opportunity. Thank you to the Nuclear Energy Institute, especially Sherry Reilly, for its hospitality, resources, and for giving me a home for the summer. Carol Berrigan, thank you for all the information on workforce issues. Thank you to Dr. Alan Levin and the rest of the ANS mentors for mentoring me and steering me in the right direction. Thank you also to Dr. Jim Dennison for arranging all of our thought-provoking meetings with officials in Washington. Last, but definitely not least, thank you to all the WISE guys and gals for the phenomenal summer, especially Jennifer Cole for being a fabulous roommate and officemate. I wish all of you the best of luck in the future!

EXECUTIVE SUMMARY

In 5 years, it is estimated that 30 percent of the current nuclear workforce will be eligible to retire; in 15 years this raises to 50 percent. The nuclear workforce includes the 14,000 nuclear engineers working in the United States today. Therefore the demand for nuclear trained professionals, such as nuclear engineers will be increasing. Unfortunately, interest and enrollment in nuclear engineering has declined this past decade. In 2000, only 160 bachelor's degrees were awarded, which is a 20 percent drop from just 1999. Additionally, there are fewer places to study nuclear engineering. Today there are only 30 universities offering nuclear engineering programs, which is a 50 percent drop from a decade ago.

It is important that there are enough nuclear engineers because of the variety of technologies using nuclear science. Food irradiation, X-rays, radioisotopes, sterilization of medical materials, and space exploration are examples of where nuclear science is utilized. The largest percent (58 percent) of nuclear engineers work in utilities, though. Nuclear power is important for the U.S. as it supplies 20 percent of the nation's electricity.

The safety of working in the nuclear industry is sometimes questioned. The Nuclear Regulatory Commission (NRC) regulates nuclear reactors and radioactive materials for the safety of both the public and nuclear workers. In addition to safe working conditions, nuclear engineers receive the second highest engineering average salary at almost $80,000 per year. As a result of the need for nuclear engineers, job outlook is good for graduates in nuclear engineering.

Even with all the advantages of a nuclear engineering career, enrollment is still low. One reason for this is the public's perception of nuclear engineering and nuclear sciences. Students of engineering (nuclear and non-nuclear) perceive nuclear engineering as old and dying, monotonous, dangerous, not diverse, and no visible products to relate to. Furthermore, no new nuclear power plants have been ordered in over 25 years, leading to the perception that nuclear power is no longer important for our electricity supply.

University programs must be stable and have adequate resources to train the nuclear engineers of the future. Nuclear programs are facing the same aging issue as industry. Two-thirds of nuclear engineering faculty members are over 45 years old. Nuclear programs are being shut down, as previously mentioned. University research reactors (URRs) are valuable part of nuclear engineering education and also are facing the prospect of being shut down. Currently there are only 26 university research reactors in the U.S., which is down from over 60 in 1980.

These issues have not gone unnoticed by industry or the government. The NRC and Department of Energy, Office of Nuclear Energy, Science, and Technology (DOE-NE) are directly involved. Because of the NRC is a regulatory agency, they can not directly advocate for nuclear engineering, but still have an influential role. The NRC provides

the public factual information about the industry, and more importantly makes sure that the industry is safe. The NRC does directly help universities by waiving relicensing fees for URRs. DOE-NE has several programs addressing workforce issues. These programs include funding research at universities, funding directly for university infrastructure, scholarships and fellowships, and funding for outreach programs. The investment that DOE-NE has put into funding university infrastructure has helped increase enrollment nuclear engineering programs. The newest DOE-NE program is Innovations in Nuclear Infrastructure and Education, which encourages further use of URRs and promotes partnerships between universities, industry, and national labs.

Non-government societies and industry are addressing workforce issues as well. These programs include outreach to pre-college students and public education. The American Nuclear Society offers scholarships as well. Industry provides internships for college students.

Current energy legislation will have an impact on increasing interest in nuclear engineering if passed with nuclear provisions. Incentives for new nuclear power plant construction and funding for nuclear university are both being discussed for inclusion.

The focus of this report is to make policy recommendations. From my research, I have made the following recommendations to the NRC and DOE-NE:

- Nuclear Regulatory Commission
  - Continue educating the public.
  - Continue waiving URR relicensing fees.
  - Continue ensuring the safety of the industry.

- Department of Energy, Office of Nuclear Energy, Science and Technology
  - Expand the INIE program.
  - Increase URR funding.
  - Increase reactor sharing funding.
  - Continue funding outreach activities for pre-college students.
  - Create a program aimed at recruiting young faculty to universities.
  - Include universities on all research initiatives.

As mentioned, this is a policy focused report, but also included are a few recommendations to industry and professional organizations. Following are these recommendations.

- Increase public outreach and promotion of the nuclear industry.
- Companies should increase participation in the DOE matching grants program.
- Continue and increase internship and scholarship opportunities.

In conclusion, the nuclear workforce is going to be challenged in finding enough nuclear engineering graduates to fulfill the jobs that will be opening because of retirement.

Nuclear science is important for the U.S. in different areas, especially as a supply of electricity. For this reason the government should provided funding for activities that would increase interest in nuclear engineering as well as improve nuclear engineering university programs.

INTRODUCTION

> *"If we are to meet the energy, environmental and medical challenges of the future, then initiatives like these are absolutely critical to preparing the next generation of nuclear engineers and scientists."*
>
> Energy Secretary Abraham in a June 10, 2002 press release unveiling the Innovations in Nuclear Infrastructure and Education Program.[1]

The nuclear industry is going to challenged to find enough trained nuclear scientists and engineers in the future. The nuclear workforce is aging, and many workers are preparing to retire. Moreover, enrollment in nuclear engineering programs is declining, the number of nuclear engineering programs is declining, and university research reactors are being shut down. This has prompted the United States Department of Energy, in addition to industry and professional, to examine these issues, and lead to the above statement by Secretary Abraham.

It has also prompted me to research these issues for my participation in the Washington Internships for Students of Engineering program. This report is a product of that research, and focuses on what the workforce challenges are, what is currently being done, and my personal recommendations for increasing enrollment in nuclear engineering programs. Because this is a policy-focused internship, the recommendations I make are primarily focused on improvements that the Department of Energy could do, but also include a few recommendations for non-governmental entities.

The majority of the information that I acquired focused on nuclear engineering programs, and as a result the recommendations that I have developed to enhance the nuclear workforce is primarily focused on increasing enrollment in nuclear engineering programs. The nuclear workforce obviously also includes technicians that do not hold bachelors or graduate degrees, but I have chosen to focus on the engineering profession. Also I feel that it is important to note that when I refer to the nuclear industry, and I am again using terminology used in information that I have found. When referring to the nuclear industry, I mean anywhere nuclear engineers work, for example in nuclear power, radioisotope production, etc.

I have found nuclear workforce issues very interesting and far-reaching. Past research has been done in this area by university personnel, the Department of Energy, professional societies, and industry, and therefore there is a large amount of information available. I have learned a great deal this summer, but recognize there is much more to learn.

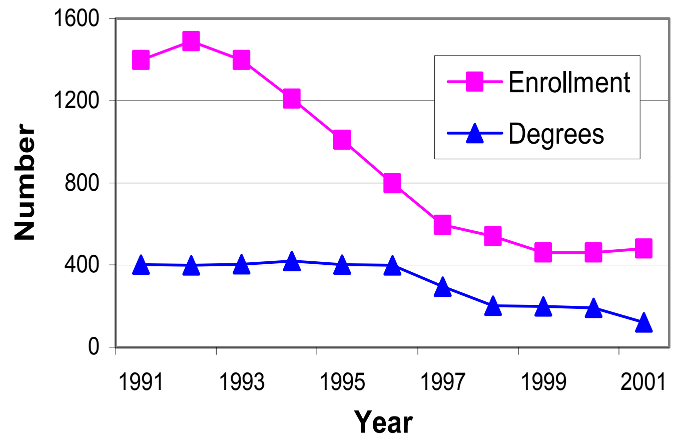

Figure 1.1 *The number of junior and senior college students enrolled in nuclear engineering programs and number of bachelor's degrees in nuclear engineering awarded for 1991 to 2001. Source:*

Nuclear science knowledge is important for our country, and for this reason it is also important that an educated nuclear workforce is in place. Unfortunately, the nuclear workforce is becoming threatened. As Figure 1.1 shows there has been a severe decline in the number of students graduating and enrolling in nuclear engineering programs. This is also coupled with a decline in the number of nuclear engineering programs, as shown in Figure 1.2. This leads to a dangerous cycle. As fewer students enroll in nuclear engineering programs, some are forced to close. As nuclear programs close, there are less opportunities and interest decreases, adding to the decline in enrollment. In addition to this, the gap between the number of students

