Feeding the Nuclear Pipeline: Enabling a Global Nuclear Future

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ABSTRACT

Nothing is more vital to the advancement of human civilization than the abundance of useable and affordable energy. It underpins national security, economic prosperity, and global stability.

Nuclear energy, which exhibits a unique combination of environmental and sustainable attributes, appears strongly positioned to play a much larger and more pivotal role in the mix of future global energy supplies than it has played in the past. Unfortunately, after a fairly rapid growth period within the industrialized nations in the 1960 to 1980 time frame, a variety of factors led to a substantial reduction in commercial nuclear power plant construction (with the possible exception of several Pacific Rim countries). This, in conjunction with concerns by some in the public following the TMI-2 and Chernobyl reactor safety accidents, led to a serious erosion in the enrollment patterns of nuclear engineering programs—causing alarmingly low enrollment levels in many countries by the turn of the century.

Numerous studies conducted over the past five years have soberly come to the consistent conclusion that the nuclear pipeline cannot keep up with the needs of the nuclear industry. In fact, when combining the aging work force with low matriculation rates in most nuclear engineering academic programs, a huge (and unacceptable) mismatch between needs and supply is strikingly evident. This is further exasperated by the lack of meaningful efforts to capture the knowledge of the "first nuclear era" professionals in a form that can be effectively transferred to the upcoming generation. Methods ***must*** be found to better capture the enormous body of experience already accumulated and both document it and then mentor the new nuclear engineers that do enter the work force to enable them to build upon this experience, rather than having to re-create it.

On the positive side, enrollment patterns in the majority of nuclear engineering programs still in existence within the United States are now generally on the rise, at least at the undergraduate level. Some programs have experienced at least a doubling or more of their undergraduate enrollments in the past half-decade. This has happened as the college generation is being exposed to a "nuclear renaissance" atmosphere in the United States. The excitement associated with the first serious debate on national energy policy in decades, new designs and serious renewed construction dialog, the possibility of producing hydrogen to service the huge transportation sector, the drama of deep space exploration, etc.—all combined with attractive scholarship programs and high starting salaries—are playing a significant role in the rebound. A few of the particularly successful efforts initiated by various sectors of the U.S. nuclear

infrastructure to stimulate this rebound will be shared in the hope that some of them might be beneficially employed in other global settings.

Introduction

World attention is again riveted to the question of a sustainable future here on planet Earth. The recent Earth Summit in Johannesburg is but the latest gathering of global leaders to debate the plight of future humanity—and initiatives that need serious consideration to render this fragile planet habitable for centuries to come.

While there are several factors that can legitimately be argued as desirable for future generations, the fact is that there is nothing more vital to the advancement of human civilization than the abundance of useable and affordable "clean" energy. It underpins national security, economic prosperity, and global stability.

A recent issue of TIME Magazine (August 26, 2002) focused on the challenges we face. Slide 2 graphically reveals that in the past quarter century (1973 to 1999), fossil fuels remained by far the largest source of global energy. Of these fossil fuels, the use of oil and coal is receding somewhat whereas the use of natural gas is gaining. Still, these three forms of fuel currently provide more than 75% of the world's energy supply, and they all contribute to global climate change. By far the largest percentage increase among the major fuel sources during this quarter century was nuclear energy, rising from less than 1% to just under 7% during this period. The question is what will be the demands upon nuclear energy use in the coming quarter century? And do we have the infrastructure in place to accommodate growth?

A major factor that will influence the demands for more energy is population growth. As noted in Slide 3, global population is expected to grow to between 9 and 10 billion people by mid-century, and this population will undoubtedly demand at least the energy per capita as currently existing, and quite likely a good bit more. It has become abundantly clear that energy equals wealth, and the only realistic way to reduce the economic gap currently existing between the developed and the developing nations is for the latter family to have access to an abundance of affordable energy. Further, with the increasing world attention being given to environmental concerns, an additional requirement will be that the energy sources employed must meet certain emission standards. Slide 4 is a grim reminder that pollution has become very real, and there is every reason to believe that acceptable energy sustainability MUST be accompanied by good environmental stewardship.

Required Attributes of Future Energy Sources

Slide 5 suggests six minimum requirements for acceptable energy sources of the future:

1. Safe
2. Affordable
3. Environmentally Acceptable
4. Sustainable
5. Transportable
6. Acceptable by the Public

Safety and affordability are both givens. A strong environmental signature must include dealing with all wastes in the system. Several potential energy sources could satisfy these three attributes, but not be of sufficient strength to satisfy long-term (sustainable) requirements. Also, the energy sources of the future must be capable of satisfying the transportation sector, which is currently supplied to a very large extent with petroleum. Finally, even with all the above attributes, the public must be willing to accept the energy source as a viable part of the overall energy mix.

