

**An Overview of Strategic Measures to Assess Workforce Needs and Ensure Technology  
Transfer to Meet Current and Future Nuclear Power Operations**

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**ABSTRACT**

Between 1956 and 1989, the number of operating commercial nuclear power plants in the United States increased from none to 109. With the exception of a few plants that were still in final construction, no new nuclear power plants were ordered in the United States as the new millennium began.

In 2005, the federal government pronounced the need for new electric power generating systems during the first quarter of the 21<sup>st</sup> century. The need comes from a desire to curb our reliance on fossil fuels, as well as to provide for a cleaner environment. One of those fuel systems noted was nuclear energy. Given the time between the last active period of nuclear power plant development and construction, there is a need to supply a talented and well-prepared workforce to operate the new plants. It will also be necessary to assess the needs of our current fleet of operating nuclear power plants, of which many are in the process of re-licensing, yet also facing an aging plant workforce.

This paper will review and discuss measures to assess diverse workforce needs and technology transfer to meet current licensing requirements as that of future nuclear power plant development in the United States.

**INTRODUCTION**

In preparing this document the authors of this paper have sent a questionnaire or interviewed many people associated with nuclear science and technology. The original focus of the paper was on workforce needs, but as the interviews unfolded, the authors found that the development of new electric power generating systems went beyond a single issue or topic. In fact, the authors have identified 12 areas or questions associated with the future of nuclear energy in the United States. The questions covered individual and public attitudes about nuclear energy; workforce priorities, capabilities, and needs; reactor types and generating capabilities; financing such projects; licensing and regulatory issues including security; waste management and disposal; education including K-12 through higher education; and the role of the media.

The authors wish to thank the government officials; environmentalists; medical and health administrators; industrial and utility administrators; basic and higher education faculty/administrators; ANS, ASME, HPS, and NEI members; nuclear support services; and radwaste managers who took time to respond to our questionnaire. As previously arranged, no responder will be identified in our document.

**THE STUDY**

**Questionnaire**

The authors' review of the history, issues, and topics surrounding nuclear energy's past in America was important. That review helped prepare and shape the twelve questions that were asked in the survey. The questions focused on the planning, human resources, fiscal and technology development, construction, and operation of a new fleet of nuclear power plants in the United States. The twelve questions were:

- 1) How do you feel about the future of nuclear reactors and building them in the United States?
- 2) Do you see any workforce problems in regard to the fact that there will be a sizeable attrition in the coming decade due to the baby boomer generation retiring?
- 3) Do you have any comments in terms of the size and type of reactors that may be built in the future?
- 4) Can you comment on the ability to finance future reactor development?
- 5) Can you comment on licensing or regulatory issues?
- 6) Can you comment on America's ability to build nuclear power plants after such a long layoff?
- 7) Can you comment on the ability to staff qualified health physicists, nuclear engineers, or other personnel to operate such plants?

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- 8) What impact will the disposal of low-level and high-level radioactive waste have on new reactor development in America?
- 9) Do you have any comments on higher education's ability to meet the needs to educate nuclear engineers in the future?
- 10) Can you comment on media regarding nuclear energy?
- 11) Can you comment on the public's attitudes on nuclear energy?
- 12) Can you comment on our schools and educating our youth about radiation, and nuclear science, energy, and technology?

**People Surveyed**

The authors contacted 106 people throughout the U.S. who represented the following categories: government officials; environmentalists; medical and health administrators; industrial and utility administrators; basic and higher education faculty/administrators; ANS; ASME; HPS, and NEI members; nuclear support services; and radwaste managers. Nearly 30 percent, or 31 of the 106 people surveyed either were interviewed or responded to the questionnaire. As previously arranged, no responder is identified in this paper.

**Question #1: How do you feel about the future of nuclear reactors and building them in the United States?**

People responded positively to this question. Words such as optimistically positive, imperative, needed, start, essential, a logical solution, improving, and confident were found in their remarks.

**Quotes regarding Question #1:**

"I am cautiously optimistic about the building of these reactors. They are great and much safer designs, taking lessons learned over the 50 years of nuclear power reactor design. The science and engineering principles are well established; however the political and public acceptances are a large roadblock to this endeavor, and especially the problem of waste. The building of these reactors should be part of a national comprehensive energy policy. The type of nuclear plants built may depend on how much renewable energy is being generated in the future. Traditionally nuclear power is a base load and not a complimentary load electrical generation. These kinds of questions are already being discussed in the science and engineering community. Politically implementing a comprehensive national energy policy, which includes more nuclear power and renewable power, is another large hurdle. However, if it is accomplished, we could have a large reduction in the use of fossil fuels within 30 years."

"I think the future frankly depends on three things. The first is the political will to finish a job that should have been done several decades ago, that is, of course, the high level waste disposal. The political will, not the technical. Secondly, the infrastructure for our interlocking electrical grid networks in the country, which are the transmission lines that connect the consumer with the power plant. There are several areas that need improvement. In other words, areas in California in particular, and some areas in the Mid-West need attention. Third, in my mind, is a mixture of environmental concerns. Most of us realize that nuclear power is not only the safest but it is the most environmentally satisfactory way to generate electricity. But there are a number of states, for example Maine, that have enacted laws which say there can't be any new nuclear power plants built in their state until a satisfactory solution to the high-level waste disposal is achieved. So, in a sense it's a little bit of a Catch 22."

"The prospects appear good for new orders during the next several years utilizing the NRC's 'new' regulation (10CFR, Part 52) which allows for Early Site Permits (ESP), Design Certification (DC) and Combined Operating Licenses (COL)."

"I feel it is the right way to go as part of our total energy needs and less reliant on fossil fuel. However, the costs of building the nuclear units must be reduced through standardization of design and construction."

