Market Analysis of a Looming Crisis –Decommissioning Trends and a Shrinking Crew - 15276

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ABSTRACT

Recent events and trends point to a scenario of more and more reactors being retired due to economic viability reasons, post- Fukushima requirements, and a stalling of the general "nuclear renaissance". Such a trend is already happening in the United States and will likely also occur in other countries where older reactors are coming to an end of their original operating li9cense periods or where regulators have imposed additional requirements. In terms of projections for the US, we have performed an analysis based on a plausible scenario that shows that as many as 25 reactors may enter decommissioning in the next twenty years, in addition to the reactors already in decommissioning. A significant change that is happening is that the power plants can no longer apply the SAFSTOR option and a "wait & see" strategy. The main driver for this change is state intervention along with other factors including the status of the decommissioning funds, long-term liability issues, and a strong public interest in early dismantlement and cleanup.

A less noticed but equally important trend in the nuclear industry has been that experienced decommissioning managers and engineers have been retiring in large numbers. With no overlapping programs to transfer knowledge and experience to a younger generation, the issue is a looming crisis that has the potential to severely impact the decommissioning of future reactors as well as the future of nuclear power development in general.

This paper evaluates data from the commercial power industry as well as reports from the national and international organizations. First, it provides a market analysis of the nuclear power, reactor decommissioning status, decommissioning trends, factors influencing the trends, and projections for the future. Second, it analyzes a critical issue for the industry related to the shrinking workforce of decommissioning managers, engineers and other professionals and the challenge it poses to the decommissioning industry and the nuclear industry in general. Finally, the paper reviews initiatives already taken in this regard and provides recommendations as what more can be done.

INTRODUCTION

Reactor decommissioning trends in the United States are shifting due to a number of factors including the post- Fukushima requirements for the reactors and a changing energy economics. Only a few years ago, almost all reactors were renewing their licenses for continued operation after their current licenses are set to expire. However, a re-examination of economic viability of reactors, especially the older reactors, is now being done across the industry.

The cost of staying in operation for aging reactors is the leading cause of shifting trends. Of the US fleet of 100 operating commercial reactors today (65 PWRs and 35 BWRs), 20 reactors are over 40 years old

[1]The views expressed in this paper are those of the author and do not necessarily reflect the views of his employer or the clients.

and if counted for reactors >30 years old, the number stands at 62. Among the BWR reactors, 23 are of Mark 1design (similar to Fukushima reactors) and most are nearly 40 years old. While many reactors in the US fleet have obtained license extensions for another 20 years of operation, aging management issues and energy economics could drive many of the older reactors towards decommissioning as uutilities re-examine the cost-benefit analysis of refurbishment and replacements of major components and the changes needed for beyond-design-basis external events.

Changing energy economics in the United States have led to natural gas becoming the preferred source of energy supply. Natural gas prices in the United States have fallen dramatically with shale gas rapidly increasing its share in the total natural gas production. The commercial gas prices have fallen to about one fifth of what they were about six or seven years ago. In a climate of such a dramatic change in the energy landscape, natural gas is becoming the fuel of choice for many electric utilities with a diversified generation portfolio.

In the past few years a number of plants have been shut down or have announced their early shut down plans for various reasons. These include Kewaunee power reactor, a 556 MWe PWR; Crystal River nuclear plant, a 860 MWe PWR: and SONGS Unit 2 and 3 (each 1127 MWe PWR) which have been shut down. The Oyster Creek reactor, a 636 MWe BWR is scheduled to be permanently shut down by 2019, ten years earlier than its extended licensed period. In terms of projections for the US, an analysis based on a plausible scenario shows that as many as 25 reactors may enter decommissioning in the next twenty years, in addition to the reactors already in decommissioning.

One significant change that is occurring in the decommissioning industry is that power plants can no longer apply the “wait & see” strategy and the states are proactively requiring the plants to adopt the “immediate dismantlement” (i.e., DECON) option. Examples are as in the case of New York, Vermont, and California. Other factors also influence the decision, for example, the status of the decommissioning funds, long-term liability issues, and a strong public interest in early dismantlement and cleanup. The industry is also hampered by the fact that no Federal facility is likely to open for decades for spent fuel after the closure of the Yucca Mountain project about five years ago and the industry is forced to continue spending large sums of money on the dry storage facilities.

A less noticed trend but equally important trend in the nuclear industry has been that experienced decommissioning managers and engineers have been retiring in large numbers. With no overlapping programs to transfer knowledge and experience to a younger generation, the issue is a looming crisis that has the potential to severely impact the decommissioning projects in the future. Interest, as well as the investment in nuclear engineering and sciences has been dwindling for almost three decades and many universities had closed nuclear departments or programs. It is only more recently that some increases have occurred in the Federal sector (such as DOE) funding and private sector funding for such programs. Nevertheless, the data show that for the specialized areas such as nuclear engineering, health physics and nuclear chemistry, the number of undergraduate and graduate level students are quite small and unlikely to support the future nuclear workforce needs including decommissioning.

While management training can be accomplished at a more expedited level, it is generally not feasible to provide technical training in a short time frame. The issue is complicated by a shortage in supply, the rate at which the current nuclear workforce is retiring and the specialized nature of the industry. Studies have shown that for an effective transfer of specialized technical knowledge the overlapping time frame may range from 3 to 8 years. The current reality is also that a large proportion of nuclear power plant workers are likely to retire within the next 10 years. This converges with the time frame when many additional reactors may enter the decommissioning phase. It is also worth noting that the “immediate dismantlement:” option for a reactor still takes about ten years to complete. The utilities have also found that it has been difficult to transfer available workforce from "operations phase" to the "decommissioning phase". It is clear that the ttransfer of knowledge is not happening at an acceptable time frame. It is also clear that it is crisis in the making for the nuclear decommissioning industry.