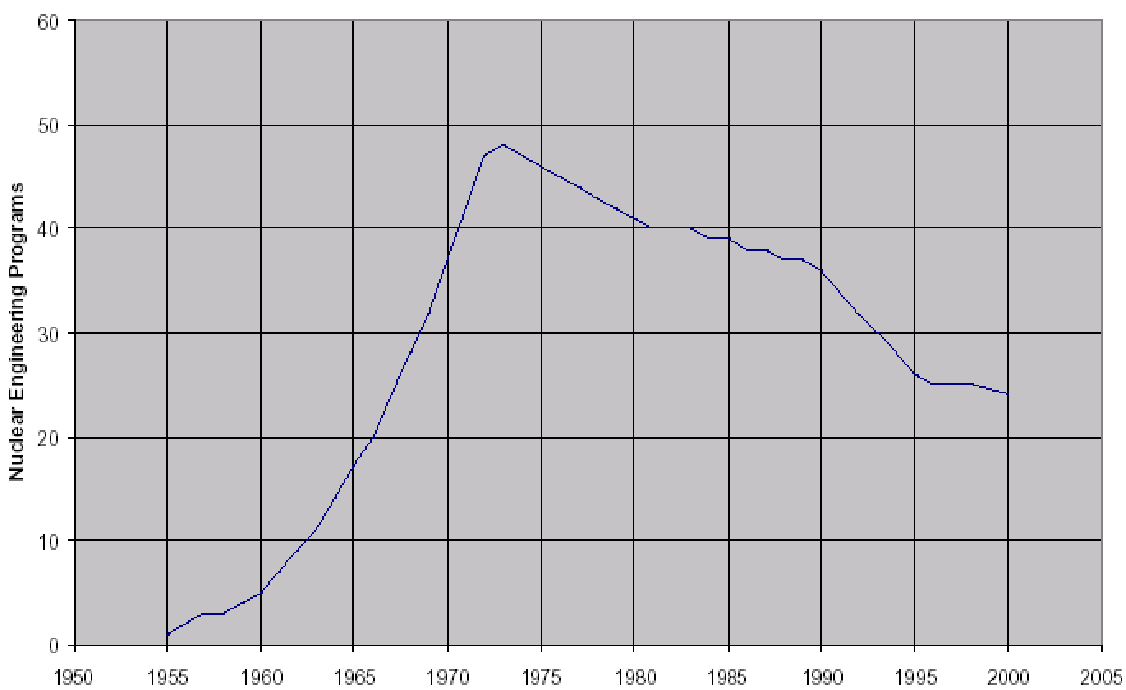

Figure 1.2 *Number of nuclear engineering programs. Source: http://www.ne.doe.gov/nerac/finalblue.pdf on 2 July 2003.*

graduating with bachelor and master's degrees and the number of available jobs demanding these degrees is widening. Figure 1.3 shows this widening gap.

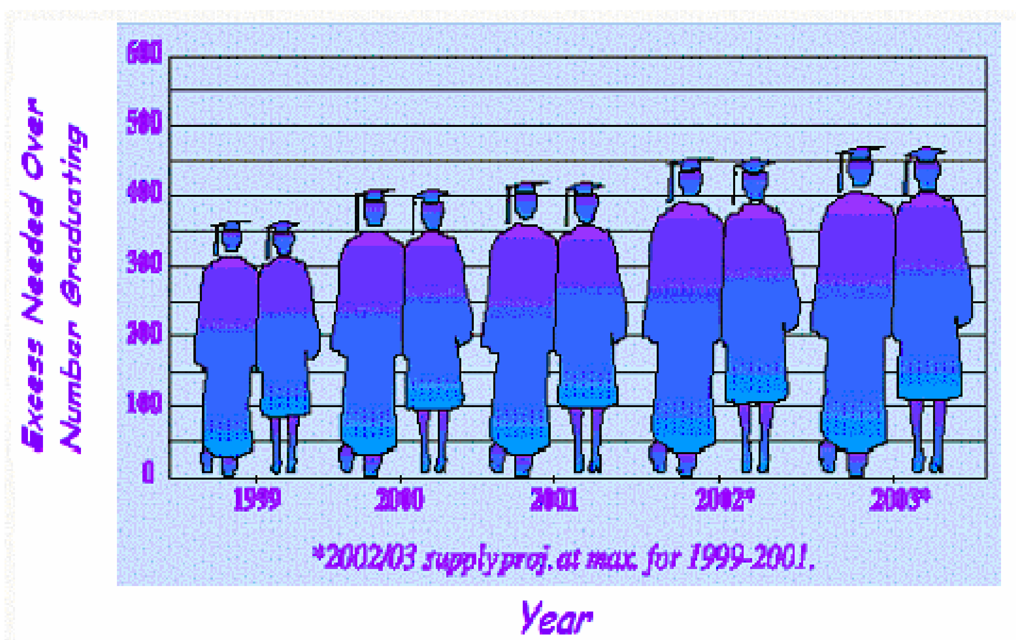

Figure 1.3 Graph showing the gap between the number of nuclear engineers needed and the number of nuclear engineers graduating. Source: http://www.ans.org/pi/np/careers/docs/demand.pdf on 16 June 2003.

At the American Nuclear Society (ANS) Executive Conference held in January 2003, workforce challenges were discussed and the following startling statistics were noted:

- In 5 years, 30 percent of the current workforce will be eligible for retirement. In 15 years, half of the current workforce will be eligible for retirement.
- There were only 160 bachelor degrees in nuclear engineering awarded in 2000, which is a 20 percent drop from 1999.
- Current enrollment, both undergraduate and graduate, is half of what it was ten years ago.
- There are only 30 universities offering nuclear engineering programs. A decade ago there were 60 universities.[2]

The declining enrollment and approaching retirement of many of industry's workers has not gone unnoticed. As mentioned, ways of attracting workers and these statistics were discussed by industry leaders at the ANS Utility Executive Conference. At the conference, Ross Ridenoure of the Omaha Public Power District made the following remark:

> "We've all heard that we're in a nuclear industry renaissance and that's wonderful. But it's not going to happen unless we have people that can continue

> to operate these plants and fuel cycles and engineering cycles and everything else that's needed for the industry….
>
> "If the people aren't there to run the plants, what we're doing today simply won't matter. We have to take more aggressive steps to attract and retain the workers we want."[3]

It is obvious that this is a serious concern of the nuclear industry, and action has been taken as a result. The Nuclear Energy Institute (NEI) has formed a Workforce Issues Task Force composed primarily of members from industry. The task force goals include analyzing workforce trend data, identifying the areas of concern, and then developing an action plan to address these areas.[4] Congress has also taken note of this pressing issue. In June 2003, the House Science Committee held a hearing, "The Future of University Nuclear Science and Engineering Programs." Expert testimony was given by representatives from the Department of Energy (DOE), NEI, and academia. The hearing purpose was to examine the DOE's role for supporting university nuclear science and engineering (NS&E) programs and their importance to the U.S. nuclear power. Support for nuclear engineering programs and research is included in the 2003 House energy bill, H.R. 6, which is awaiting action in the Senate as of July 2003.

Professional societies involved with NS&E have taken note as well. The Health Physics Society has taken action by urging the Congress and federal agencies to provide funding for health physics programs. ANS has formed "The Special Committee on Workforce" with the following four specific objectives:

1) Support the ongoing nuclear industry staffing analysis programs.
2) Identify programmatic responses to address workforce issues at all levels.
3) Organize a funding schedule and coordination process with other related and affected organizations.
4) Establish an electronic method for communicating workforce information.[5]

NERAC (Nuclear Energy Research Advisory Committee), who offers advice to DOE concerning issues arising in nuclear energy programs, is another committee concerned with the viability of university programs and the lack of interest in NS&E professions. In 1999, NERAC established a panel to examine the future of nuclear engineering programs, and subsequently produced the report "The Future of University Nuclear Engineering Programs and University Research and Training Reactors."[6]

Additionally, NERAC developed a long term plan for nuclear technology research and development plan in June 2000 which includes support for the NS&E education system and maintaining sufficient U.S. nuclear expertise.[7] Nuclear engineering faculty members are also concerned about declining enrollment for obvious reasons. The Nuclear Engineering Department Heads Organization, NEDHO, has produced two reports concerning the workforce for the nuclear future: "Vision for the 21st Century" and "Manpower Supply and Demand in the Nuclear Industry."[8]

This issue is not isolated to the U.S. The Nuclear Energy Agency, NEA, is part of the Organisation for Economic Co-operation and Development, OECD, and has membership of 28 different countries including the U.S. The NEA recognized and studied the decline of enrollment and number of nuclear programs around the world. The report "Nuclear Education and Training: Cause for Concern?"[9] published in 2000 is a product of their study.

Moreover, this is not a new industry concern. The National Resource Council produced a report in 1990 entitled "U.S. Nuclear Engineering Education: Status and Prospects," which studied the declining enrollment in nuclear engineering trend and offered recommendations to curb the decline. An article appeared in the October 12, 1992 issue of *The Scientist* magazine entitled "Undergraduate Enrollment Drop Threatens Nuclear Science."[10] This article consulted the National Resource Council's study, individuals in industry, and professors of nuclear engineering -- who all agreed that there is indeed a significant decline in interest in nuclear programs, and that action needed to be taken. The predicted staffing crisis did not occur, largely because of factors working against new nuclear power plant orders,[11] but today is this still a concern.

Declining enrollment in nuclear science and engineering programs is definitely a threat to the advancement of nuclear science and technology that is vital to our nation. Industry, academia, and government have been aware of this issue that is not only affecting the U.S, but also other nations, for over a decade now. Many studies have been conducted on this problem, but yet it is still an issue of concern.