"I believe nuclear power to be strategically necessary to meet the future energy demands of the United States. I believe that we are at a crossroads in our ability to build (i.e., regulatory, engineering, construction, financial) nuclear reactors in the U.S."

"Energy needs, public perception, and political climate (questionnaire received prior to November 2006 election) all seem to be aligning for the first time in decades, to make a new nuclear construction once again favorable."

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There are two key unknowns at this point, the COL process and financing new plant construction...this means that there is still uncertainty about the political/regulatory commitment to new plant construction.”

“The future is much brighter than it has been at any time in the recent past. However, plant issues like Davis Besse do not help the outlook. Security, emergency planning and other such issues are significant for the public. The most pronounced issue is high level rad waste (spent fuel). We control plant performance. The other issues are political in nature. Without the successful resolution of the political issues, the future of nuclear power will remain uncertain.”

“...I am concerned that avid, ill-informed ‘environmentalists’ will continue to distort the benefits of nuclear. To mitigate this concern, the industry needs to push as hard as it can to ensure Congress is well educated on the benefits of nuclear power. We need to learn how to fight the misconceptions presented by opponents to nuclear power...”

“I believe nuclear power should be an important part of the nation’s energy strategy both for eliminating our reliance on foreign oil and for the environmental benefits of reducing greenhouse gases. I find it encouraging that some utilities are thinking about building new reactors. However, I am concerned about the capability of these same utilities to safely and efficiently operate them given the recent trend of downsizing and corporate profit requirements. I am also concerned that the lack of a definitive solution to the waste disposal problem, including HLW and LLRW will result in both financial and public perception problems that will doom the industry to the same fate as the current generation of reactors.”

**Question #2: Do you see any workforce problems in regard to the fact that there will be a sizeable attrition in the coming decade due to the baby boomer generation retiring?**

Nearly 90 percent of the responders were concerned about potential workforce problems. Most felt that the problems would be short term. Some felt the workforce problems would happen in a specific area. Only a few felt that the workforce problems would be felt across- the-board.

The remainder felt that it was not a problem. One basic reason was that there would be retired employees who could fill in. Others felt that with proper planning on the part of utilities, INPO, training organizations, and colleges and universities, the problem could be alleviated.

**Quotes regarding #2**

“Absolutely. Consider the current work force relative to regulatory, engineering and construction experience. When considering the experience of the entire fuel cycle work force (enrichment through production through disposal), most of the U.S. work force is at or approaching retirement age. Key federal agencies (e.g., NRC, DOE) have already expressed concern regarding the ability to meet future hiring needs when considering those persons eligible for retirement.”

“Life is an ongoing endless learning curve, so that you can move from a static facility to a mobile nuclear facility with relative ease because all of the science remains the same. It’s just the various rules and regulations of the location you’re in that varies. And they are learnable, they are not unique.”

“If more reactors are built than present today, there could be a shortage of qualified persons with a good engineering and science background in nuclear and mechanical engineering and radiation sciences to manage the actual plants, provide competent government oversight, and other ancillary duties related to the nuclear power infrastructure.”

“The Health Physics Society has already pointed out the potential shortfall of trained health physicists in the future (October 2006 issue of HPS newsletter) and I have no reason to doubt them.”

“Yes, there will be workforce issues unless we have a fully committed future for our industry. Heavy vessels, piping, machining and large site construction infrastructure are no longer USA strengths. We need to rebuild that infrastructure. In addition, we need to develop interest in our younger folks to become pipe fitters, welders, concrete experts, engineers and technical specialists. In order to regain these strengths, we need a committed future or our brightest and most capable students will not be attracted to their career options.”

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“I think there will be a workforce shortage especially for qualified operators. However this could be solved with commercial training schools for candidates with courses designed specifically for operating and maintaining the nuclear facilities much like the US military offered in the Army and Naval Nuclear Power Programs.”

“While there are currently only a few younger health physicists coming into our industry, I am confident that demand will increase supply and that the anti-nuclear movement will not dissuade the more pragmatic younger generations.”

“Yes. There is already a reduction in experience in the industry due to retirement and attrition. Very few colleges and universities offer Nuclear Engineering and Health Physics programs of the same caliber as even 15 years ago. Most of the people I see at nuclear-related conferences have hair at least as gray as mine. The others are fresh to the industry and seem to lack even basic understanding of the issues. There seems to be a whole class of mentors missing that will be needed to ensure past mistakes are not repeated.”

“...it is across the board. INPO is only at about half of the size it was in the past. NRC staff, licensed operators, start-up engineers all will be needed. The loss of personnel throughout the industry will, in itself, present significant challenges. Efforts need to be taken to do all we can to provide financial incentives to the potential retirees to retain their much-needed support to make the necessary transition.”

“To some extent, I assume plant construction will have to draw on cross-training technical folks from domestic airlines and auto manufacturing as those industries relocate off-shore to reduce labor costs. Importation of technical workers from Eastern Europe can be expected if U.S. students continue to decline work in construction.”

“...along with constant downsizing and less than adequate training, given to the current workforce, yes, I believe there will be issues with the workforce in handling the growth. However, it can be done as long as energy companies put strong training and preventive maintenance systems in place to ensure safe and secure processes. Qualified training of new workers is key to the future of nuclear power.”

**Question #3: Do you have any comments in terms of the size and type of reactors that may be built in the future?**

People responding to this question spoke in terms of desiring inherently-safe, advanced reactors, standardized, standard design and concepts, within power ranges from 800 to 1200 MWe and 1000 to 1600 MWe - LWRs.