This paper provides a market analysis of the nuclear power industry and the decommissioning industry with an emphasis on the above topics. First, it discusses a broad overview of the issues facing the industry today. It focuses on the commercial nuclear power and evaluates data from the industry as well as the reports from the national and international organizations. It provides an analysis of the nuclear reactor decommissioning status, decommissioning trends, factors influencing the trends, and decommissioning projections for the future. Second, the paper discusses a critical issue facing the industry that the workforce of decommissioning managers, engineers and other professionals is shrinking rapidly. The paper provides an analysis of the issue, the significant challenges for the decommissioning projects now and into the future, and it summarizes initiatives that are being taken to remedy the situation. Finally, the paper also provides recommendations to do more in this regard.

MARKET ANALYSIS OF ENERGY DEMAND AND ROLE OF NUCLEAR POWER

Worldwide Energy Projections

The nuclear power industry plays a significant part in the world's energy supply mix. However, the trends in the energy market are changing. Worldwide, the overall energy demand is set to grow by 37% by 2040 in the central scenario in the projections released by International Energy Agency (IEA) World Energy Outlook 2014 [1]. However, it is expected the economy will be less energy-intensive as a result of price and policy effects and a structural shift in the global economy towards services and lighter industrial sectors. The energy demand remains essentially flat in North America (and much of Europe, Japan, Korea) but rises more dramatically in the rest of Asia (60% of the global total), and some other areas. By 2040, the world's energy supply mix divides into four almost-equal parts: oil, gas, coal and low-carbon sources (including nuclear). Electricity remains the fastest-growing final form of energy. However, the power sector contributes more than any other to the reduction in the share of fossil fuels in the global energy mix. These projections also outline that in total, some 7 200 gigawatts (GWe) of capacity needs to be built to keep pace with increasing electricity demand while also replacing the existing power plants (fossil, nuclear) due to retire by 2040 (around 40% of the current fleet).

In the IEA projections, the global nuclear power capacity increases by almost 60% in the central scenario, from 392 GWe in 2013 to over 620 GWe in 2040, even though its share of global electricity generation, rises by just one percentage point to 12%. This pattern of growth reflects the complex challenges (economic, technical and political) faced by this sector. China accounts for nearly half of this growth, while India, Korea and Russia collectively make up a substantial part of the reaming share.

The Word Nuclear Association (WNA) data from April 2014 [2] show that over 435 operable commercial nuclear power reactors operating in 31 countries provide a combined capacity of over **370** GWe and account for about 11% of the world's electricity. Worldwide, 71 reactors are currently under construction in 13 countries, with major construction activity in China, South Korea, Russia, India, and United Arab Emirates.

Shifting Energy Economics in US

Projections from US Energy Information Administration (EIA) in the Annual Energy Outlook 2014 (AEO 2014) [3] show that for the Reference case, total electricity use grows by an average of less than 1% per year from 2012 to 2040. Growing domestic production of natural gas and oil continues to reshape the energy landscape, largely as a result of rising production from tight formations, even though it is acknowledged that expectations about resources and technologies used could substantially affect the future projections. After 2020, natural gas plants are expected to account for more than 70% of all new generating capacity added for electricity in the United States. Similar trends were projected in the previous Outlook Report 2013 with more reliance on natural gas continuing. The projected share of the nuclear growth is directly impacted by the ample supply of natural gas. Natural gas prices have fallen dramatically in the US as the extraction of shale natural gas though hydrofracturing continues to expand. The nuclear power plant capacity grows only slowly and it is primarily through the uprates and some new build.

The 100 operating US reactors make it the largest nuclear fleet of commercial power reactors in one country and nuclear provides about 19 % of the electricity generation in the US. The initial licenses issued by the Nuclear Regulatory Commission (NRC) for a power reactor are for a period of 40 years; however, more than 70% of the US nuclear fleet has already received approval from the NRC for 20-year license extensions.

The AEO 2014 Reference case mentioned earlier assumes that plants reaching 60 years of age between 2030 and 2040 will be granted a second life extension. From the industry trends at the present time, this main assumption may have a large uncertainty in it because the power plants may be shut down for other reasons at the end of their licensed period or prematurely before their extended licenses expire. The decommissioning trends in the US are discussed in later sections.

Role of Reactor Retirements and Decommissioning in Energy Projections

Related to nuclear power worldwide, the IEA estimates that a total of 200 reactors (of the 434 operational at the end of 2013), i.e., about 38%, will be shut down over the next 25 years. About 44% of these are in the EU, 16% in the US and 12% in Japan. The decommissioning bill for the nuclear reactors that will be closed between now and 2040 will exceed $100 Billion. More importantly, and related to the subject of this paper , the report also points out that there is a danger that the scale of costs may be underestimated because, in general, the governments and their atomic energy agencies have so little actual experience in decommissioning.

MARKET ANALYSIS OF DECOMMISSIONING TRENDS

Post Fukushima Nuclear Environment (International and US)

Fukushima events have impacted the role of nuclear power in many countries and some of them may decide not to pursue new build further or some may even plan to phase out their nuclear power programs. However, in the longer-term, the nuclear energy will continue to play an important role in the world's energy supply mix, especially in the emerging economies where the with demand for energy is strong.

Only a few years ago, nuclear industry was thought to be in the early stages of a worldwide "renaissance" and it had been estimated that anywhere from 60 to 130 new power reactors might be built worldwide over the next twenty years. However, following the Fukushima event, several countries have put such plans on hold until the safety reviews have been completed for the existing reactors. The effect of the Fukushima accident on Europe's nuclear power industry has been significant. Germany reversed an earlier decision to extend the service life of the country's 17 nuclear reactors and has now permanently shut down 8 reactors. In a referendum held in 2012, Italians voted overwhelmingly against the resumption of nuclear growth. Switzerland has put all plans to build new nuclear plants on hold, at least temporarily.

However, other European countries (e.g. Finland, Russia, United Kingdom and Slovakia) have kept their nuclear programs unchanged.

In Asia, China, Korea, and India are expected to continue with their nuclear expansion because of the limited fuel options for energy production and a substantial need for the energy now and even greater need projected for the future. In fact, about 50% of future nuclear construction, through 2035, will come from China and India. China has more than 25 reactors currently under construction; another 34 more were also approved by the government, even though following the Fukushima accident, the government did order a safety review before proceeding further.