Slide 6 focuses on the carbon dioxide problem, which is identified as a major global environmental concern. This figure dramatically illustrates that a "business as usual" approach to global energy yields nothing less than potentially catastrophic results. Climate modelers are in agreement that atmospheric carbon stability can be achieved only when the net balance of new CO_2 in the atmosphere returns to the conditions existing throughout the past 400,000 years.

Therefore, if we are concerned about global climate changes, there is no one solution to the problem. Rather, we need to strenuously pursue all non-carbon polluting energy sources, plus carbon sequestration methods and push hard toward a hydrogen economy (where hydrogen and oxygen are used as fuel, with only water as the waste product). This will be a monumental task! Given the inherent characteristics of nuclear energy, it now appears that nuclear is the only major energy source having the capacity to provide future generations the quantities of energy needed, where all requirements can be met. This places an awesome responsibility upon the shoulders of the nuclear profession.

The Student Pipeline Dilemma

The logical conclusion from the above section is that the clear demand for prodigious increases in nuclear energy over the next quarter century would be so strong that students would be flocking into nuclear programs to be a part of this tremendous opportunity.

But what is the present reality? In most parts of the world, just the opposite is true. Nuclear engineering enrollments near the end of the century were plummeting, as well as the number of university research reactors. Slide 9 illustrates these trends in the United States.

Why the downturn—especially in light of the arguments of the preceding section?

Whereas there are differing reasons in other parts of the world, the major reasons for this downturn in the United States are summarized in Slide 10. No new nuclear plants were ordered in the last quarter of the century, and construction activity progressively dwindled to nothing as the last plants of that era started up in the early 1990s. Indeed, it was not just nuclear plants that suffered the lack of orders. A general glut of electrical production capacity substantially reduced the need for *any* type of generation, and this situation lasted until about the midpoint of the last decade. Further, the negative publicity associated with the Three-Mile Island and Chernobyl accidents soured public opinion and this attitude was, in turn, reflected at the highest levels of government. Also, the plethora of new regulations promulgated after the TMI and Chernobyl accidents, and admittedly some poor operations and management, added substantially to the costs of both construction and operation of nuclear power plants. This was further aggravated by a strong anti-nuclear lobby that succeeded in delaying plant construction—a factor that caused huge cost overruns in several instances.

All of this led many bright young students to the conclusion that nuclear power was dead, and they flocked to popular programs such as computer science, bioscience and business.

Hopes and Challenges for the Future

But there is good news on the horizon!

Despite the gloom and doom that prevailed during much of the previous decade, there is new hope for nuclear, at least in the United States. The 103 nuclear power plants that were completed in the U.S. are currently operating at historic peak performance. Plant capacity factors cleared the 90% barrier by the close of the century (up from about 60% as recent as the mid-80s. This, plus upgrading several plants to higher power levels, allowed the U.S. to maintain its 20% electrical reliance on nuclear energy, despite the lack of new plants coming on line. In fact, the upgraded performance of the nuclear plants resulted in the equivalent of more than 23 new 1 GW plants coming on line in the last 10 years!

Further, the May 2001 announcement of a new National Energy Policy that explicitly included nuclear as a key part of the U.S. energy picture brought a long-awaited shot of adrenalin in the nuclear community. Despite the events of 9-11, and other political changes, the implementation of this new policy has slowly progressed, and the nuclear community has been moving aggressively ahead in anticipation of the requirements necessary to fulfill such a policy. Keynote addresses by the DOE Secretary Abraham to international audiences in February and August of this year have only reinforced the Administration's resolve to move forward. Active talk of new nuclear power plant construction is now commonplace—a phenomenon unthinkable even two years ago! Also, the combined Presidential and Congressional support of the Yucca Mountain nuclear spent fuel storage repository has further encouraged the U.S. nuclear community.

Given this upturn of events, combined with the clear long-term energy needs identified at the start of this talk, a major question is whether a sufficient number of new nuclear professionals can be brought into the field to supply the necessary manpower. Numerous studies have been conducted over the past few years by the Nuclear Energy Institute (NEI), American Nuclear Society (ANS), Nuclear Engineering Department Heads Organization (NEDHO) and others to seek answers to this crucial question. Whereas there are some differences in the scope and sought responses to the surveys conducted, these studies were in complete agreement that there is a huge present and future need for new nuclear professionals, and the shortages are of major concern. Perhaps the most extensive study, conducted by Navigant Consulting for the NEI, concluded that approximately 90,000 new nuclear professionals would be needed over the next 10 years in the United States alone. This included a plethora of disciplines, including trades personnel. Slide 13, which contains the year-by-year needs, indicates that about half of the needs arise from the government and government contractor segments, whereas another 30% will be needed in the utility arena. The specific academic degrees in the areas with the largest mismatch between projected graduates and expected demand were found to be nuclear engineering and health physics. In particular, the study identified the need for approximately 2400 new nuclear engineers and 1300 health physicists over the next 10 years. The mismatch between the number of nuclear engineers (800) and health physicists (700) needed verses the number produced is a factor from 2 to 3. The actual staffing gaps for these two disciplines are shown year-by-year in Slide 14.