**Quotes regarding #3**

“I think the workhorse of the future is still going to remain as the light water reactor. Either the boiling or pressurized water reactor...if we have a high degree of grid stability, which we do not have now, I think the larger-sized reactors are obviously going to dominate. But if we have weaker grid stability, distributed smaller-sized reactors would appear to me to be more feasible.”

“Any suitable design can be operated safely given the proper expertise and focus. I would expect reactor designs that minimize waste generation and the volume of contaminated systems to be more favorable. I would expect the light water designs to be the most likely to be developed due to the experience of the industry. Exotic coolants will require significant changes to the technology before they will be considered reliable and effective.”

“...I would suspect (in the future) that the staff requirements would be less (than today's staffing needs) and the reason for that is, you're going to have a base staff load at any plant for any given operation. Where the manpower changes radically is where you're into a refueling operation or in a sudden turn down of activity such that you are in a repair mode...the bottom line is that the manpower, because it going to be in a standardized design, you're going to have technical experts in the pool in a regional concept or you may have an expert...which a utility can contract out, this person may be a unique person...to go to 20 different plants in a year...outsourcing their own people...a gigantic pool of talent that is interchangeable, just like all the components of the future reactor systems...”

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“I think that a standardized reactor should be built that can supply 250 MWe and be coupled in tandem to give whatever total output is needed.”

“They will be big in output, small in footprint, sited in large load growth areas, and located near existing transmission corridors. That is the only way you will be able to justify the cost and duration of construction.”

“Vendors seem to be all over the place on this issue. They seem to feel reactors in the 300 MW range are suitable for developing countries (IRIS, The Chinese are exporting a 300 MW design). For the more developed countries (U.S., China, France), in the near term 1000 MW – 1600 MW LWRs seem to be ruling the market. LWR technology has a long-history, is well understood, and for the next decade should be the dominant reactor type.”

“Smaller modular unit is better especially if they do not rely on a large cooling water source.”

“In my experience Pressurized Water Reactors seem to have a better design as opposed to Boiling Water Reactors and should be limited to 1000 Megawatts with a n allowable six reactors per site. Brackish Water Cooled BWR’s and PWR’s should be avoided to due their inherent corrosive and waste issues.”

**Question #4: Can you comment on the ability to finance future reactor development?**

This question was described by one person as a “tough one.” The answers tended to be based on timing, politics, government assurances, Wall Street, oil prices, coal and its relationship to environmental concerns such as mercury and carbon discharge, and regulatory interactions to the process in making new construction feasible.

**Quotes regarding #4**

“Energy needs, public perception, and political climate all seem to be aligning for the first time in decades to make new nuclear construction once more favorable. There are two key unknowns at this point, the COL process and financing new plant construction. Many utilities are willing to make the investment of time and money to go through the COL application process, but they are still unwilling to commit to new plant construction until they see the results of the COL application process. This means there is still uncertainty about the political/regulatory commitment to new plant construction.”

“If it makes business sense and the financial ratios are there with a good degree of certainty and trust in schedules, there will be no problem for financing. Financing is all in the numbers, if the investment meets the thresholds of the investment banking community, there is plenty of money to finance all new construction.”

“For now, only regulated utilities will be able to afford to build these units because they will have greater certainty of cost recovery. Merchant generation will have a much tougher financial model and will be less likely to assume the financial risk of siting, licensing, and building nuclear generation.”

“I think this country has the ability to finance anything it wants. Our present government (Congress) needs to get their heads out of the sand and get on with dealing with our energy needs and mandating the Yucca Mountain Disposal Facility. These problems have been solved and it is not an issue.”

“The ability to finance will be a challenge. Because it has been too long since a new reactor has been constructed in the United States, those who take the initial steps will unfortunately be burdened with the difficulties associated with being in the forefront. Because material/component suppliers will have to ‘gear up’ to support the effort, problems associated with the lack of qualified vendors, equipment acceptance, and delays will cause schedule delays. Perhaps what is needed is some form of innovative government funding incentives to compensate for the associated financing and funding challenges associated with the initial new plants.”

“Again this ties in with a comprehensive energy plan. The national government should decide on which types energy generation they think would be best for the country and use bonds to provide seed money for research and development and building. I think the modular designs in the advanced nuclear reactors will be cost effective (without government subsidies) eventually. However the LLRW and HLW waste disposal costs may be a wildcard in this cost estimate.”

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“By development, I assume you mean financing construction. Certainly, the risk insurance being provided by the U.S. for the first six plants will have a major effect on financing those units. If there is success in building those units, I believe that financing will be readily available.”

**Question #5: Can you comment on licensing or regulatory issues?**

This question received a wide variety of responses. From comments about Congress, the NRC, Yucca Mountain, the COL, streamlining licensing, federal, state, and local government involvement, minority input in licensing, and regulatory constraints in addressing real vs perceived concerns.

**Quotes regarding #5**

“Licensing new plants under Part 52 is partially untested especially for Combined Operating Licenses (COL). The Early Site Permit (ESP) and Design Certification (DC) processes have been tested with general success. The COL process of melding the Early Site Permits and Design Certified plants will be the real test, especially understanding and designing meaningful ITAACs (Inspections, Tests, Analyses, and Acceptance Criteria) where many items such as Control Room designs were swept under the rug for expedience at the time the first plants went through the DC process.”

“NRC has the licensing ability and ample regulations to accomplish this. Staff needs may be somewhat inadequate however layers of bureaucracy could be peeled away to allow streamlining the licensing process. Look at what other foreign governments have been able to accomplish without compromising safety.”

“The NRC will be changing commissioners, department management and technical staff at a fast rate in the next few years. It will be incumbent on the license requester to ensure the submittals are perfect and meet requirements. With a largely inexperienced NRC staff, the time frame for licensing will be based to a greater degree on the quality of the applications.”