In the US, prior to Fukushima, almost all reactors were renewing their licenses for continued operation after their current licenses are set to expire. In addition, several applications had been filed with the NRC as the first step for the construction of new power reactors. Then, the Fukushima accident happened and the net effect has been to stall the nuclear renaissance. The new build in the United States now may be limited to only the existing projects to build the four new reactors at Vogtle and V.C. Summer sites, which are already in some stages of construction.

The Fukushima accident on March 11, 2011 was caused by a combination of a magnitude 9 earthquake and the related big tsunami off the eastern coast of Japan. It has led to a global re-examination of the design basis for nuclear power plants for natural events. While the Fukushima reactors and the site have been stabilized, cleanup of contaminated water from cooling of the reactors and the Spent Nuclear Fuel (SNF) pools continues and decommissioning of the site and cleanup of surrounding areas will take decades. The impacts of the accident continue to be assessed from a technical perspective; however, a number of actions have already been taken in most countries. The existing nuclear power plants and nuclear construction projects have been examined from a perspective of coping with extreme natural events, specifically the Beyond-Design- basis External Event (BDBEE) scenarios.

In the US, the Nuclear Regulatory Commission is in the process of implementing recommendations of the Near Term Task Force (NTTF) [4]. These recommendations build on the longstanding defense-in-depth philosophy and NRC has started issuing Orders for the industry to implement. Three Orders originating from the NTTF were issued in 2012: Order EA-12-049 (Mitigating Strategies), Order EA-12-50 (Hardened Vents) and Order EA-12-51 (Spent Fuel Pool Instrumentation). In addition, the industry has begun assessing the flooding issues where relevant to the plant site and many plants have conducted comprehensive flooding walkdowns and implemented mitigating design actions.

Challenge for Aging Reactors in US

Of the US fleet of 100 operating reactors, 20 reactors are over 40 years old; 42 reactors are between 30 to 39 years old; 37 reactors are 20 to29 years old; and 1 reactor, the youngest in the fleet at the present is 17 years old. Thus, 62 reactors in the fleet are >30 years old. Two of the oldest operating reactors are Oyster Creek and Nine Mile Point 1 which entered commercial operation at the end of 1969. Watts Bar 1 is the last unit that started operation in 1996. Many of these reactors have obtained license extensions for another 20 years of operation. While the reactors continue to perform safely, the aging management issues are becoming more obvious and more costly.

Aging issues relate not only to the mechanical systems but also to the structures and are a high priority for the regulators and the industry. Refurbishment, retrofitting and upgrading nuclear reactors is expensive. Even for planned/scheduled replacements, major components are very expensive to replace; for example, the reactor head replacement can cost approximately $100 million, steam generator replacements at over $300 million. Some utilities may be spending up to $1 billion per plant to support the 20-year license extension for the plant.

Examples of high cost refurbishment (and where additional problems arose) include the steam generators replacement at Crystal River plant where (due to other problems) cost estimates ranged between $900 million and $1.3 billion. Duke Energy, the new owner of the plant (when it took over Progress Energy) eventually decided to shut down the facility. At the SONGS Units 2 and 3, steam generator replacements cost $780 million in 2010. However, within two years, significant damage was detected in steam-generator tubes and the leakage of radioactively contaminated water. By January 2012, the owner utility decided to shut down the units. At Vermont Yankee, the leakage of tritium was attributed to deteriorating underground pipes and the repair cost was estimated to be $700 million. At the David-Besse station where reactor pressure vessel (RPV) head degradation was identified in 2002, it was estimated earlier that RPV head replacement and the replacement power during the two year shutdown cost over $600 million, even though updated figures have not been available.

Decommissioning - Worldwide

According to the data from World Nuclear Association, to date, about 100 commercial power reactors, 46 experimental or prototype reactors, over 250 research reactors and a number of fuel cycle facilities have been retired from operation. Some of these have been fully dismantled.

It is worth noting that while a majority of the reactors have been shut down after reaching their operation mission or for economic reasons, so far 27 reactors closed prematurely due to political decisions or considerations and 11 reactors closed following damage in an accident or following a serious incident.

Application of decommissioning strategies is based on three options: Immediate Dismantling (called DECON in US), SAFSTOR or deferred dismantling, and Entombment (or Entomb): The first option allows for the facility to be removed from regulatory control relatively soon after shutdown (approximately ten years) or termination of regulated activities. Final dismantling or decontamination activities can begin within a few months or years, depending on the facility. Following removal from regulatory control, the site is then available for re-use. The deferred dismantling postpones the final removal of controls for a longer period, usually in the order of 40 to 60 years. The facility is placed into a safe storage configuration until the eventual dismantling and decontamination activities can occur after residual radioactivity has decayed. The entombment option entails placing the facility into a condition that will allow the radioactive material to remain on-site without ever removing it totally. This option is generally for application to the site of major reactor accidents (such as Chernobyl).

Policy on nuclear power in Germany has undergone changes. In 1998, the then government planned the phasing out of nuclear energy entirely. In 2009, the new government cancelled the phase-out but then reintroduced it in 2011with eight reactors shut down immediately. Currently, a total of 11 of Germany's 19 nuclear reactors are subject to decommissioning.

In UK, the 16 operating reactors generate about 18% of its electricity. Ten reactors (all Magnox) have been closed (7 of these since year 2000). UK’s decommissioning program is managed by the Nuclear Decommissioning Authority (NDA) that became operational in April 2005. The NDA is responsible for decommissioning of the nuclear legacy sites including the most challenging site, Sellafield. The lifecycle costs for NDAs decommissioning program have been stated at £73 billion but other estimates have put the cost over £100 billion.

France currently derives about 75% of its electricity from the 58 nuclear reactors operated by Electricite de France (EdF), thirteen experimental and power reactors are being decommissioned, nine of these are the first-generation gas-cooled, graphite-moderated types, the other four include, two fast reactors, a gas-cooled heavy water reactor, and a PWR (Chooz A).

