UNIVERSITY OF CALIFORNIA, BERKELEY

Responses to Questions on the Future of University Nuclear Science and Engineering Programs

by

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

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

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

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

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

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

   In this scenario, the total number of new nuclear workers (new workers + retirement replacements) over the next decade is essentially only the retirement replacement number. Thus, assuming a retirement rate of 3%/year, 50 – 60 new engineers are needed each year, or under 1,000 over the next decade. This is very far from the 90,000 in the NEI forecast. Even if some number of new reactors are built, I would not consider it to be more than 5 – 10, for which the current production rate of engineers is likely to be sufficient. My estimates here are, in fact, *below* the number of nuclear engineers that are currently produced at the undergraduate and graduate levels (345 in 2003). Even with the current yield of only 20% of nuclear graduates taking jobs in the commercial nuclear power sector, the current rate of graduates appears to be sufficient to meet the needs of the industry.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. **Your written testimony ends with a quote from the head of your nuclear engineering department saying that most department heads believe that the best approach to reinvigorating nuclear engineering education – even over providing direct funding for universities – would be for the government to commit to create "incentives" to build a**

small number of additional commercial nuclear plants, allowing those incentives to decrease over time.

a) What are the incentives these department heads have in mind?

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

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

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

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

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

Several approaches exist:

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

d) What is the appropriate industry share for these incentives initially?

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

Questions from the Minority

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

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

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

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

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

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

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

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

Several approaches exist:

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

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

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

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

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

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

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

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

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