THE PRESENT AND FUTURE USES OF NUCLEAR SCIENCE AND TECHNOLOGY Section 2

When most people think about nuclear science, the energy industry often comes to mind first, but it is certainly not the only application of nuclear knowledge. Nuclear scientists have specialized knowledge of radiation and radioisotopes which can be utilized in a variety of ways. For example, nuclear scientists work in nuclear medicine, food preservation and safety, product safety, agriculture, environmental applications, and as health physicists.[12] Following is more detail about the current and future uses of nuclear science.

Radioisotopes are one area of nuclear science utilized in industrial settings. For example, smoke detectors rely on a small amount of americium-241 to detect smoke. The carbon dating method used to determine the age of a sample that was once alive takes advantage of the radioactive properties of the carbon radioisotope, C-14, which is present in all living beings. Neutron activation can be used to determine the elemental composition of a sample. This method is especially attractive and widespread because of its ability to determine concentrations as small as a few parts per billion and a number of different elements in one sample simultaneously. In addition to that, this can be done swiftly and inexpensively.[13]

Radiation knowledge is used in the irradiation of food. The irradiation of food kills microorganisms that cause food to spoil. Currently, there are regulations allowing spices and dry vegetable seasoning, dry or dehydrated enzyme preparations, red meat, and poultry to use radiation to control micro-organisms. Additionally, all foods are approved to be irradiated in order to control insects.[14] The support and clear benefits of food irradiation show that nuclear scientists with knowledge of this process are going to be needed in the future.

X-ray technology is a more commonly recognized use of radiation. Airports rely on x-ray screening to scan luggage, and this has become increasingly important following the events of September 11th. X-ray radiography is also widely used in the medical community. X-ray scanning is helpful to help doctors diagnose injuries and ailments. There are several additional opportunities that employ both nuclear and medicinal knowledge. For example, radiation is used as cancer treatment.

Doctors and dentists require sterile tools. Radiation can be used to sterilize medical materials that would not withstand sterilization by extreme heat. According to ANS, about 50 percent of all medical disposable materials such as bandages, sutures, and surgical drapes are sterilized by irradiation.[15]

There is also a place for nuclear technology in space exploration. Nuclear energy was the source of energy for over 25 missions that traveled around the earth, to other planets, and moons.[16] Heat produced by the decay of radioactive elements is also used to protect and heat instruments on missions.

These are just a sampling of where nuclear science knowledge is needed outside of the nuclear energy sector. All of these technologies rely on the knowledge of nuclear sciences, either in the implementation of the method or technique, or in the development of equipment that must safely utilize radiation. These are all areas that will only continue to grow, advance, and need trained workers.

The nuclear energy industry is going to strongly competing with these various industries for workers trained in nuclear science. According the Bureau of Labor Statistics (BLS), about 58 percent of nuclear engineers work in utilities.[17] There are several reasons why nuclear energy is an attractive energy source and interesting industry to work in. With increasing concern about global climate change, the environmental benefits of nuclear energy are apparent. Nuclear energy production does not involve burning any fuel; therefore it does not emit any harmful gases, which contribute to acid rain and the greenhouse effect. According to NEI, if the US would have been using fossil fuels instead of nuclear energy, carbon equivalent emissions would be 30 percent higher, and 66.1 million more tons of sulfur dioxide would have been emitted from 1973 to 2000.[18]

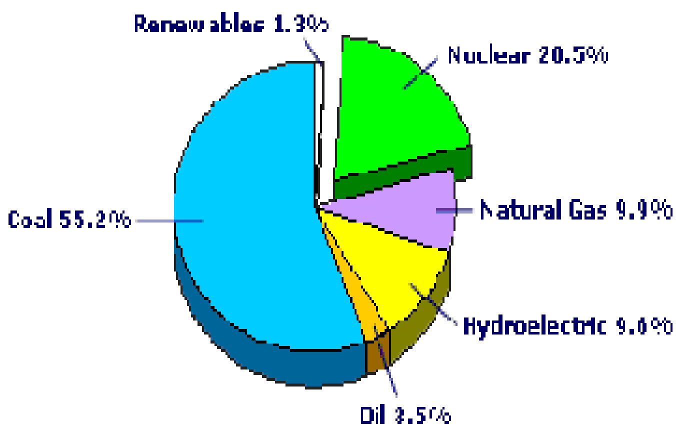

Figure 2.1 *Sources of electricity for the U.S. in 2000. Nuclear energy supplied 20.5%. Source:*

These are just a few reasons why in 2000 nuclear energy supplied 20 percent of the nation's electricity, up from only 4 percent in 1973.[19] Figure 2.1 shows graphically what all the sources of the U.S. electricity are. Coal is the only source more significant than nuclear, supplying 55 percent of US electricity.

Nuclear energy is obviously important for our nation's electricity supply, and will likely continue to be influential in the future for several reasons. First of all, the demand for energy is expected to increase in the future. In order to even maintain its 20 percent hold in the U.S. energy supply, nuclear energy production capacity will have to be increased. This can be accomplished by three means: building new power plant(s), license renewal and capacity uprates for already existing nuclear power plants. This process is already moving forward. According to NEI, 16 U.S. reactors have 20 year license extensions, 14 have applied for renewal, and an additional 20 are expected to apply for license renewal by 2008.[20]

Building a new power plant faces several barriers such as costs, licensing, and siting. Partly because of these barriers, it has been over 25 years since a new nuclear power plant has been ordered.[21] I hope this will change in the near future. The need for expanded electric generating capacity has prompted the development of the Nuclear

Power 2010 (NP 2010) program. Industry and government have joined together for NP 2010 with a goal of having a private sector decision by 2005 to order new nuclear power plants for deployment by 2010.[22] In addition to NP 2010, the nuclear energy industry has established Vision 2020. Vision 2020 calls for adding 50,000 megawatts of new nuclear electric generating capacity for the US by 2020, which is equivalent to 50 new nuclear power plants.[23]

Vision 2020 and Nuclear Power 2010 programs show the commitment that the government and nuclear industry have made to maintain and expand nuclear energy's use in the United States. However, their goals can only be accomplished if there are adequately trained individuals.

Nuclear science and engineering benefits reach several industries, and only a few areas where a nuclear science career can be pursued have been highlighted here. The advancement of nuclear science depends on innovative ideas and work of the future nuclear scientists and engineers. It is imperative that the government takes an interest in the education and recruitment of future nuclear scientists.

THE SAFETY OF WORKING WITH NUCLEAR SCIENCE — Section 3

The benefits of applied nuclear science are clear, but unfortunately accidents like those at the Three Mile Island Unit 2 Plant (TMI) near Middletown, Pennsylvania in 1979 and at a nuclear power plant in Chernobyl, Ukraine in 1986 raise questions about the safety of nuclear technology, and the perceived danger of working with nuclear prevents people from entering the nuclear workforce. That is why the Nuclear Regulatory Commission is important for the nuclear industry's safety. The NRC's mission is:

> *"… to protect the public health and safety, and the environment from the effects of radiation from nuclear reactors, materials, and waste facilities."*
> *(From http://www.nrc.gov/what-we-do.html accessed on 10 July 2003)*

The NRC responded to both TMI and Chernobyl. The NRC responded by in-depth investigation of TMI and subsequent changes in regulations. It is important to note that the TMI accident was the most serious in U.S. commercial nuclear power plant operating history, yet there were no resulting deaths or injuries to plant workers.[24]

The Chernobyl accident is the most severe accident at a nuclear reactor and resulted in the deaths of 31 people (although most of these deaths were by fighting the fires). Additionally, the U.S. NRC conducted thorough reviews of the accident and reassessed U.S. regulations, and the resulting report "Implications of the Accident at Chernobyl for Safety Regulation of Commercial Nuclear Power Plants in the United States" was issued in April 1989.[25] In this report the NRC first points out that a Chernobyl type event is not likely to occur in the U.S. -- due to differences in reactor design, broader shutdown margins, robust containment structures, and preventative operational controls. The report also concluded that no immediate changes in U.S. NRC regulations were necessary.

As part of their job, the NRC ensures that working conditions for anything nuclear related is indeed safe. The possible dangers of nuclear energy and radioactive material make the NRC's job challenging and closely scrutinized by the government and public. The resulting regulations that the industry must follow has produced an astounding safety record.

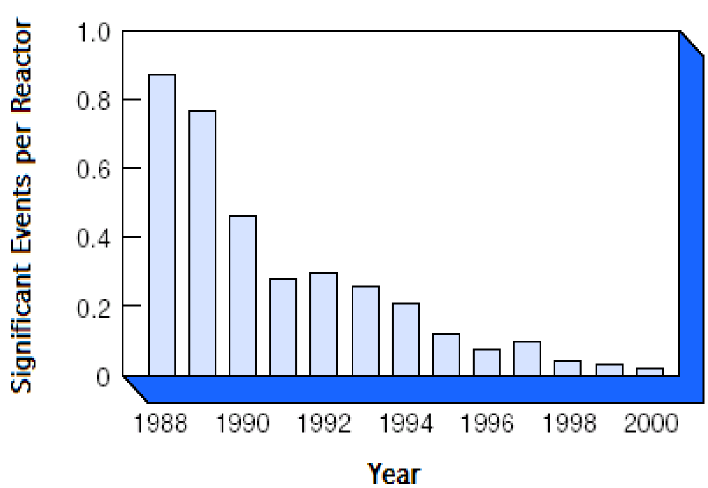

Figure 3.1 *Chart of the number of significant events per reactor for 1998 to 2000. Source: http://www.nrc.gov/reading-rm/doc-*

While NRC believes that it is ready to respond to an incident, and industry is continually improving reactor safety. Figure 3.1 shows that the frequency of significant events has dramatically decreased from 1988 to 2000. Overall radiation exposure to workers at a reactor has also decreased during this time period, as is shown in Figure 3.2. As technology improves and knowledge increases, these numbers are only going to improve.