Decommissioning - United States

Status-At-a-Glance

The US reactor decommissioning projects have used either DECON or SAFSTOR option. Commercial reactor decommissioning is carried out under NRC jurisdiction and considerable experience has already been gained in full size reactor decommissioning

A snapshot of the decommissioning status of the reactors and the options selected for decommissioning is presented below based on the industry information. Many of the reactors sites have chosen to store spent fuel at the sites in Independent Spent Fuel Storage Installation (ISFSI) at the site.

License Terminated (No Dry Storage at Site): Pathfinder, Saxton, Shoreham

Decommissioning Complete (ISFSI at Site): Big Rock Point, Fort St. Vrain, Connecticut Yankee (Haddam Neck), Main Yankee, Trojan, Yankee Rowe, Rancho Seco [Note 1]
([Note 1]complete except on-site waste storage)

Under Decommissioning (DECON); Humboldt Bay, LaCrosse, Zion 1, Zion 2

Under Decommissioning (SAFSTOR) : Dresden 1, Fermi 1, GE VBWR, Indian Point 1, Millstone 1, N.S. Savannah, Peach Bottom 1, SONGS 1,Three Mile Island 2

Recent Additions: Crystal River 3, Kewaunee (SAFSTOR), SONGS 2 and 3 (DECON)

(Note that decommissioned demonstration reactors include Elk River, CVTR, and Piqua).

The license termination process requirements in the United States are well established and substantial guidance and technical documents are available from the NRC. The requirements for the release of a decommissioned site are contained in 10 CFR 20 Subpart E (10 CFR 20.1401-1406) and guidance for decommissioning is available in NUREG-1757, NUREG-1700, NUREG 1575, NUREG-1575 Supplement 1, and RG 1.184.

The cost of decommissioning of a commercial power reactor can range from $400 million to $1 billion depending on the size of the facility, location, access to disposal for radioactive waste, state release requirements and other factors. For a full size commercial reactor, the decommissioning costs are near the top end of the range. Among the most recent reactors entering decommissioning, the combined cost for the decommissioning of SONGS Units 2 and 3 is estimated at $4 billion.

Among other factors, it is because of this type of high costs that many utilities would rather choose the SAFSTOR option than dismantle it immediately. While there are benefits in terms reduction in risk from the radioactivity decay, the primary driving factors are economic.

Unintended Consequence of Deferred Dismantling Option

As stated earlier, it is well understood that decommissioning a nuclear reactor is costly and difficult. Even under the immediate dismantlement option (DECON), decommissioning projects can take 10 or more years to complete. Regulatory challenges are also significant, especially in those cases where states have taken up a prominent role in the decommissioning process and the outcome.

Normally, in the past experience with decommissioned power reactors, there has been a nearly equal split between the DECON and SAFSTOR options. Specifically, the SAFSTOR option has advantages for sites where multiple units are present and where one unit enters decommissioning and other units remain operational. SAFSTOR, as deferred decommissioning, allows radioactive materials to decay to lower radioactivity levels thus reducing both the radiological risk and the disposal issues. This is especially significant in special circumstances such as the TMI Unit 2, where the accident had taken place.

The goal of decommissioning is the safe removal of the facility from use, decontamination and decommissioning of the equipment and release of the site under a regulatory process. A number of reactors have undergone this process and the facility sites (except for ISFSIs) have been released. For most part, this is the preferred path. The technologies for decontamination, removal of the major components, removal of radioactive waste, as well as for radiological survey and release of a site are well established. Funds for decommissioning are generally collected throughout the operating lifetime of the plant as a ratepayer levy on a kWh basis. While in some cases availability of adequate funds may be an issue, typically enough funds have been collected by most reactors for decommissioning to take place. However until recently, it appears that as reactors are shut down for economic or other reasons, the method of choice has been the SAFSTOR option. While SAFSTOR has its role and advantages as mentioned earlier, there are clear advantages for immediate dismantlement and decommissioning in most cases. The industry has substantial experience with large scale decommissioning including decommissioning of a dozen commercial power reactors and numerous small scale facilities. The industry has also substantial experience in building dry storage facilities for longer term storage of spent fuel while the national policy debate on the issue drags on.

As companies make decision to choose SAFSTOR over DECON and let the plant sit for 40 or more years, some states are weighing in on the decommissioning path chosen. As an example, the New York state administration has maintained that they will work to decommission nuclear reactors at Indian Point (rather than allow Entergy, the operator of the plant to use the deferred decommissioning option). The licenses for Indian Point Unit 1 and 2 are set to expire in 2013 and 2015 and it is estimated that the cost of decommissioning both units will be approximately $1.5 billion.

Another significant concern related to SAFSTOR that is gaining public attention is that shutdown reactors could dot the landscape, much the same way as the ISFSIs are across the country due to a lack of disposal pathway for the spent nuclear fuel. In addition to the pressure form the states as mentioned earlier, the regulatory guidance at the federal level may evolve in future to address this issue.

<u>Impact of Stalemate on Spent Nuclear Fuel</u>

What to do with the Spent Nuclear Fuel, SNF (also called with the Used Nuclear Fuel) has stymied the national decision making in US for decades. Its impact has been a long term impasse that has resulted in the decommissioned reactors still having onsite storage of SNF to deal with.

The operating reactors at many sites have little pool storage capacity left and have resorted to dry storage facilities constructed at the reactor sites. Dating back to the Nuclear Waste Policy Act (NWPA) of 1982 the US Department of Energy (DOE) is responsible for taking SNF from the US commercial power reactors and the utilities have continued to contribute money to the Nuclear Waste Fund. Note that while some countries have regarded SNF as a resource and proceeded with the reprocessing programs, the US national policy has been to treat SNF as waste. The DOE was initially set to begin accepting commercial SNF by January 31, 1998. However, a series of delays due to legal challenges, concerns over how to transport nuclear waste, as well as the political pressures have kept a site from being developed. The NWPA as amended in 1987, provided only for the evaluation and licensing of a single repository site at Yucca Mountain, Nevada. The DOE has been studying the site located near the former Nevada Test Site for almost three decades. After an expenditure of approximately $13 billion on the project and pursuing a NRC license for the site in 2008, the DOE backtracked in 2009 with a changed direction from the new Administration. A motion to withdraw the license application was filed with NRC in 2010. The project funding was zeroed out in the 2011 DOE budget cycle.