Whereas these figures reveal a very significant problem, which needs very careful attention, we should point out that it is not a hopeless case. For example, Slide 15 reveals that a conversion of far less than 1% of engineering students enrolled in the traditional engineering disciplines would be sufficient to provide the pipeline necessary. This is not to say that this would be easy, but it does reveal a ready audience for targeted persuasion.

Specific U.S. Attempts to Refill the Pipeline

The next series of slides provide a glimpse of some of the actions already under way in the United States to address this critical problem. Perhaps the first major attention came from the President's Council of Advisors on Science & Technology (PCAST). In its 1997 report, the Council acknowledged the death spiral underway in the undergraduate enrollment patterns in the nation's nuclear engineering programs and the Council was instrumental in creating the Nuclear Energy Research Advisory Council (NERAC), which was subsequently formed in 1998 under the chairmanship of Professor James Duderstadt, President Emeritus of the University of Michigan. NERAC subsequently formed nine subcommittees to study essential aspects of the problem and prepared a long-term nuclear R&D roadmap. Among other things, they pushed for the formation of the Nuclear Energy Research Initiative (NERI), which encouraged the full nuclear community to creatively network to originate and develop new concepts. They argued that NERI should be ramped up in funding to about $250 M/yr within five years. They also pushed for the Nuclear Engineering Educational Research (NEER) program, specifically geared to stimulate research at the universities. It was pushed for a funding level of about $20M/year. Their most recent focus has been to encourage the U.S. Department of Energy (DOE) to help support university reactors—given the continual hemorrhaging of reactor closures. This has become known as INIE (Innovation in Nuclear Infrastructure & Education), with a NERAC recommended funding of about $15 M/yr. NERAC also urged the funding of graduate students at a level of about $5 M/year.

And what has been the response? As indicated in Slide 17, DOE, under the new Bush Administration, has announced the NP 2010 program, which would push for at least one new nuclear power plant to come on line by the year 2010. It has also supplied funding on a 50/50 cost share basis to three nuclear utility companies (Entergy, Exelon, and Old Dominion) to conduct siting studies for new plant construction. Further, the NERI, NEER, and INIE programs were funded at the levels of $23.4M, $5M, and $5.5M (pro-rated) in fiscal year 2002. In addition, an international version of NERI, called INERI, was funded at the $7.9M level. These are well below the levels recommended by NERAC, but given that these accounts were at zero in 1998, it is encouraging to see them moving in the right direction. Further, DOE is funding about 50 scholarships and 20 fellowships, along with matching industry support to nuclear engineering departments (approximately $1.0M/yr).

Industry is now providing considerable focus on the workforce issue. The NEI, in developing its Vision 2020 (a program aimed at considerably raising the impact of, and public/policymaker understanding and appreciation for, nuclear energy, science and technology by the year 2020), is focusing considerable effort on the needs for qualified personnel to support the "nuclear renaissance." NEI has conducted a series of workshops and focus groups to both frame the concerns and discuss corrective actions. They plan significant partnering relationships with both the DOE and the university community—including web-based recruiting techniques and additional scholarship support. The Institute for Nuclear Power Operations (INPO) already manages a significant scholarship/fellowship program. Approximately $1.0M is now allocated each year to students expressing an interest in launching a career in the nuclear power program.

The ANS also has been active in contributing to the solution of the pipeline dilemma. ANS has leveraged DOE assistance to provide over 50 teacher workshops within the last year alone—directly reaching approximately 1000 teachers and indirectly some 90,000 students. These workshops have uniformly received exceptionally high ratings from teachers who attend. The ANS also recently distributed some 30,000 career posters and 50,000 career brochures to their extensive educational network. They have also placed some 13,000 Geiger counters in U.S. high schools to help stimulate student interest.

It may be of some help to delineate some of the efforts made at one U.S. University (Texas A&M University) to turn student enrollment back in the right direction. This example is picked for illustration because 1) it once had the largest undergraduate student enrollment in the nation and 2) this presenter is intimately familiar with its recent history (having served as Head of Nuclear Engineering of this program from 1998 to 2002). As noted in Slide 20, the eight-step recruiting process consisted of 1) building a case that could be honestly conveyed to high school or first year general engineering students (which emphasized the mammoth benefits of nuclear technology--one of the key points determined as important at the recent IAEA workshop on this topic),
2) solidifying industry support in the form of a strong industrial advisory council, 3) providing "headliner" four-year scholarships of $10,000 (that gets their attention!), 4) encouraging students to apply for and win multiple scholarships, 5) making sure the students are aware that nuclear engineering students are obtaining the highest average starting salaries in the entire university (another grabber!), 6) supporting a strong high school recruiting program (11 faculty members plus a few dedicated students went out to 42 high schools in the 2001 academic year, directly contacting approximately 6300 students with a very professional packet of materials),
7) recruiting on-campus via "open house" formats to encourage a shift from other engineering majors, and 8) working hard to retain the students who do come into the program (via strong mentoring efforts and sending students to professional conferences, worldwide).