“Right now, I see one of the biggest issues being the lack of a permanent disposal site for the fuel. I don’t believe this is a technical issue, but rather a political and public relations issue that must be dealt with. Also, I fear that nuclear energy has become something of a politicized issue and may suffer from changes in political parties.”

“Licensing of the new plants should be easier if they are built on current nuclear power plant sites, however there will still be intense opposition from a select public. To this select public, the new safety concerns resulting from terrorism still are not adequately addressed in the new plant designs.

I think regulatory mechanisms will basically be the same as they are now. The NRC will handle these as they do now. Of course start up of the new plants and the first few years of run time will have to be more rigorously regulated and scrutinized due to the higher probability of an accident during this time. However, since the new plants are more modular, expertise can be consolidated, thus reducing the manpower needed to do this oversight.”

“A streamlined licensing and regulatory approach is a must. If you look at the changes that have occurred throughout the licensing regulatory process over the past 35 years, many improvements have been made. However, a no-nonsense approach based on standard requirements and regulations will be essential. We need to clarify the current regulations and eliminate the need to strive to be a lawyer to understand what is intended. Streamline-streamline-streamline!”

“The licensing process needs to be streamlined to assure that the minority input is heard but only carries the weight it reasonably deserves in the public interaction process and cannot unreasonably delay the process through procedural manipulation rather than legitimate stakeholder concerns.”

“I don’t see it happening in the US. Utilities are not going to fund research in the type of competitive environment currently in place. The federal government has already shown that it is unwilling to fund research in this area on its own although there are cooperative efforts with other countries taking the lead. Most of these involve research on fusion designs rather than fission reactors.”

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“The new reactor licensing process has yet to be tested in public. I do not expect that the anti-nuclear community will let the process go without significant challenges. In other areas, regulators have not been active with setting policies to guide the future. Rather they are retreating to enforcement & limited interpretation of existing regulations. Some have been positive for the industry in the areas of decommissioning & release from regulatory controls. However, there does not appear to be consensus among the regulatory community on how to apply these interpretations leading to widely varying practices. There appears to be a more conservative movement in recent decisions as the industry pushes the envelope in applying the more liberal interpretations.”

**Question #6: Can you comment on America’s ability to build nuclear power plants after such a long layoff?**

Responses to this question included issues related to our country’s manufacturing infrastructure, our long-term layoff of being able to build such facilities as American-made, and several issues related to global involvement in construction.

**Quotes in regard to #6**

“One issue I do have is on the back end (solid and liquid radwaste). The new plants appear to be designed with a stronger emphasis on nuclear safety; however, lessons learned over the past 30 years on the solid and liquid radwaste end do not appear to be applied to new plant design. I think, if we look back, a lot of the anti-nuclear focus has been in the waste area. With more forward thinking, waste management issues could be solved as well.”

“One thing for sure is that the building and manufacturing components for new plants are going to be a worldwide endeavor. This is apparent already with large replacement part such as reactor heads and steam generators, which are presently mostly foreign, made and fabricated. Operation of the plants will depend more on domestic technical ability. This aspect is where there may be a significant shortage in talent, because of the aging work force in the nuclear field.”

“In many ways we will have to reinvent the wheel. Much of the U.S. manufacturing infrastructure that supported the nuclear industry is gone. The U.S. may have to depend on overseas suppliers should new construction begin. This means they will be competing with other countries’ nuclear programs for limited global manufacturing capability. Constellation Energy even went so far as to order pressure vessel and steam generator forgings, even though they have not made a decision about new plant construction, because they feared that by the time they made their decision, there may not be any available manufacturing capability to get the components they will need.”

“I don’t have a lot of confidence in America’s current abilities to build nuclear power plants. I’m sure the ability to complete construction activities is adequate but the industry currently does not think ahead very well and makes too many decisions based on short-term costs. Quality assurance and control is also lacking.”

“Should the U.S. opt on more self reliance, a U.S. nuclear manufacturing infrastructure would need to be rebuilt.”

“The US has the technical ability to do anything it wants, e.g. our space program. We have the talent and qualified engineers.”

“We have beat the labor force up so much that it will be hard to expect the constructors to have the resources to build a large fleet ( 15 or more) all at one time. The AE’s, the constructors all have been through big swings, have downsized and shaped their businesses to make solid businesses as the market environment supports. Many shifted to DOE /DOD for business and returning to a massive construction phase will be a challenge.”

“There has been significant consolidation in the marketplace and with it a more concentrated talent pool to lead our next generation of reactors. In addition, many of the former reactor design and build contractors are forming teams/partnerships to target new plant construction.”

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“It will be very difficult to reestablish the various supporting industries. It is a shame that the country that developed nuclear power will need to buy technology and components from other countries like our great ally France.”

“The good thing about this issue is a number of companies are in the process already of building new plants in other areas of the world. This will help immensely when the first plants are constructed in the U.S.A.”

“The U.S. has many competent capabilities, but unquestionably the U.S. will be dependent on the experience and capability of numerous foreign companies for efficient construction know-how and for the fabrication of major components.”

**Question # 7: Can you comment on the ability to staff qualified health physicists, nuclear engineers, or other personnel to operate such plants?**

Key words and phrases abounded in the responses to this question. Words and phrases such as job training and lag time between demand, combating attrition, growing shortages, and learning from the ‘grey beards.’

**Quotes regarding #7**

“What qualified health physicists? The nuclear power industry has done an excellent job over the last 15 years of discouraging health physicists and engineers from thinking outside of specific limits based on short-term costs.”