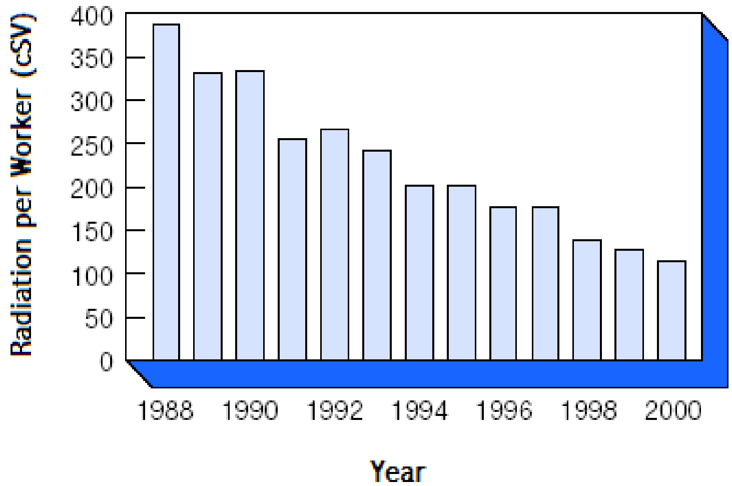

Figure 3.2 *Chart of the collective radiation exposure to a worker at a nuclear power plant for 1998 to 2000. (1 cSV = 1 millirem) Source: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1542/v7/sr1542v7.pdf on 6 August 2003.*

In addition to the impressive safety records, here is additional information about the NRC and radiation exposure:

- NRC inspectors spend over 3,000 hours per year inspecting a typical nuclear reactor plant.[26]
- A National Cancer Institute study showed no evidence of any increase in cancer mortality – including childhood leukemia – among people living in 107 counties that host, or are adjacent to, 62 major nuclear facilities in the United States.[27]
- The average occupational dose of radiation in the US nuclear energy industry was 115 millirem per worker in 1998. Cosmic radiation doses to airline pilots and cabin crews who regularly fly the high-altitude New York to Tokyo route is around 900 millirem.[28] The average annual radiation from natural sources is about 300 millirem to everyone.[29] Doses of 10,000 millirem spread over a time period of years to a decade pose no immediate problems for any body organ.[30]

NRC limits the radiation to members of the public to 100 millirem per year, and 5,000 millirem per year for adults working with radioactive material. These regulations were developed to be consistent with recommendations of national and international scientific organizations.[31]

The nuclear industry is strictly monitored and regulated by the NRC; safeguarding workers and public alike. The nuclear industry complies with the NRC regulations, and the outstanding safety history is a testament to the work of the NRC, government, and industry's commitment to safe nuclear and radioactive working conditions.

THE BENEFITS OF A NUCLEAR CAREER — Section 4

A career in the nuclear industry is appealing for several reasons. Several of these reasons have already been addressed. First of all, the industry is safe to work in. Second of all, in today's economy job security is also a concern. The annual unemployment rate for 2002 was 5.8% in the United States, which is the highest rate since 1994.[32] Yet the job outlook for nuclear engineers and scientists remains good, because of the shortage of educated professionals. +

Another advantage of working in the nuclear industry that has not yet been mentioned is the monetary benefits. According to 2001 BLS data, the average starting salary for a nuclear engineering bachelor's degree candidate is $49,609, and the average salary for the 14,000 nuclear engineers in the U.S. is $79,360.[33] This is the second highest engineering average salary. Only petroleum engineers have a higher average salary.

Finally, what I believe is the most appealing aspect of a career in nuclear science is the opportunity to continue learning. Like other scientific fields, there is always research occurring and something new being discovered. The technology is always being improved upon, and a successful nuclear scientist or engineer must be knowledgeable of this. No one person could ever know everything there is to know about nuclear science, and therefore there is always the challenge of learning more.

Job opportunity and variance, monetary compensation, safety, and learning opportunities make nuclear science career appealing, and need to be utilized to attract interest to the field.

CAUSES OF LOW ENROLLMENT Section 5

There is obviously no one reason why enrollment in nuclear engineering is declining. People who are concerned with this issue all have differing opinions as to what is the cause for declining enrollment. In my opinion, public attitudes and knowledge, lack of new nuclear power plant construction, and closing of nuclear engineering programs and university research reactors (URRs) are all key elements in declining enrollment that can be improved upon.

PUBLIC KNOWLEDGE AND VISIBILITY OF NUCLEAR SCIENCE AND ENGINEERING

In order for a high school student to choose nuclear engineering as a major, they must be aware of the nuclear industry. Public opinion and knowledge towards nuclear science will influence a student's decision, especially that of their parents and teachers. Therefore opportunities available in nuclear science must be visible. Additionally, the safety of the industry must be stressed.

Vice President of Human Resources & Corporate Relations for the Westinghouse Electric Company Tony Greco points out that:

> "If we don't educate today's young people about nuclear energy and its benefits, we are likely to lose this entire generation of workers to other technological fields… We must reach out to young people, whenever feasible, by means of print advertisements, television and the World Wide Web."[34]

It is important to not only make sure and educate the young people, but their parents and teachers as well. Bisconti Research conducted focus groups in spring 2000 to determine why students choose to study nuclear engineering. Not surprising, one of their major findings was that parents and teachers are an important influencing factor.[35] Parents and teachers of students entering college today lived when the Chernobyl accident occurred, and their perception of nuclear safety might be influenced by the accident. This is why it is imperative that the safety record of the industry and the work of the U.S. NRC are visible to the public.

In addition to potential danger, Bisconti research found these additional perceptions of a career in nuclear power:

- Well paid because of stress
- Monotonous, routine, repetitive
- Highly regulated and bureaucratic
- No visible product to relate to[36]

These views need to be addressed in order to gain interest, and not by Homer Simpson. Every group in the Bisconti study mentioned Homer Simpson[i] as a "defining source" of their views of the nuclear power industry.[37] Positive and factual information needs to be disseminated to counteract the views of the cartoon safety inspector for the Springfield Nuclear Power Plant.

A further view of the industry is that it is "maturing = old and dying."[38] It is has been established in this report that the workforce is aging and a large number of workers will be eligible for retirement in the near future. Instead of meaning more available job opportunities, some students get the impression that the industry is "old and not an inviting place to work."[39] Prospective students and public in general need to be assured that even though the workforce is aging and retiring, in no means is the industry preparing to "retire" and cease being important.

The lack of activity in the nuclear power sector is another possible reason that students do not view nuclear engineering as a career with job opportunities. Although it has been over 25 years since a new nuclear power plant has been ordered,[40] nuclear energy still supplies 20 percent of the U.S. energy.[41] Energy is something that is often taken for granted without thought of where it comes from. I think it needs to be stressed that without nuclear powered energy, one in five homes would not be able to turn on their lights, and nuclear engineers are needed to run the nuclear power plants.

The public and prospective students need to be aware that the industry is moving forward. Dr. Bill Vernetson notes that that University of Florida is noticing increased interest and enrollment which almost exactly coincides with decisions of utilities to apply for re-licensing and the announcement of Generation IV initiatives.[ii],[42] Programs like Nuclear Power 2010 and Vision 2020 show that the industry is looking to the future, and the public needs to be aware of these plans.

I believe that the opinion and knowledge of the public has a significant impact on capturing the interest of prospective students. The public needs to be aware that working in the nuclear industry is safe, interesting, exciting, and important for our country.

<u>UNIVERSITY INFRASTURTURE</u>:

To facilitate the staffing needs of the industry, nuclear education programs must be stable and inviting. Currently this is not necessarily the case. Nuclear programs are plagued by low enrollment and aging faculties. Furthermore, university research reactors are a key component to many programs, but many have been shut down.

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[i] Homer Simpson is a cartoon character on the popular Fox TV show "The Simpsons" in which many episodes are centered around the Springfield Nuclear Power Plant, where Homer works as a safety inspector.

[ii] DOE's Generation IV Nuclear Energy Systems Initiative is established to look toward the future of using Generation IV reactor technologies to the commercial market place ("Government Programs for Building New Nuclear Plants" by NEI, available at http://www.nei.org/doc.asp?catnum=&catid=&docid=775 accessed on 25 July 2003.)

The state of a nuclear program is a direct reflection of the faculty in my opinion. As previously mentioned, nuclear professionals are nearing retirement age. This is true for nuclear program faculties as well, over two thirds of the faculty are 45 years or older.[43] It then may appear that the knowledge and research is aged and dated. Younger professors can help convey a fresh image of the department and industry.