This was exhaustive work, but the numbers depicted in Slide 21 indicate considerable success. The steep decline in the middle 1990s mirror the national trend (Slide 9), but the rebound is refreshing. Tentative numbers for the 2003 academic year (just starting) indicate a continual climb to about 150 undergraduates.

Slide 22 is perhaps even more refreshing. The bottom black bars denote the number of undergraduate students in 2001 and the increment on top indicates the change for 2002. Blue indicates an increase and red indicates a decrease. Note that the vast majority is blue. The boats are rising! We should note that some university programs are not entered because enrollment numbers for those schools were not supplied. Nevertheless, one can draw considerable encouragement from these trends.

Equally important to the raw workforce problem is capturing the expertise of the retiring generation of nuclear professionals and effectively transferring their knowledge to the new generation. Since this crucial topic, directly related to the pipeline challenge, is the primary focus of the remaining three papers in this session, time does not permit additional discussion in this presentation. However, we have a vital interest in this topic and look forward to participating in the discussion and follow on efforts.

Challenge for the Path Forward

Whereas we hope that some of these initiatives may prove useful outside the United States in helping to replenish the pipeline, we fully recognize that major differences exist among the numerous nations facing this problem, and "one size does NOT fit all!" We do believe that all nations will eventually need nuclear energy, because we see no other alternative on the horizon that has the capability of meeting all six criteria mentioned earlier. However, current economic and public perception conditions vary sufficiently throughout the world at present, suggesting that differing approaches will be needed.

At the risk of oversimplification, we suggest that one potential step in the path forward would be to organize the interested nations according to clusters that currently have a somewhat similar economic infrastructure and public attitudes toward nuclear power. Slide 24 is intended as a starting point. Several of the current developed nations have a reasonably strong economy and a mixed public response toward nuclear energy. Despite this mixed public attitude, they have been able to enjoy reasonable success in the field of commercial nuclear power. Examples might include the U.S., France, and Japan. A second group might include nations with a likewise strong economy, but where public support has been sufficiently lacking that expansion of commercial nuclear power has been essentially stopped. Italy, Germany and Sweden come to mind as possible examples, although there now appears more optimism in the latter two nations. Then there is a relatively large cluster where the current economic infrastructure is relatively weak but where there is stronger public support for nuclear power. Several developing nations might fit into this category.

This attempt at clustering is certainly not intended to provide any artificial or misintended labeling; rather, it is suggested as a draft zero attempt to allow nations with a reasonably similar set of circumstances to jointly formulate a set of initiatives that might help solve the pipeline problem appropriate to their setting. The IAEA is in an excellent position to help facilitate such an approach. In fact, some feel it could be considered necessary for the IAEA to ensure that this assistance is captured within the broader mission that it serves for its members. A strategic plan for each member state that outlines the objectives and timeframes for the application of nuclear energy, science and technology, is vitally important. The vision held by each member state will compel certain types of actions, similar to how the US nuclear industry is applying VISION 2020. If this is determined to be a useful approach, the IAEA might provide a timeline for draft reports to be written and then discussed for possible implementation by member states.

Conclusion

The IAEA is to be commended for focusing much needed attention to the critical question of pipelining. Nuclear energy is going to be called upon to supply substantially more energy in the future than it has done in the past. In addition to the prodigious amounts of electricity that will be needed by the expanding population of the future, nuclear energy could be the crucial link in providing energy for the transportation sector (likely via the hydrogen economy), heat for industrial processes, and energy to desalinate water. But in order for this to happen, we must find ways to attract bright members of the young generation into our profession and train them with the skills necessary to carry out such tasks.

We have attempted in this talk to identify some of the disturbing trends in the United States and then review a few of the initiatives currently underway in an effort to alleviate the problem. The challenge is daunting, but we are optimistic that deliberate and concerted efforts can and will be successful.

But the initiatives mentioned herein are only examples. More, much more, must be done. Further, we are well aware that different techniques will be needed in regions of the world that have substantially different economic and cultural conditions than exist in the U.S. Hence, we suggest that each region of the world (or regions of relatively similar economic and cultural conditions) commit deliberate focus to the problem. By developing a clear vision of the role of nuclear energy in the region of interest, and then effectively communicating that vision to the youth of the nation, we believe that the pipeline problem can be solved.

Indeed, the problem MUST be solved. The very future of our planet depends upon it!

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