“At present, I think there will be a shortage of persons with good academic and field experience in these occupations.”

“Here is a good link on education statistics for science and engineering degrees,  
<http://www.nsf.gov/statistics/seind06/c2/c2h.htm>.”

“I believe that we need to continue to train personnel to support the operation of plants since we still have them. The military continues to need qualified personnel as well. It is important that recruiting in this area occur since the options may seem very limited to potential students when evaluating the viability of a career in these areas, thus the reason for my comment earlier about full scholarships, training, etc.”

“There is time before any new plants go into operation to educate and train these personnel if the effort begins now. However, this will mean that utilities should increase their current staffing at existing plants in order that the new personnel have an opportunity to learn from the ‘grey beards’ before they retire and their experience and knowledge are lost.”

“We may not have built any nuclear power plants in the U.S. in the near past, but the technologists and engineers who did were probably U.S. educated. However, we need to ensure that colleges and universities are adequately prepared to handle the resurgent interest in the nuclear power industry. They need to have on their staff qualified instructors and trainers (possibly recent attrition personnel) to help with the understanding of the nuances of nuclear energy.”

“Both nuclear engineers and health physicists will be in short supply during the early phases of new builds. However, our dynamic economy and academic institutions will quickly respond. Mid-level engineer/managers will be in the greatest demand.”

“Research/ manufacturing companies will probably see the shortages first, because their trained HP personnel will go into energy. This is not new because it happens today, but not necessarily people moving into nuclear energy...they are going to other venues.”

“In addition to equipment, there will need to be a huge influx of people into an industry that for many years was not viewed as a place with many lucrative career opportunities. Many universities have shutdown their nuclear engineering programs. For years, enrollment in those programs was very low compared to other engineering disciplines. There will need to be a drive to get students into nuclear programs. But this will require them seeing job opportunities to make it an attractive path to follow. As a result, during the early stages of a nuclear

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renaissance in the U.S., there may be years of lag time between demand and the ability of universities to turn out students in sufficient numbers.”

“This same will probably hold true in some of the craft areas and application focused engineering areas (nuclear welders, QA/QC inspectors, construction specialists, startup engineers, etc.)”

**Question #8: What impact will the disposal of low-level and high-level radioactive waste have on new reactor development in America?**

The responses to this question focused on history, failed national programs, waste minimization, a public perception linked to all nuclear activity, challenge for new reactor design to minimize waste, and the subject of risk.

**Quotes regarding #8**

“I believe this is a major issue in the minds of the public and an easy target for opponents of nuclear power. If we don’t get this issue corrected, I think it has the potential of derailing the effort to build new reactors.”

“This is, and has been the main public perception problem with the industry. The technology exists for safe disposal but the political will to choose the site is lacking. The public will continue to have questions and concerns until some political leadership ‘solves’ the problem by forcing the creation of a suitable disposal site(s). Until then, there will be public opposition to the development of new reactors.”

“Opponents have used this issue as the primary weakness to attempt to kill the industry for many years. It is critical that we resolve this relatively low-risk issue.”

“Unfortunately, the impact will be great as we have not fully educated the citizens on the safeguards of low- and high-level radioactive waste. We need to do a better job in that area to ensure that the licensing and permit processes do not become a stumbling block on the building of nuclear power plants. There will always be opponents to the building process which should be taken by the nuclear power industry as another set of eyes to help their commitment to excellence in ensuring a safe and secure industry.”

“I remember first hearing about Yucca Mountain...almost 25 years ago...Yucca Mountain has been worked on and it’s not going to happen in my lifetime...Why? There’s no political will. The first thing you have to do if you’re going nuclear is you have to deal with the nuclear waste, specifically the high-level waste. President Carter’s elimination of the reprocessing of nuclear fuel I think was a mistake.”

“These will have some impact however these problems have been solved technically. We just need to get on with public policy in this regard and avoid the political quagmire.”

“Higher education should be provided with government grants as incentives under our energy policy and laws to fund these nuclear engineering and related disciplines.”

“This impact is the most important when it comes to public acceptance. If there is no significant progress in Yucca Mountain and LLRW disposal, I think the industry will have a hard time stabilizing new plants. Again this can be tied to a national energy policy. If the national government truly wants lessen our dependence on oil, they have to truly push harder on establishing national repositories for HLW and LLRW.”

“Very little. The waste issue is manageable or life of plant, decay in storage is also doable. We have vast capacity at desert sites and at the current (2) B/C sites (politically constricted) as well as at DOE facilities (Nevada Test site). With the anticipated WCS opening and their large capacity, there should be no physical problem, only a political one. I don’t think it will have an impact on a utility building a plant. It is all financial ratios and assurance of schedule.”

“Certainly waste minimization will be an economic necessity and one might expect that new designs would take this into consideration. It may be that uranium re-enrichment can impact the volumes of high level waste generated. With careful planning, low activity waste could be pre-exempted by the NRC to take maximum advantage of such facilities as US Ecology Idaho which have vast potential capacity and very robust design.”

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“The lack of access to waste disposal will not limit an additional 20 power plants in the U.S. in the south as they can store waste on-site. However, without access to waste disposal pursuit of 400 new nuclear power plants required to replace coal and natural gas base load electric generation in the U.S.A. to reduce CO2 emissions will not be possible.”

“This will have little initial impact, but if we hope to continue growth of nuclear energy past the initial builds, we need to solve both the low- and high-level waste disposal access problems.”