In addition to that, gender and ethnic diversity in faculties needs to be encouraged. Women and minorities are a small percentage of engineering programs in general. In 2002, an American Society for Engineering Education (ASEE) survey found that 20.9 percent of engineering bachelor's degrees were awarded to women, and 32.4 percent were awarded to non-Caucasian students.[44] I believe that the appeal of a nuclear department can be increased by having more diverse student population and younger faculty.

The facilities that a university has access to is another important part of any science and engineering program. For NS&E, having access to a research reactor (URR – university research reactor) can greatly enhance learning. Unfortunately, the number of URRs is declining swiftly. In the late 1960's there were 58 URR's and today there are only 26.[45] Figure 5.1 shows the decline in the number of URR since 1980. This decline coincides with the decline in enrollment, as shown in Figure 5.2.

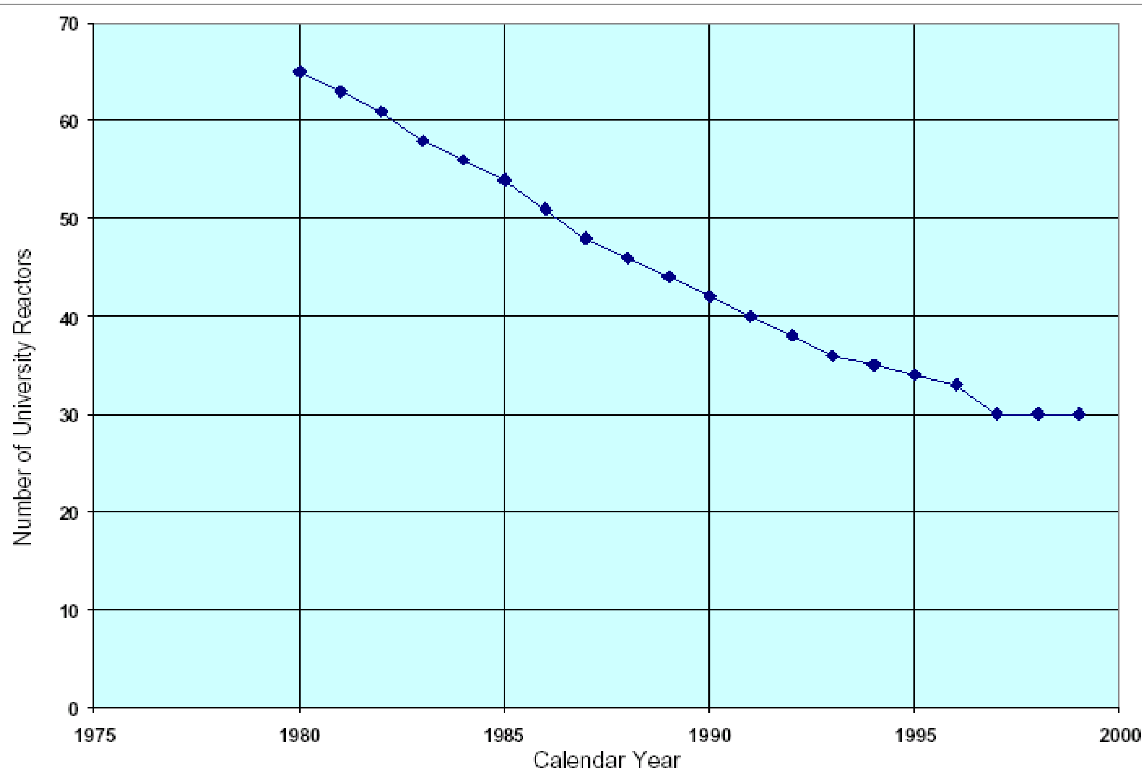

Figure 5.1 *Number of URRs from 1975 to 2000. Source: http://www.ne.doe.gov/nerac/finalblue.pdf on 2 July 2003.*

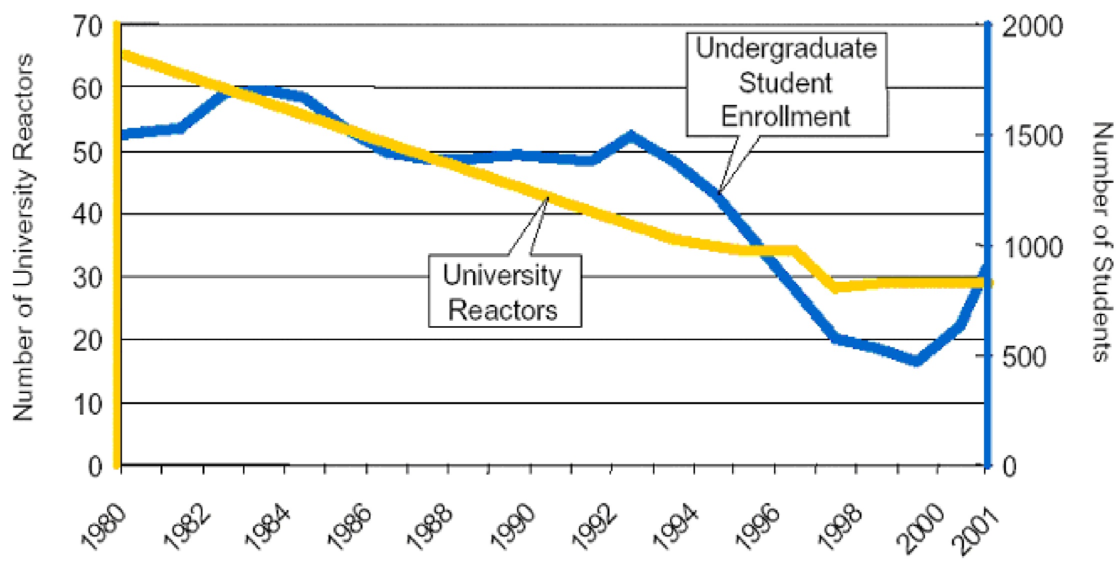

***Figure 5.2** Number of URRs and undergraduate enrollment in nuclear engineering from 1980 to 2001. Source: http://www.ne.doe.gov/briefings/Oct28_02%20AlbanyRPIConf.pdf on 2 July 2003.*

URRs are important to university programs for several reasons. Although URRs are very different than power reactors,[iii] they are still able to give students hands-on experience with a nuclear reactor while still in school. Most universities do not have a large staff and count on students to become licensed to operate the reactor.[46] Additionally, the reactors are utilized for research and learning, which is not only limited to nuclear engineering programs. The radiation and neutrons produced by an URR can be used by different university programs, such as geology, environmental studies, archeology, forensic studies, medicine, and nutrition.[47]

URRs can be a valuable tool to increase interest in nuclear programs. URRs are incredibly visible on a university campus. In my opinion, being able to show people how "cool" a reactor is, they will then believe that nuclear science is "cool" as well. For example, at Kansas State University the Society of Women Engineers hosts a Girl Scout Day for fourth and fifth grade girls. One of the activities is to tour the URR, and when surveyed, the girls often say that this is their favorite part of the day. The University of Massachusetts at Lowell (UML) has the ROSE program. ROSE is the Reactor Operations and Systems Experience Co-op program that allows interested students to learn about and use their URR. Dr. Gilbert Brown from UML uses this program and the URR to create interest in the nuclear option of the chemical engineering program.[48]

Other nuclear engineering faculty members reiterate that their URR is an important aspect of their department and program. When asked how vital they believed their URR was, following are two responses I received:

[iii] Power reactors are typically 600-1200 megawatts, but URR's are only from 5 – 100 megawatts. (Interview with Warren Eresian, 21 July 2003)

> "Very important! It is what attracts many students to our program and is a very visible (and cool!) part of our facilities tour. It is also useful in that it brings visibility for Oregon State to other researchers across the globe who send us samples for irradiation and use our other reactor facilities. It's a wonderful neutron producer and can be used for many research purposes."
>
> E-mail from Dr. Andy Klein, Oregon State University

> "The University of Florida Training Reactor (UFTR) facility is a key component of our undergraduate program. Though sometimes underutilized and always under funded, it attracts much outside interest from precollege students leading to later interest in NRE [Nuclear & Radiological Engineering]. It is also a recognized factor simply in attracting students into engineering regardless of emphasis area."
>
> E-mail from Dr. Bill Vernetson, University of Florida

The recognition of the importance of a URR to both nuclear education programs and research for the advancement nuclear science in various areas and concern about the possibility of being shut down has prompted several studies specific to URRs. A National Research Council conducted a study which resulted in the 1988 report "University Research Reactors in the United States – their Role and Value." A NERAC ab hoc panel studied the university and URR situation and presented their findings to DOE the report "The Future of Nuclear Engineering Programs and University Research & Training Reactors" in 2000. The DOE NERAC committee formed a task force specifically for URRs, which submitted a report of their findings in April 2001.

I believe the image of NS&E programs in the U.S. is important to recruit new students for the industry. Diversity, in both ethnicity and gender, should be encouraged in the faculties of nuclear sciences. Universities should also strive to hire young professors to help project a fresh image of their department, as well as the industry as a whole. University research reactors are valuable tool to NS&E students and faculty for several reasons. They are important part of educating and enticing the workforce of the future and need to be preserved.

The declining enrollment in NS&E programs, decrease in number of nuclear engineering programs, and shutting down of URRs has been noticed by organizations dealing with nuclear issues. The NRC, DOE, NEI, universities, industry, and professional societies are all concerned about these issues and have their own programs to address these issues.