Litigation against the DOE from the nuclear utilities has continued and already substantial judgments have been granted by the courts as compensation to utilities for the management of the SNF. The industry's response to the lack of progress at the national level has been the design, fabrication, and installation of dry storage cask facilities at reactor sites. ISFSI locations dot the map as 69 such facilities are already located in 34 states and new ones are expected to be added.

The issue is significant to the future of nuclear power as well as the status of decommissioned sites. At those sites where decommissioning is complete, the ISFSIs are the only facilities left at the site i.e., stand-alone facilities, a legacy of the stalemate on the SNF disposition issue. The stored SNF will remain at the sites until removal by the DOE to a repository or a central storage site. Currently, the SNF is stored at several decommissioned reactor sites: Main Yankee, Connecticut Yankee, Trojan, Rancho Seco, Yankee Rowe, Big Rock Point, Humboldt Bay, and La Crosse. In total this quantity is about 1,756 t. In addition, the Zion station, which is currently undergoing decommissioning, has SNF stored in the pool. Once this SNF is transferred to dry storage, it will add 1,019 t; bringing the overall total at decommissioned sites to 2,813 t.

DOE's Office of Nuclear Energy has been conducting research to lay the groundwork for evaluating consolidated storage concepts, providing a central storage option until such time when a national repository can be built.. However, with Yucca Mountain project stopped, the hopes have faded that SNF will find a path to geologic disposal any time soon.

<u>Decommissioning Projections - A Potential Scenario</u>

In 2014 we presented a plausible scenario to make some projections of the decommissioning scene in the near future [5]. From 1998 until 2013 there were no reactor shutdowns. During the past decade prior to the Fukushima event in 2011, things were quite optimistic for the future of nuclear power industry and there were significant plans for the new build. However, as mentioned earlier, Fukushima changed that optimistic outlook. Combined with the new trend in electricity generation sources and the changed economics, new plant retirements are on the horizon. As utilities make decisions on the economic viability of continued operation of the aging reactors, more are expected to be shutdown and enter the decommissioning phase. In turn, the decommissioning industry will expand. A perspective of potential future landscape in decommissioning is presented in Figure 1. This figure was generated based on the actual shutdown data so far and a projected plausible scenario. The data is plotted in five year intervals. The plausible scenario is built on a number of assumptions and is based on the license expiration data including the license extensions already granted by the NRC. Approximately half of the country's fleet of commercial power reactors is over 30 years old. Of the BWR reactors, 23 are the Mark 1 (similar to Fukushima reactors) and most are nearly 40 years old. While these operating reactors continue to perform safely, due to aging management issues for the older reactors, these reactors are assumed to enter a phased in decommissioning. Within the assumptions and limitations discussed in Reference [5], Figure 1 shows a sharp rise in the cumulative total number of reactors within the decommissioning scene (decommissioned, in decommissioning, and those expected to enter decommissioning).

MARKET ANALYSIS OF NUCLEAR AND DECOMMISSIONING WORKFORCE

The Makings of a Perfect Storm

The nuclear workforce is being impacted by trends in two different directions at the international level and in the United States. At the international level, a strong nuclear growth is expected to continue, especially in China and Southeast Asia even as the nuclear growth projections remain flat in North America. China's plans would increase its nuclear power five-fold by 2020, while India plans an eightfold increase by 2022. Over 34 plants are currently under construction globally with many more in various stages of planning.

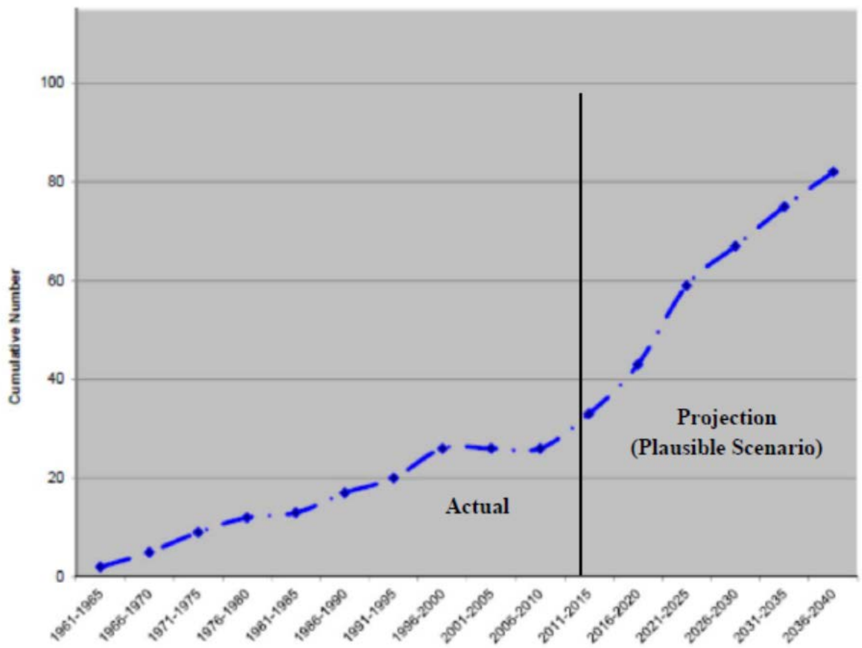

Figure 1: Cumulative Reactor Shutdowns in a Postulated Scenario
(Source: Reference 5)