“I believe that the waste disposal issue (both LLW and HLW) will be decoupled from new reactor development in the US. Our policy makers will recognize that we do not have the luxury of allowing waste issues to stifle a strategic energy source such as nuclear. However, I also believe that the entire radioactive waste management system (e.g., LLW, HLW, Mixed waste, TRU waste, commercial and defense) in the US needs to be reconsidered and that there is a need to provide a solution to the radioactive waste disposal issue. At present, I do not consider there to be sufficient vision or resolve among key stakeholders to cause this issue to be resolved.”

“It is a political, not a technical issue. The anti-nucs have been effective in convincing parts of the public that there is no solution to the waste problem. We must let the public know of the success of the WIPP project and Congress must act to provide for interim aboveground storage of spent fuel at Yucca Mountain and move the Yucca Mountain Repository to completion. (I have always favored long-term storage above ground of spent fuel rather than underground, until that fuel is reprocessed as it eventually will have to be.)”

**Question #9: Do you have any comments on higher education’s ability to meet the needs to educate nuclear engineers in the future?**

Responses to this question ranged from no problem, to a concern about decimated university engineering programs, faculty qualifications, economic support for programs in place, and a discussion about research training reactors versus computer simulated research reactor training.

**Quotes regarding #9**

“I believe higher education is on the verge of losing the majority of its expertise in this area and will soon be in the position of having to re-invent the knowledge and experience base.”

“I don’t work in the academic environment. However from a government employee point of view, there are very few persons with advanced degrees in nuclear engineering except at national laboratories and universities. Universities in the close proximity of the aforementioned laboratories probably will have adequate adjunct professors to educate the future nuclear engineers.”

“I believe that the waste disposal issue (both LLW and HLW) will be decoupled from new reactor development in the US. Our policy makers will recognize that we do not have the luxury of allowing waste issues to stifle a strategic energy source such as nuclear. However, I also believe that the entire radioactive waste management system (e.g., LLW, HLW, Mixed waste, TRU waste, commercial and defense) in the US needs to be reconsidered and that there is a need to provide a solution to the radioactive waste disposal issue. At present, I do not consider there to be sufficient vision or resolve among key stakeholders to cause this issue to be resolved.”

“Universities are well-equipped to meet the need for nuclear engineers, but one of my concerns is that we have an awful lot of faculty who have little or no nuclear power plant experience. I do not have a great concern over the fact that many universities have been combined with other engineering fields or their programs have been lost. First off, we had too many universities in the field to start with and too many reactors. I feel that if we had 15, 20 at the most competent, experienced universities involved in these programs, we’d be fine from a national concept. I do have a concern about training young people how to operate a reactor. We can do that with a simulator but, again, I use the comment that the safety culture of dealing with the real thing vs. the image thing cannot be ignored. I think both are needed. There’s a lot of opportunity, I think, in the research reactor applications. For example, one of the things I think that has deteriorated nationally is radio chemistry. We used to have really sharp radio chemistry programs which were the basics of health physics and environmental protection, but that has decayed away, this area needs attention.”

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“Many universities have dropped their programs. Those who currently have programs may not be able to increase enrollments because of a lack of professors to teach the courses.”

“The biggest problem will be staffing the new/expanded NucE and HP academic programs with qualified and experienced staff. The academic programs have deteriorated over the years, and it will be very difficult to find and attract qualified instructors and researchers in a very tight market.”

“Higher education should be provided with government grants as incentives under our energy policy and laws to fund these nuclear engineering and related disciplines.

“I believe that the general engineering programs (electrical, mechanical and civil) will be fine. The other technical disciplines such as HP, fuels and analysis areas will need more attention, as schools have scaled back these programs due to limited career opportunities in recent years.”

“I believe this issue needs to also be part of a national initiative since it has been seen as a dying option and schools have been reducing their efforts in this area.”

**Question #10: Can you comment on media regarding nuclear energy?**

All respondents shared their opinion on this question, some were positive, but most were negative about the media’s role and actions in communication information to the public.

**Quotes regarding #10**

“The media thrives on negative reporting and generally lacks the knowledge to write intelligently about scientific matters. Therefore, it will be necessary for professional personnel to be willing to spend the time and effort to communicate directly with the public. I have found that to be an effective, but inefficient, way of getting facts before the public.”

“While this might be regarded as heresy in some circles, I think the media is actually viewing nuclear energy more favorably today than anytime since Three Mile Island. They know better than anyone that nuclear energy has been staying under the radar in terms of bad public relations, and they are also aware of some of the other environmental issues such as global warming that are on the horizon. Nuclear energy is not making any bad news right now and good news seldom sells newspapers so I don’t think they will suddenly become nuclear energy advocates, but I do believe that they will not have the ‘knee-jerk’ negative reaction that seemed to be the case once.”

“I think since nuclear power issues and radiation issues are hot button items, the media will always take advantage of this situation to sell their product. Fair and balanced reporting is probably only achievable on PBS or in more technical journals.”

“Because the media has direct access to the public, they have great influence over the public’s perception of nuclear energy. The unfortunate truth is engineers often make terrible spokespeople. For inexplicable reasons, the public will be more apt to listen to a popular actor than to a technical expert. It’s as though they equate popularity with knowledge. This is something the nuclear industry never did a good job in dealing with. The nuclear industry needs to embrace the media, be open, and make them part of the sales effort for nuclear energy...”

“The media is also a current mess! How many times have you recently watched a news show and someone is trying to explain what someone meant to say or intended, as though we, the public are unable to make an intelligent decision without someone providing their opinion. It is not news, it is rehashed gibberish for the most part. Yes, the media will continue to be a significant problem and sadly to say there will be little that can be done to change it.”

“The media is drawn to conflict, and its news coverage is generally based on perception and emotion rather than logic and science. They are in the business of selling news and will always follow what does that. Our

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challenge is not so much changing opinions in the news media as it is to earn the public's trust. It is our responsibility to design, manage and operate properly in order to keep a balance. By earning public trust, we minimize the conflict that tends to drive negative news coverage of the nuclear industry."