THE NUCLEAR REGULATORY COMMISSION:

The NRC was established in order to protect the public and workers from radiation as a result of nuclear materials, reactors, and waste facilities. Because the NRC is a regulatory commission, they must be careful to ensure that they are factual and informative. The NRC does not advocate for or against the use of nuclear energy or radioactive materials. Therefore, the NRC does not have programs specifically targeting these issues.

The NRC does have influential role in these issues, though. As previously noted, the NRC regulates the nuclear industry to ensure its safety. Clearly a safe working environment is essential for recruiting new workers to the industry, and should be communicated to the public.

Although the NRC can not advocate for the use of nuclear power and technologies, they can – and do – publicize their safety and allow the public to voice their concerns about safety regulations. The NRC holds public meetings in order to gain the public's confidence in the NRC and their regulatory activities which are advertised on the NRC website (www.nrc.gov).

More directly affecting workforce issues is the NRC's work with URRs. The NRC is responsible for regulation and re-licensing of URRs. Even though URRs have far less power, their safety is undoubtedly important as well. When it comes time for a URR to be re-licensed, the NRC waives the fees.[49] In my opinion this is important for URRs as it eliminates one possible reason that it might be shut down.

Although the NRC does not have programs directly addressing workforce and related issues, they have a very important role for maintaining the workforce for the future. The NRC regulates URRs, nuclear power reactors, and any thing else nuclear related to ensure that working and learning environments are safe. Additionally, the NRC keeps the public informed of the industry's safety.

THE DEPARTMENT OF ENERGY, OFFICE OF NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY:

The DOE Office of Nuclear Energy, Science and Technology (DOE-NE) is the recipient and distributor of federal funds designated for nuclear education. As a result, DOE has several different programs for university infrastructure (including URRs) and research.

DOE-NE uses a considerable amount of their funds for R&D and URR support. Figure 6.1 shows where the money requested for the DOE-NE will be used for. Note that not all of the R&D funding will be for universities. The investment that the DOE has made in nuclear university programs appears to be helping increasing enrollment, as shown in Figure 6.2.

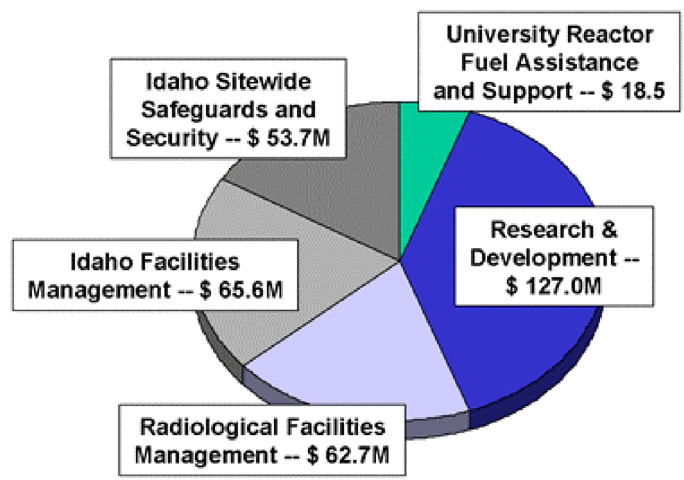

Figure 6.1 *Fiscal year 2004 budget request for DOE – NE. (In millions of $) Source: http://www.ne.doe.gov/admin/budget-soon.html on 17 June 2003.*

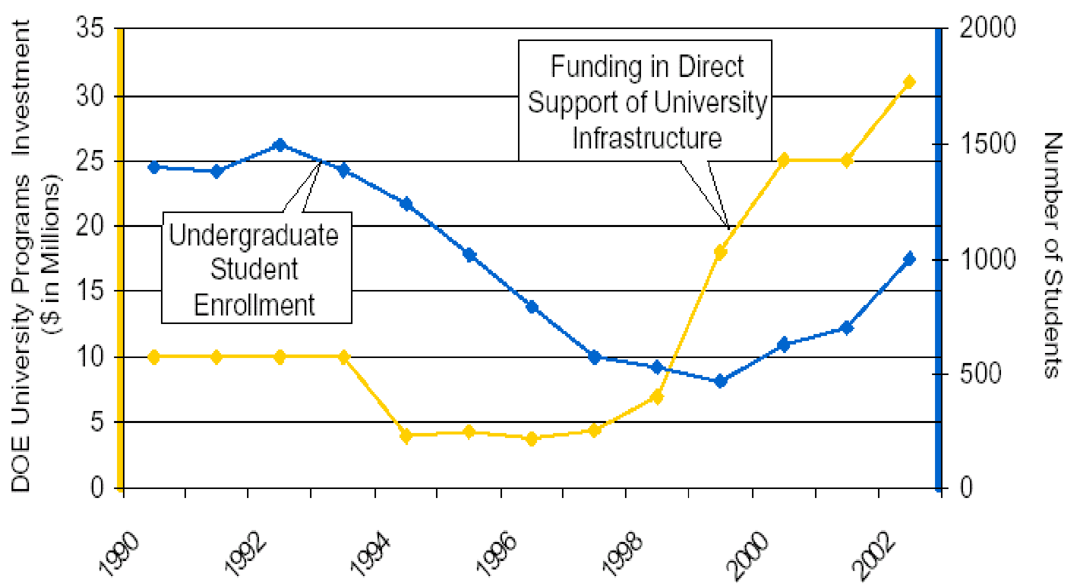

Figure 6.2 *Enrollment in nuclear engineering and the amount of DOE-NE funding to direct support of university infrastructure for 1990 – 2002. Source: http://www.ne.doe.gov/briefings/Oct28_02%20AlbanyRPIConf.pdf on 28 July 2003.*

The University Nuclear Infrastructure (UNI) program was established in FY03, and unites DOE programs that enhance university infrastructure. There are four elements to this program:

- Innovations in Nuclear Infrastructure and Education (INIE) – Encourages partnerships between universities, industry, and DOE national laboratories for further utilization of research reactors. Six consortiums, involving twenty three universities across the nation receive funding.[50]
- Reactor Fuel Assistance – DOE supplies fresh fuel and accepts spent fuel for URRs requiring it. Transportation of the spent fuel has posed a bit of a challenge in identifying who is responsible for the fuel as it is in transit, DOE or the university.
- Reactor Upgrades – About 20 – 25 universities a year receive funding to use toward upgrading their URR.
- Reactor Sharing – Provides funds to universities with URRs to allow them to share their facilities with other institutions, for tours, and other educational activities.[51]

UNI programs explicitly target maintenance and further utilization of URRs as an important aspect of nuclear education infrastructure. The INIE program is a new and innovative approach to assisting URR usage and encourage partnerships, and it is really too early to tell what the impact of the program will have on the involved universities.

Universities can receive additional DOE funding to perform research. The Nuclear Engineering Education Research (NEER) grant program is specifically for university research. [52] Also important for university research funding is the Nuclear Energy Research Initiative, which is open to researchers from universities, industry, and labs. Between 1999 and 2002 universities received 31 percent of $110 million invested in the initiative.[53] The latest figures show that 71 bachelors, 131 masters, and 65 doctorate students have participated in NERI projects.[54]

Industry works along with DOE to provide financial support to universities through a matching grants program. This program provides funding of up to $60,000 from each side for approximately 20-25 universities per year, and involves 35 utilities and private companies.[55] Universities are allowed to use this funding as they deem necessary. For example, the funds may be used for scholarships, modernizing equipment, or improving NS&E curricula.

Students may also receive support directly from DOE as well. Scholarships in nuclear engineering for undergraduate students and fellowships and scholarships for graduate students in nuclear engineering and health physics are available from DOE. Paid internships at U.S. national laboratories allow undergraduate and graduate students to gain work experience while still in school. Students can also apply to be part of the International Student Exchange Program (ISEP), which sponsors students of nuclear engineering to research abroad.[56]

DOE support is not limited to the university level. DOE, along with member and corporate donations, help fund American Nuclear Society (ANS) outreach activities. ANS uses these funds to educate teachers and students from elementary school through college about careers in NS&E. ANS does this by hosting workshops for pre-college teachers and interacting with students. Through these activities, ANS has taught 1,000 educators with 50 workshops and reached 90,000 students.[57] ANS also distributes educational tools, such as the power point presentation, "Nuclear Careers," to college freshmen and middle school children and 30,000 careers posters plus 50,000 brochures to educators.[58] Students majoring in nuclear engineering and related programs are eligible to apply for ANS scholarships. In 2002, ANS awarded $212,500 to 80 students at 21 universities and colleges.[59]

NON-GOVERNMENTAL ACTIVITIES:

Although the focus of this paper is the government's role in the future of the nuclear workforce; professional societies, NEI, and industry have outreach activities to promote and increase interest in NS&E, which I think are important to note here.