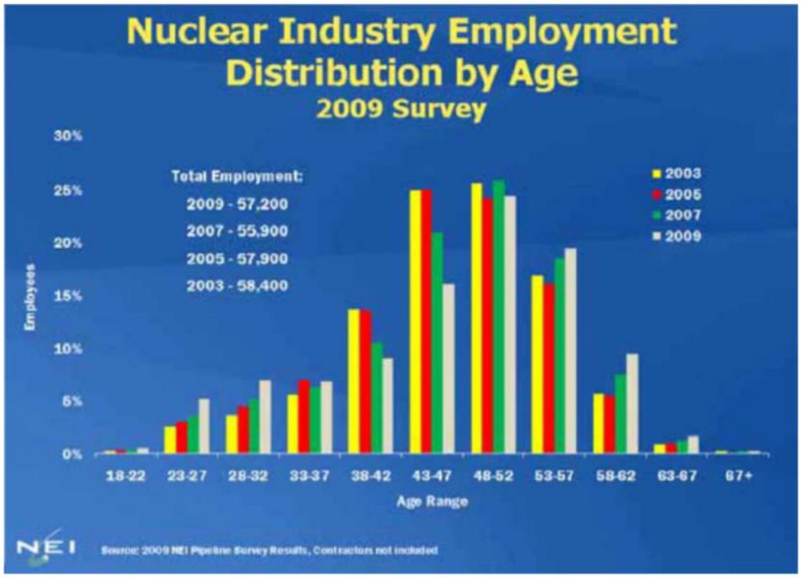

Figure 2: Direct Nuclear Industry Employment and Workforce Distribution by Age
(Source: NEI, Reference 6)

In the United States, prior to the Fukushima accident, there was strong optimism and the nuclear industry in the United States was on the verge of an emerging nuclear renaissance. In fact the first projects to be approved in decades (Units 3 and 4 at Vogtle, and Units 2 and 3 at V.C. Summer) were considered the front wave of new reactors that will be built for increased energy demands and replacement of the aging fleet However, since Fukushima, impacted by other factors, main among them the changing energy economics that favors natural gas, the heady projections of nuclear growth have been scaled back to essentially flat.

Within the projections of rapid growth in nuclear energy in several countries and scaling back or even phasing out nuclear in others lies a looming crisis –a shortage of nuclear workers who have the training, skills, and experience to support the future of this specialized industry. The crisis is fed by a number of factors and a “perfect storm” is in the making due to a complex set of circumstances:

1. Aging workforce profile,
2. Expanding demand for technical workers in the industry,
3. Decommissioning projects - current and expected,
4. Federal nuclear remediation programs,
5. Lack of comprehensive workforce planning,
6. Inadequate transition period,
7. Lack of sustained training support in academia and industry.

A discussion of these topics follows below.

The Nuclear Energy Institute (NEI) has warned that about half the industry's workforce is eligible to retire within the next ten years. The data are consistent in general with the overall trends in the “baby boomer” generation reaching the retirement age. Specific to the aging nuclear workforce, Figure 2 from NEI [6] is quite revealing. A vast majority of the workforce is nearing sixty years of age. The figure only shows the direct nuclear industry employment distribution by age (excluding contractors). For 2009 this figure was 57,200. The NEI data indicate that 38 percent of nuclear utility employees were eligible to retire in the

2009-2014 period, and the total potential workforce loss from retirement and other attrition could be as high as 48 percent of the total direct industry employment. This means that the industry will need at least 20,000 new nuclear workers over the next few years alone to start replacing the retirees and attrition.

It should be noted that total for workers employed in the US nuclear industry, combined both for utilities and the supporting consulting companies is much higher at approximately 120,000. The combined profile would also look similar to the NEI figure discussed above and even with updating to today would shift the distribution to the right onwards the older workers. Thus, there is a lot more impact on the nuclear industry than the direct nuclear data presented above in the figure.

The nuclear workforce profile is not very different from the national workforce age profile in general or the national population profile in the US. The US Census Bureau projects that a significant shift in demographics of the US population is the increase in older population cohorts. In 2020, the 55-years-and-older age group will total 97.8 million, composing 28.7 percent of the 2020 resident population. The year 2000 marked a high point as far as the impact of demographics on the labor market is concerned. The entirety of the "baby boom" generation was in the prime working-age group (25 to 54 years old). Every year following 2000, more members of this huge cohort, numbering 77 million, have pushed into the 55-years-and-older age group. This substantial shift of the population to older age groups will impact the growth of the labor force over the next decade. This means that as baby boomers retire there will be a need for replacing workers in all areas including in technical fields as well as the skilled trades. This has to be considered in the context that national projections show that forecasts show one million-plus job openings by 2018 that will require science, technology, engineering, and math skills. The nuclear industry will be competing with other industries for the technical workers.

Let us consider the above from a perspective of the nuclear decommissioning industry. The decommissioning costs for an full size reactors can range from 600 million to a billion dollars. Even with the immediate dismantlement option, the decommissioning process takes about ten years. At least 500 skilled personnel are required to perform the decommissioning over this period of time supported by additional workers for logistics such as transportation of wastes.. Given the projections in the scenario discussed earlier, it can be estimated that even if 20 more reactors enter decommissioning over the next fifteen years, the demand for skilled nuclear professionals will be at 10, 000 and these projects will likely continue into 2025. Additional reactors are expected to enter the end of their extended license period and enter decommissioning.

Experience from the decommissioning of large commercial reactors in the US can provide some insight into the scale of the projects. Maine Yankee, a single-unit 860 MWe PWR cost $635 million and took 8 years (1997 and 2005) for decommissioning. The site was also cleaned radiologically to a level significantly more stringent than required by the NRC due to the state imposing such stringent criteria. Connecticut Yankee, a 590 MWe PWR cost $820 million AND took about 9 year (1998-2007) to perform decommissioning under the immediate dismantlement (DECON) option. Decommissioning work is currently in progress at Zion 1 and 2 reactors (1040 MWe each) and the budget is approximately 1 billion in 2007 dollars. Southern California Edison'sSONGS 2 and 3 just entered decommissioning process with a requested estimate of 4.2 billion dollar. The costs of the above projects provide a realization with respect to the scale of the projects and the need for nuclear decommissioning workforce which can account for approximately forty percent of the project costs.

Remediation projects in the federal sector also have large demand for the specialized workforce.
The Department of Energy's Office of Environmental Management (EM) is dealing with deactivation, decommissioning, and cleanup of the nuclear legacy sites from the activities done in the past in the defense complex and the activities conducted for nuclear research. The program has had a budget of approximately 6 billion dollars a year since its inception in 1989. Two of the major sites within the DOE

complex are Hanford sire, Savannah River site. In addition, remediation activities are taking place for several years now in the Environmental Protection Agency's (EPA) Superfund Program.