"They don't understand it, don't want to understand it, they don't accept it and they cater to the vocal anti-nuclear minority."

"I'd rather not. I have spent an entire career trying to provide the media with real facts and it is a losing battle. "

"The media are alarmists and need to be educated. Somehow we need to reach out through community outreach programs to educate them."

"The media will follow any story that they think will generate controversy and increase viewership."

"We need to do a much better job of promoting the benefits of our industry. Higher cost fossil fuels and the recognition to be independent of foreign supplies will do more to promote nuclear power."

"We have had a very successful period of generating electricity from reactors since TMI. The media is not often interested in long-run success stories."

"Media can be expected to still be predominantly liberal and therefore have a tendency to be anti-nuclear."

"Since the energy crisis, the media seems to reflect a more tolerant view of nuclear power, reflecting our society as a whole."

"Typically negative. Tony Snow is the only reporter I've ever heard on TV asking anti-nuclear politicians and environmentalists about nuclear power's ability to reduce CO2 emissions."

"It is very encouraging to see the environmental community (e.g., CASEnergy) backing nuclear energy. Overall, there still tends to be a negative bias."

"The media is in the business of selling their product. So as long as there is public and political concern, they will jump on the bandwagon."

"Unfortunately, the media is driven lately by the insatiable appetite of the viewer, listener or reader of disaster-related stories. So unless there is something that presents itself as a disaster, coverage will be limited and the good of nuclear power will be downplayed."

"Unfortunately, if something bad happens, it's front page and if it's good it's found on page E-35 below the classified ads or obituaries."

**Question #11: Can you comment on the public's attitudes on nuclear energy?**

The responses to this question are a companion to the previous question regarding the media. Respondents noted that time and current issues seem to be a factor in public perception and attitude. With more stories related to climate, brown- and black-outs, greenhouse gases, and the rising cost of other fuel systems, the public has seemed to have undergone a change of attitude of being more positive about nuclear energy. However, Chernobyl, TMI, stories related to radiation and its effects, and the safety at existing plants are constant reminders of how quickly public attitudes can be swayed.

**Quotes regarding #11**

"Public attitudes on nuclear energy are still based on their ignorance of the basic sciences on radiation and the ability to not quantify the risk from radiation. This is basically not their fault, due to the unfamiliarity of these sciences, because of our education system. Most high school and college graduates never have a course taught in radiation, nuclear power, and risk quantification. This situation coupled with a lot of misinformation from the media and rumor mills leads to an unwarranted fear of radiation."

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“The public will follow their pocket books. I believe NEI surveys have shown that the public supports nuclear power. We need to get the media and Congress on our side.”

“It definitely appears to be improving but is strongly dependent on continued safe operation of existing plants.”

“The public is 20 years removed from Chernobyl and 27 years removed from TMI. Opposition groups will bring all those misgivings back. Utilities will respond with the changes in safety and design since that time. Public attitudes are mixed, but a majority of people seem to support diverse energy supplies. Americans have seen the downside of foreign oil for a long time.”

“My sense is that the public is not terribly concerned about nuclear power and realizes that it is a necessary part of our energy mix.”

“Here again, media hype needs to be curtailed but realistically our leaders need to be educated more to avoid political intervention. But I’m afraid it will take more brown-outs and back-outs before our political leaders and the public will be convinced that nuclear energy is the solution.”

“The public does not appreciate or understand the long term thinking and implications of energy decisions as it relates to a national or worldwide strategy. Simply put, most are lemmings, and don’t care or even know where their electricity comes from. Very few will even take the time to learn or care, unless you put it directly in their line of site (backyard) or ask them.”

“The public sees nuclear energy, radiation and radioactive materials" as threats to their health and environment. TMI and Chernobyl have scared them.”

“Since the energy crisis, the media seems to reflect a more tolerant view of nuclear power, reflecting our society as a whole.”

“Positive in the south. Negative on the coasts.”

“Improving. I think more people are starting to see the link between conflicts in the Middle East and the struggle for securing energy resources. We need to promote nuclear energy more as a step in the path toward energy independence. The link of CO2 emissions and global warming is also helping the nuclear option.”

“Based on our energy situation, it appears that this problem is turning around. A lot more quality education is needed for our children in this area to create a knowledgeable future generation and there can be no serious accidents.”

“I believe the public as a whole is ready to support the new nuclear plant transition. However, more needs to be done to make the public aware. For example, I doubt that many are aware that nuclear power is currently the lowest cost (\$17/MWh compared for example to coal at \$22 MWh), not to mention the significant safety improvements.”

“After the brown outs in California and the east coast blackout a few summers ago, public opinion polls showed a more positive view. Hopefully this trend can be continued.”

**Question #12: Can you comment on our schools and educating our youth about radiation, and nuclear science, energy, and technology?**

Several key words and phrases came from respondents in regard to this question. Some of the words and phrases were: the lack of nuclear science in our school curriculums; the teacher as the best multiplier effect in learning about science, not TV; the need to link professionals with public outreach; anti-nuclear information in our schools; a general negative bias about nuclear energy by secondary school teachers; and teacher-education programs that include radiation, nuclear science and technology.

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**Quotes regarding #12**

“Current high school curricula do not do a good job of teaching about these topics. There is no room for such ‘advanced’ topics in a system designed to lower academic standards to the point that no child is ‘left behind’.”

“We need to open up our plants for tours and actively educate the public, particularly the youth. We need to go to the public and schools. We cannot rely on others to do our education.”