Some of the ANS activities were described in the previous section as they are partially funded by the DOE. Additional proactive efforts include working to increase government funds and expanding industry participation for scholarships and fellowships. ANS does not work alone though. In addition to coordinating efforts with DOE, ANS works with HPS, NEI, and employers of nuclear engineers. Monthly communication is maintained between ANS, NEI, and HPS regarding the human capital crisis, and ANS and HPS are exploring the possibility of a joint student conference.[60]

On their own, HPS is involved in similar activities as ANS. HPS is also seeking support for students and academic programs from both the government and private sources. Another HPS focus is strengthening the existing academic programs through accreditation.[61] HPS communications activities to increase the visibility of health physics include a newsletter, website, and position statements. Additionally, HPS developed a new brochure specifically for recruiting students.[62]

North-American Young Generation in Nuclear (NA-YGN) and Women in Nuclear (WIN) are two organizations formed to offer networking opportunities for young members and women in the nuclear industry. NA-YGN joins together professionals who are under 35 years of age and offers professional development for its members.[63] The WIN program is much the same, except it targets women (men may join as well).

NEI is the nuclear energy industry's policy organization. Its activities include providing accurate information to policy makers, news media, and the public. The NEI website (www.nei.org) provides the public with volumes of information about a large variety topics dealing with nuclear energy and science. The "Science Club" section of the webpage is targeted towards children and provides information to teachers to help pique their interest in nuclear science. Additionally, as previously mentioned, NEI has responded to workforce issues by forming a Workforce Task Force to study the issue and develop an action plan to ensure there are enough workers for the nuclear industry.

Companies, such as Westinghouse (www.westinghouse.com) and the Tennessee Valley Authority (www.tva.gov), have set up programs and websites for educating the public. Both companies have portions of their website set aside specifically for teachers and children, much like the NEI "Science Club." Internships and coops are an additional part of their recruitment program to give college students actual knowledge of what working in the nuclear industry is like.

Although not funded by the government, the various outreach and educational activities of nuclear companies, NEI, and professional societies are important for recruiting the nuclear workforce for the future.

CURRENT LEGISLATION Section 7

Summer 2003 was an exciting time for legislative action for nuclear energy programs. The Energy Policy Act of 2003 (S. 14)[iv] sponsored by Senator Pete Dominici contains two important provisions for the future of nuclear energy. Specifically related to the future of the nuclear workforce are the appropriations for nuclear energy research and development (R&D) initiatives for FY 2004 through 2008.[64] The funding is to be used in six different programs in which universities are encouraged to participate in.[65]

Section 944 of S. 14 outlines nuclear universities support. It includes fundamental research and collaborative (industry, national laboratories, and universities) research through the NERI program. University and national laboratory interaction is encouraged in Part (d) of Section 944, which states:

> "The Secretary shall develop sabbatical fellowship and visiting scientist programs to encourage sharing of personnel between national laboratories and universities."[66]

Activities toward maintenance university infrastructure, including URR support, are included in Section 944 as well. These include support for relicensing and upgrading reactors and allowing portions of research funding to be used for reactor operating and maintenance costs.

I believe the support provided for nuclear university programs in S. 14 is important for the nuclear workforce of the future.

Support for nuclear energy included in S. 14 might not directly address nuclear workforce issues, but I believe it is important as well. For example, a June 10, 2003 vote rejected an amendment to S. 14 that would have removed loan guarantees and power purchase agreements as incentives to bring new nuclear power plants to market.[67] I view this as key for increasing visibility of nuclear energy and careers in NS&E by stimulating a utilities company to build a new nuclear power plant. A new nuclear power plant would show that nuclear technology is still sophisticated and important for the U.S. electricity supply.

The latest action for the energy bill occurred on July 31, 2003 when the U.S. Senate passed comprehensive energy policy legislation, but it was the 2002 version of energy bill (H.R. 4) that was previously passed by Senate. This bill does not include some of the nuclear provisions that S. 14 does, but its passage now allows a conference to resolve differences in the House and Senate bills. Domenici will chair the conference committee, and plans to add incentives for new nuclear power plant construction.[68] Domenici assures that "The final bill will look more like what I produced in committee this spring than it will the bill we are passing tonight. Tonight's bill is just a vehicle to get to conference."[69] I hope that for the future of the nuclear workforce, and the future of

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[iv] Full text of Bill S. 14 can be found using http://thomas.loc.gov and searching for S. 14.

nuclear in general, Senator Domenici is successful in providing the nuclear energy industry and university nuclear programs governmental support through energy policy legislation.

RECOMMENDATIONS Section 8

Based on what I have learned through my research this summer, I do believe that the nuclear industry is going to be challenged with not having enough educated professionals in the future. I also believe that there are opportunities that the government can take to address this challenge. Much research has been conducted in this area, and reports with recommendations addressing the challenge have been published. I have attempted to learn as much as I can during these past ten weeks, but by no means claim to know everything about nuclear workforce issues. The following recommendations are simply my own opinion based on what I have been able to learn, and do not reflect the opinions of the American Nuclear Society, the Nuclear Energy Institute, or anyone except myself.

RECOMMENDATIONS TO CONGRESS

Now that an energy policy act will be discussed in conference, House and Senate members have an opportunity to pledge governmental support for university nuclear programs and the future of nuclear science, particularly nuclear energy. I urge Congress to include funding for nuclear research in the energy policy act, and to earmark a portion of the funding for research at university. Congress also needs to recognize the importance of URRs to university nuclear programs and allocate enough funds so that they can continue to be used without risk of being shut down by university officials because of lack of funds. These funds are needed to maintain current equipment integrity and also to improve the current equipment.

Congress should also include incentives, such as loan guarantees, for building new nuclear power plants in the final energy bill. I believe that building new power plants will generate interest in careers in the nuclear industry, and will show pre-college students that the nuclear industry is not stagnate and is a cutting-edge technology to study.

RECOMMENDATIONS TO THE DEPARTMENT OF ENERGY

I would first like to commend DOE on their various programs for universities and research. As shown in Figure 6.2 the increased investment in university programs has in fact coincided with an increase in enrollment, but there is always room for improvement. DOE-NE needs to use its funds as best they can to revitalize university enrollment in NS&E. Following is what I believe can have the most impact on NS&E enrollment and infrastructure maintenance:

- <u>INIE Program</u> – I have faith in this young DOE-NE program. I believe that this will allow universities to share their resources effectively and also foster relationships with industry and national labs. DOE should increase funding for this program, and urge all universities with NS&E programs and/or URRs to join a consortium.

- University Research Reactors – As I have mentioned through out this report, I feel that URRs are important to the future of NS&E programs in the U.S. I hope that Congress recognizes this as well, and allocates appropriate funding. DOE needs to ensure that URRs are well maintained through the URI program, and use additional funding to upgrade reactors so that they are really able to perform cutting edge research. The University Reactor Fuel Assistance Support should also be continued. One improvement to this program should include DOE taking responsibility of the transportation of spent fuel. This would eliminate an obstacle that universities that URRs face.

- Reactor Sharing – URRs are a visible way to promote NS&E. Reactor sharing funds be increased and used to promote and allow URRs to be used by a variety of different college departments and industries. Allowing and promoting other university departments to use the URR would accomplish two objectives in my mind. First the URR is benefiting more than just the nuclear engineering department, which would appeal to administration. Secondly, this increases interest in NS&E and could possibly recruit students from other departments to either study NS&E or eventually pursue a career in this area.

  These funds should also be utilized for reactor tours to students at the K-12 level, as well as current college students. I think that showing a URR to a student who might be undecided about what career they are interested in, but have an aptitude for math and science (such as undecided or general engineering students), and could persuade them to enroll in an NS&E curriculum. Tours should also be targeted to high school math and science students.

- Kindergarten - 12th Grade Outreach – Right now DOE gives funds to the American Nuclear Society to use for outreach activities, such as teacher workshops. DOE should make certain to continue funding is available for outreach activities for pre-college students. I think students this age can be shown that NS&E is "cool" and "neat" and therefore want to study it more in the future. In my opinion outreach to pre-college students is an important aspect to attracting students to NS&E, and DOE-NE should be funding these activities.

- Young Faculty Recruitment – I believe that it is important for the health of NS&E department to have young faculty members with fresh ideas. I think this is also good for the image of the department and attracting students to the departments. A recommendation from "The Future of University Nuclear Engineering Programs and university Research & Training Reactors" was to have a "Nuclear Engineering Junior Faculty Research Initiation Grant." This program would be a competitive program to provide junior faculty (six years or less from the time of their first academic appointment) the opportunity to compete for DOE support so that they may begin their research careers. I think that this is great idea for increasing interest in pursuing a career as NS&E professor.

- Research Funding – DOE supports research funding through different programs and for different initiatives. I think for all research initiatives, DOE needs to make sure and allocate a portion of the total funding for universities. This way students and professors across the nation are always involved in the latest technology being developed. This would not take away work from national laboratories, but would expand the research knowledge and facilities working on technologies. On my opinion, this would also help diversify the research by allowing different people with different ideas to work on the same project.

  I also think that special care should be taking to involve undergraduate students. This would be another way to increase interest in undergraduate NS&E programs by showing students that they can be involved in cutting edge research initiatives early in their careers.

  For graduate research assistance, I believe that DOE should work to attract students from other engineering disciplines. Other engineering disciplines have skills that can be applied to the nuclear industry, and prospective graduate students might not see that. DOE should somehow develop a program that would attract these talented individuals to the nuclear industry.

- Recruit Women and Minorities – DOE should work hard to make sure that nuclear workforce is diverse in order welcome more interest, in my opinion. They could do this through three different means: scholarships, fellowships, and internships at national labs. I believe that the opportunity to work in a diverse workforce adds to the appeal of a nuclear career.