The general national workforce outlook is of interest. The US Department of Labor projections show an employment growth for nuclear engineers at 9 percent (total) from 2012 to 2022, about as fast as the average for all occupations. It does acknowledge that employment trends in power generation may be favorable because of the likely need to upgrade safety systems at existing power plants. However, it should be noted that decommissioning industry and the nuclear industry in general need not only nuclear engineers, but mechanical engineers, electrical engineers, structural engineers, health physicists, radiation technicians, waste management specialists, environmental professionals, as well as skilled trades such as welders. The general engineering disciplines have strong demand from many other industries. It is also worth noting that the statistics at the national level as overall outlook projections does not always reflect the true picture of what is going on in a specialized industry.

A report from the National Research Council of National Academies [7] has stated that the current educational system is not producing enough qualified workers to fill future positions that increasingly require science and math skills. The warning in the report states that US is facing the loss of large number of experienced energy and mining workers in industry, academia, and the government, in general. Related to nuclear energy, the report states that the nuclear industry is in a transformational phase, and precise prediction is difficult; however, with coming retirements, the current pipeline of future workers is inadequate to meet the expected needs.

The science and math areas have been underrepresented for decades. For example, tin 2010, the U.S. ranked 25th out of 30 in an international assessment of high school student performance in math. Yet, many of the occupations require such basic education as a stepping stone to more speculated training later on at the university and professional colleges. Individual state surveys and data corroborate the need for such basic skills. Only about 400 students graduate with bachelor's degrees in nuclear engineering. Given the size of the nuclear industry with a fleet of hundred operating reactors, and the need of the large federal organizations such as Nuclear Regulatory Commission, the DOE, the Department of Defense (DOD), National Laboratories and the nation's activities at the complex remediation sites, this is clearly not enough. Even though there appears to be a slight turnaround, only about thirty nuclear engineering programs are currently offered in the country.

The fact that a general shortage of technically educated and experienced workers exists in the US has negative consequences for the economy. Many of the technology based industries including nuclear that depend on a skilled workforce are in a worse situation. It is an issue that covers the entire facets from the education and training to experience transition from an older workforce to a younger workforce. For a healthy nuclear industry and for the decommissioning projects in the pipeline, the industry needs technically qualified and experienced professionals as well as a skilled trade workforce.

A factor of concern is that even with the hiring and training of new workers the workforce in the nuclear energy industry is shaping up in what has been termed as a bimodal form i., e either over 55 years of age, or under 30 years of age. Similar situation exists for nuclear related jobs at the Federal level. The challenge is exacerbated by the fact that capturing knowledge of skilled experienced workers and transferring it to a new generation is not a task that can be completed in a week or a month of intensive training. Many specialized skills and experience will require a transition phase extending several years for a smooth transition.

At the international level, many of the nuclear programs will face shortages of qualified and skilled workers. For example, even in China, a significant shortfall in nuclear power engineers and administrators is being forecasted. With over twenty new reactors under construction, it is estimated that

6,000 new hires are needed each year in the nuclear power sector alone but only several hundred college graduates meet the job requirements every year.

In another example, in the United Kingdom, the country is looking towards expansion of the nuclear power again, but may have difficulty in staffing such an expansion. The nuclear industry is concerned about the skills gaps in the workforce and science and engineering jobs are hard to fill. In addition, the nation has a strong initiative in decommissioning of the legacy facilities since the inception of the Nuclear Decommissioning Authority in 2005.

Organizations such as the International Atomic Energy Agency (IAEA) and OECD have been raising the alarm at the international level for some time now. In a report published in 2000 [8], the OECD/NEA focused on the concern related to decreasing nuclear education and training and concluded that failure to take appropriate steps will seriously jeopardize the provision of adequate expertise. In a press release issued in 2007 [9], the OECD/NEA countries adopted a statement about qualified human resources in the nuclear field.

In a report published in 2004 [10], the IAEA examined the nuclear power industry's aging workforce: It stated that downsizing and right sizing efforts in NPP operating organizations can result in the departure, almost simultaneously, of much of the organizational knowledge. Of significance is the observation that for transfer of knowledge, the planned overlapping time ranges several years depending on the function, for example, 8 years for Shift Safety Advisors, 6 years for Shift Supervisors, and 5 years for Reactor Operators.

In a subsequent report published 2011 [11], the IAEA states that an appropriate infrastructure is essential for the efficient, safe, reliable and sustainable use of nuclear power. The need to maintain nuclear safety in operations and the safety and security of nuclear materials make nuclear energy unique among the various energy options. Related to workforce planning, the IAEA defines it as the systematic identification and analysis of what an organization (and a country) is going to need in terms of the size, type and quality of workforce to achieve its objectives. It continues that workforce planning determines what mix of experience and competencies are expected to be needed, and identifies the steps that should be taken to get the right number of the right people in the right place at the right time. Retirement and succession planning are a significant element of the workforce planning.

From the above analysis and discussion, it is evident that the magnitude of the problem is lrage. The nuclear industry is recognizing that it is facing a crisis that is further exacerbated by the fact that the employment and training to replace the retiring workers is much more difficult, and transition periods for skills and experience stretch into years.

Initiatives

The good news is that the message is finally being heard at the national and international level. Several large scale initiatives have been undertaken by the industry, national labs and educational establishment, both at the international level and at national level. The World Nuclear Association is industry's group at the international level that disseminates information on status, projects and issues critical to the nuclear industry. It also launched the World Nuclear University in September 2003 to provide specialized courses and training in the nuclear area. Many large utilities and engineering services companies provide in-house training to their young engineers on a continual basis in a variety of areas, especially where such specialized knowledge is gained from experienced professionals in the industry rather than in the academia.

Large international companies such as EDF with 58 PWR units on 19 sites, with net installed capacity of 63 GWe, have been concerned about the looming large scale retirements in the French nuclear industry and have taken large initiatives to train and to update skills to meet their needs.