“I live in a community that is host to a nuclear power plant. The plant site is proposed for consideration for a next-generation plant. In general I would say that the residents of the county and the county government are very favorable toward nuclear energy.”

“It is very important that children be taught science, in my opinion, and it needs to start at the earliest stages as possible. However, before you can teach a student, you have to have a trained teacher. If you’re going to start a program, you have to go back and take the teachers who are in place and teach them science and they’ve got to believe that it’s worth teaching. Most teachers don’t teach science because it’s hard. It’s hard for them. They don’t understand it. Yet most kids, if you present them with practical applications of science, things that they can see and observe, simple little experiments that can be done, get enthusiastic and they’re going to want more, because science is fun. You’re always learning, there’s always something new coming on, and most kids like things that are new.”

“I think these subjects should be mandatory in all our educational institutions starting in our primary schools. However, or teachers need to learn and teach the real facts rather than being allowed to convince students with their own opinions.”

“What we need...it’s the old story that we’ve used for many years, it’s that you’ve got to get into the multiplying media. And the only place you’ve got the multiplying media is the teacher. Even the television media isn’t multiplying. It’s hitting a vast audience, but it’s not multiplying.”

“Education in the sciences needs to begin at the youngest ages. While we need to be careful not to bias the information provided, information on energy, its sources, risks and benefits is essential in order to allow the students to someday make the best decisions regarding their own energy use. The topic of radiation is a little tougher since it is usually regarded in a negative way. One method I have used to show the benefit of radiation is to discuss the revolution in diagnostic medicine in the last 20-30 years. We have gone from ‘exploratory surgery’ with weeks of recovery for a patient who may not even have a surgically treatable problem, to diagnostic techniques that can be done on an out-patient basis. For most people today, their greatest exposure to radiation will be in an effort to diagnose and treat an illness they are suffering from.”

“This is another challenge but is vital. Building new reactors will be easier with an educated public. Energy education – including nuclear energy – should be a priority in all schools. Building new facilities in the current vacuum only makes the matter more difficult. The utilities and the Dept. of Energy should fund intensive energy education programs for teachers. Good educational materials should also be developed so that future generations will have the “facts” upon which they can base more educated decisions – rather than sound bites from a cable news channel.”

“The schools are not doing enough in this area. It is sad to say that in general these subjects are rarely discussed. Much more exposure is needed to science and technology. Students can readily operate a computer with the best of us, but ask them to explain how it works and they are at a loss.”

“What about educating our youth? If anything, it is educating against and it is done when they are young and impressionable. Therefore, they are educated to be against nuclear power while they are still in elementary school.”

“Schools need to link with professionals involved with public outreach programs and invite them to make presentations to their students during classroom hours. Many professional organizations such as the HPS, AIHA and ACS have developed programs, handouts, and brochures and have volunteers willing to talk and share their knowledge.”

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“K-12 gets a lot of free material from anti-nuclear sources. Many teachers are opposed to nuclear power. Many of the vocabulary home work sheets my ward brings home from grammar and middle schools have anti-nuclear sentences embedded in the work sheets.”

“Our schools neglect this training most likely due to the fact that it is not called for in the curriculum. To change this, individual state departments of education must be lobbied to change their curriculum and stress a basic understanding of nuclear energy and its relevant issues.”

“As with society in general, the secondary school educators maintain a negative bias toward nuclear energy. Nuclear power has to be more than just financially competitive with other sources of energy; it needs to bring other benefits (e.g., reduced reliance of foreign oil, reduced greenhouse gas emissions, good high-paying and safe jobs, and possibly even an export market).”

“We need to get students interested in science and math at an early age and to capitalize on the current technology out there so they will become the engineers and technologists of the future.”

“Education is the best solution, starting in the public school system, the earlier the better.”

“Like the media, many schools lack the unbiased teacher knowledge of such matters which results in graduates that are largely science illiterates.”

“I would guess most science teachers in schools never had courses in radiation or nuclear science, except those who had some physics and biology majors in college. However, I am only guessing on this. Probably, if it has not been done already, this should have a study done on it to see if this premise is true or not.

## **CONCLUSION**

The development of nuclear energy in the United States started with little or no public input back in the 1950s. A nuclear renaissance in the 21st century will require public input, acceptance, and an informed citizenry. It will also require leadership and political fortitude on the part of our elected federal, state, and local government officials to expedite policy that has been adopted.

The authors of this paper have found the workforce issue to be significant. Each question presented needs to be considered and reviewed during the process. In summary, the authors have identified 11 challenging areas that should be considered while starting a new era of nuclear energy development in the United States. They are:

- 1) Governmental leadership and the political will to follow-through with the difficult process of siting, licensing, and building a new nuclear power plant.
- 2) Ensure that we have a streamlined and concise regulatory process.
- 3) Prevent SLIPPAGE (special legal intangibles politically propelled around galvanizing entropy).
- 4) Financial assurances need to be in place to prevent unnecessary or unwarranted delays and expenditures
- 5) Ensure that new plants continue to have well-trained personnel who operate in today’s safety culture as well as providing a service with a high level of confidence and reliability while safeguarding our environment.
- 6) Provide services that will be not only safe and secure, but also effective and efficient.
- 7) Enhance communication and information initiatives to employees, customers, government officials, the media and the public at-large.
- 8) Work in a cooperative and professional manner with regulatory and other governmental bodies.
- 9) Work to incorporate science subjects including energy systems, radiation, radioactivity and nuclear technology as part of our K-12 educational standards and curriculum in our schools for our youth of today and tomorrow.
- 10) Encourage and support teacher-education courses about nuclear science and technology
- 11) Support, promote, and provide funds to higher-education institutions that train and teach nuclear science and engineering.

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