RECOMMENDATIONS TO THE NUCLEAR REGULATORY COMMISSION

The nature of the NRC does not allow it to directly advocate for NS&E. I believe the NRC should continue educating the public about the safety of nuclear industry. They should continue holding public meetings and posting information on their webpage. In my opinion, the NRC should be the main supply of unbiased and factual information to the public.

The NRC should also to continue to waive the relicensing fees for URRs. Waiving these fees allows universities to apply for relicensing with out having to raise the funds to do so; something I believe would cause even more URRs to shut down. The government should make sure that the NRC is adequately funded for this to occur.

What I believe is the most important role of the NRC is to ensure that the nuclear industry remains a safe place to work and live around. If another accident such as Three Mile Island were to occur, I believe that the public's opinion of nuclear energy and interest in studying NS&E would decline sharply. Although the NRC is not directly involved in workforce issues, they do have an important role in educating the public and ensuring that the nuclear industry is safe. I think that both of these roles are important in attracting workers to the nuclear industry.

<u>RECOMMENDATIONS TO NON-GOVERNMENTAL ENTITIES</u>

Although the focus of this paper is government programs for the nuclear workforce for the future, there is effort outside of the government to promote NS&E and help increase enrollment. In my opinion professional societies are working hard to promote the industry and I do not have specific recommendations regarding their programs.

I believe that industry plays an important role for the increasing interest and enrollment, and could increase their involvement in workforce initiatives. Companies will be directly impacted by the low number of students graduating in NS&E, and should therefore be working hard to increase interest in these programs. Following are suggestions that could increase interest in these programs:

- <u>Community Outreach</u> – Companies need to make sure that they are promoting their company as well as the entire industry. Industry representatives, preferably actual nuclear engineers, should visit grade, middle, and high schools and inform them about nuclear science, which I believe would increase interest to further study NS&E.

- <u>DOE Matching Grants Program</u> – I believe that companies should supply as much funding as they can to the DOE Matching grants program. This would let industry directly help university infrastructure. Universities can use this money where they need it most. In my opinion industry should be making significant investments in the workforce for the future, and the Matching Grants program allows them to do that.

- <u>Internships and Scholarships</u> – Industry should continue to hire undergraduate students for internship work. This really gives a student a hands on look at the industry and what a career in NS&E is like. Additionally most internships are well compensated and therefore draw student interest. Companies could also focus on recruiting students in other engineering disciplines that have skills and knowledge that can be applied to the nuclear industry, but would just need nuclear specific training that the industry work experience could offer. I think that this would work especially well by targeting freshmen and sophomore undergraduate students who are interested in engineering, but are unsure of their specific interests. In my experience it is often difficult to obtain an internship as a sophomore, and especially as a freshman, not because of lack of intelligence or interest, but rather lack of classroom and hands on experience. The internships then must be an enjoyable experience for the student. One way to do this is to make an intern is doing more than just a redundant task, and instead give them projects, or parts of projects, that they can take responsibility for. Mentoring and social activities are additional ways to make an intern feel welcome in a company and leave their internship with a positive view of the nuclear industry. The nuclear industry needs to make sure that they are doing their part to increase the visibility and interest in the nuclear industry.

CONCLUSION

- There is going to be a shortage of nuclear engineers in the future.
- Because of the wide range of uses of nuclear science, especially for nuclear energy, it is important that there are enough trained nuclear engineers.
- Working with nuclear science is safe, and there are additional advantages to work as a nuclear engineer:
    - Good job outlook
    - Substantial monetary compensation
    - Lifetime of learning
- Two areas that I believe cause low enrollment and can be improved on are:
    - Public perception of nuclear science and engineering
    - University infrastructure including university research reactors and faculty
- There are current programs aimed at these issues, both directly and indirectly, by government (Department of Energy, Office of Nuclear Energy, Science and Technology; and the Nuclear Regulatory Commission), professional societies (American Nuclear Society and Health Physics Society), and industry (Nuclear Energy Institute and individual companies).
- The Energy Policy Act of 2003 could have an impact on enrollment trends if passed with nuclear provisions.
- Based on my research I have made recommendations to the following:
    - Congress,
    - Department of Energy,
    - Nuclear Regulatory Commission, and
    - Non-Governmental Entities

regarding what I believe would help increase enrollment in nuclear engineering.

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IMPORTANT WEBSITES & REPORTS — Appendix B

WEBSITES:

- American Nuclear Society
  http://www.ans.org

- Department of Energy, Office of Nuclear Energy, Science and Technology
  http://www.nuclear.gov

- Health Physics Society
  http://www.hps.org

- Nuclear Energy Institute
  http://www.nei.org

- Nuclear Regulatory Commission
  http://www.nrc.gov

- WISE Internship Program
  http://www.wise-intern.org

REPORTS:

- "The Future of University Nuclear Engineering Programs and University Research & Training Reactors"
  May 10, 2000
  Corradini, Michael L. et al
  <http://www.ne.doe.gov/nerac/finalblue.pdf>

- "Long-Term Nuclear Technology Research and Development Plan SUMMARY"
  June 2000
  Nuclear Energy Research Advisory Committee (NERAC) Subcommittee on Long-Term Planning for Nuclear Energy Research
  <http://nuclear.gov/nerac/LTRDP-Summary.pdf>

- "Manpower Supply and Demand in the Nuclear Industry"
  2000
  Nuclear Engineering Department Heads Organization
  <http://www-ners.engin.umich.edu/NEDHO/publications/manpower_report/Manpower_report2-17.pdf>

- "Nuclear Education and Training: Cause for Concern"
  2000
  Nuclear Energy Agency; Organisation for Economic Co-operation and Development
  <http://www.nea.fr/html/ndd/reports/2000/nea2428-education.pdf>

- "Three Research Studies About Engineering And Careers"
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- **Figure 1.1** The number of junior and senior college students enrolled in nuclear engineering programs and number of bachelor's degrees in nuclear engineering awarded for 1991 to 2001.
  - Source: http:www.orau.gov/orise/pubs/brief50.pdf on 16 June 2003.

- **Figure 1.2** Number of nuclear engineering programs.
  - Source: http://www.ne.doe.gov/nerac/finalblue.pdf on 2 July 2003.

- **Figure 1.3** Graph showing the gap between the number of nuclear engineers needed and the number of nuclear engineers graduating.
  - Source: http://www.ans.org/pi/np/careers/docs/demand.pdf on 16 June 2003

- **Figure 2.1** Sources of electricity for the U.S. in 2000. Nuclear energy supplied 20.5%.
  - Source: http://www.nepo.ne.doe.gov on 17 June 2003

- **Figure 3.1** Chart of the number of significant events per reactor for 1998 to 2000.
  - Source: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1542/v7/sr1542v7.pdf on 6 August 2003.

- **Figure 3.2** Chart of the collective radiation exposure to a worker at a nuclear power plant for 1998 to 2000.
  - Source: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1542/v7/sr1542v7.pdf on 6 August 2003.

- **Figure 5.1** Number of URRs from 1975 to 2000.
  - Source: http://www.ne.doe.gov/nerac/finalblue.pdf on 2 July 2003.

- **Figure 5.2** Number of URRs and undergraduate enrollment in nuclear engineering from 1980 to 2001.
  - Source: http://www.ne.doe.gov/briefings/Oct28_02%20AlbanyRPIConf.pdf on 2 July 2003.

- **Figure 6.1** Fiscal year 2004 budget request for DOE – NE. (In millions of $)

- Source: http://www.ne.doe.gov/admin/budget-soon.html on 17 June 2003.

- **Figure 6.2** Enrollment in nuclear engineering and the amount of DOE-NE funding to direct support of university infrastructure for 1990 – 2002.
  - Source: http://www.ne.doe.gov/briefings/Oct28_02%20AlbanyRPIConf.pdf on 28 July 2003.

ACRONYMS — Appendix D

- ANS = American Nuclear Society
- ASEE = American Society for Engineering Education
- BLS = Bureau of Labor Statistics
- DOE = Department of Energy
- DOE-NE = Department of Energy, Office of Nuclear Energy, Science and Technology
- FDA = Food and Drug Administration
- FY = Fiscal Year
- HPS = Health Physics Society
- INIE = Innovations in Nuclear Infrastructure and Education
- ISEP = International Student Exchange Programs
- NA-YGN = North-American Young Generation in Nuclear
- NEA = Nuclear Energy Agency
- NEER = Nuclear Engineering Education Research
- NEI = Nuclear Energy Institute
- NEDHO Organization = Nuclear Engineering Department Heads
- NERAC = Nuclear Energy Research Advisory Committee
- NERI = Nuclear Energy Research Initiative
- NP 2010 = Nuclear Power 2010
- NRC = Nuclear Regulatory Commission
- NS&E = Nuclear science and engineering
- OECD = Organisation for Economic Cooperation and Development
- R&D = Research and Development
- ROSE = Reactor Operations and Systems Experience
- TMI = Three Mile Island
- UML = University of Massachusetts Lowell
- UNI = University Nuclear Infrastructure
- URR = University Research Reactor
- U.S. = United States
- USDA = United States Department of Agriculture
- WIN = Women in Nuclear
- WISE = Washington Internships for Students of Engineering

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