Many of the US power utilities have taken similar initiatives across the board to train and to continually update the skills. The new build plants such as the projects at Vogtle and V.C. Summer are taking their own initiatives to train and staff the new units when they come on line.

The governments have also taken action. For example, in UK, recently £8 million investment was announced to train the next generation of the nuclear workforce. In US, the Employment and Training Administration (ETA) of U.S. Department of Labor announced the availability of approximately $100 million in grant funds in response to the skill shortages in high-growth industries and occupations. The program aims to prepare the Science, Technology, Engineering and Mathematics (STEM) literate workforce in order to fill the pipeline of potential future positions for scientists, engineers, and technicians. Several national laboratories and DOE sites have also undertaken these programs; for example. the programs at Idaho National Laboratory and at Savannah River Site. Other smaller programs are also in use such as the Troops to Energy Jobs which is designed to help veterans make a successful transition to an energy related career

A nuclear plant is operated and maintained by trained and experienced professionals and the safe operation depends on this resource. The decommissioning projects also depend on trained and experienced professionals. Therefore, the demand for the nuclear workforce over the next ten years will increase substantially. The nuclear sites are aware of the looming crisis and many have implemented plans to train the younger employees through intense training efforts m specialty areas and continual upgrading of skills though the Learning Management System (LMS) and though Community of Practice training sessions.

Recommendations to do More

1) Succession Plans with Adequate Transition Period

Succession plans can provide a methodology for identifying and developing employees in advance of actual needs to ensure that specialized positions and responsibility areas at the nuclear operating sites and at the decommissioning sites can be filled with qualified personnel when the need arises. A key element of the succession planning is the adequacy of transition periods. As discussed earlier, in many cases the transition period may extend to several years for certain type of responsibility areas.

2) Retain Current Workers Longer

An incentive based program can convince potential retirees to work a few more years. In general, the retiree benefits have been one of the more important characteristics of working for US nuclear utilities. Workers who have earned such benefits working over a lifetime are potentially less likely to change their retirement plans. However, the workers in the consulting engineering industry which have generally used 401 K retirement type plans are likely to respond positively to incentives to stay on for a few more years. These can be in the forms of increased compensation, flexible hours, part time work, and occasional consulting roles. There is a wealth of experience and knowledge in this segment of the industry as many of the engineers have worked with numerous power plant projects and have dealt with numerous complex technical issues and designs. In addition, such workers can provide an institutional memory for site-specific historical issues, processes and challenges.

3) Provide Resources for Mentoring

Generally, the mentoring programs at utilities and at consulting engineering companies are limited. The senior technical staff at consulting engineering companies, have knowledge and experience gained over decades of engineering practice. However, due to the work environment based on project, schedules, and hourly budgets, there is little margin to devote efforts to training and mentoring the younger staff. A sustained effort sis needed in this regard where resources are made available to encourage mentoring and to fund such efforts over a longer term.

4) Enhance Existing Programs and Establish New ones

Several programs such as STEM already show promising results. These programs should be expanded and enhanced with resources and durations. Additional new programs can be set up on a targeted basis by the government organizations such as Department of Labor and the state governments. The industry has also developed initiatives such as the NEI's Nuclear Uniform Curriculum and the industry's Center for Energy Workforce Development program. Industry can play a significant role in enhancing the training related programs at the nuclear sites through the industry based groups such as NEI, INPO, and EPRI.

5) Close the Gender Gap in Science and Engineering

Great progress has been made in closing the gender gap in the science and engineering (S&E) education over the past decades. However, according to the 2014 report on Science and Engineering Indicators from the National Science Foundation [12], women represent half of the college-educated workforce, but they are underrepresented in the S&E workforce. In 2010, women accounted for only 37% of employed individuals with a highest degree in an S&E field and 28% of employed individuals in S&E occupations. Even though, these percentages represent increases since 1993, when the comparable figures were 31% and 23%, respectively, a lot more can be done to increases the proportion of women in S&E professions and in the nuclear related fields.

6) Prepare Students for Nuclear Careers

While some progress has been made, a lot can be done in reviving degree offerings in nuclear engineering and related fields at the nation's universities and institutes. A coordinated national program is needed. Initiatives in France can provide one model. CFEN (French Council for Education and training in Nuclear energy) was set up in 2008, followed by establishment of the International Institute of Nuclear Energy in 2010 to develop additional engineers and technicians for nuclear related professions for France and partner countries. The needs were estimated at about 1500 engineers per year and about 1000 technicians per year for at least the next ten years. The French government program works with government departments and academic institutions as well as the nuclear industry (AREVA, EDF, GDF-SUEZ, sub-contractors), and the main nuclear R&D institutions (CEA, IRSN, ANDRA).

In the US, in addition to the degree programs at the universities, programs can be instituted and expanded at the community colleges for preparing students for industry based trades and nuclear related technologist positions. Government departments, especially the DOE and DOD, can assist more in this regard by instituting programs and by funding university based programs. Other organization such as the National Academies can also assist in this regard by expanding their initiatives.

7) Promote Cooperative Work Between Industry and Universities

Academic training is only the first step towards addressing the manpower shortages in the nuclear industry. An equally important follow on step is the internship at practicing engineering companies to provide practical training to young professionals. Such apprenticeship programs should be expanded with joint efforts from the industry and local universities. An additional step can be the use of practicing nuclear professional providing lectures and training on adjunct faculty basis. The advantages of such training are the development of critical thinking and problem solving that the student gains along with their academic training.

CONCLUSIONS

Nuclear industry in the United States is already at a critical juncture due to several reasons including the energy market conditions. A major cause of concern in the industry is the critical workforce shortages that are expected across the board including in nuclear decommissioning.

Along with the shift in the energy market conditions towards natural gas, a number of other factors have impacted the commercial nuclear power. In this environment, more reactors are expected to exit the energy production for economic reasons and enter the decommissioning phase. Post-Fukushima regulatory actions require nuclear reactors to make provisions and changes for Beyond-Design-Basis External Events. Among other factors, for many older reactors, it may lead to a tipping point on their economic competitiveness with other sources of power.

The reactor decommissioning scene is changing and after a hiatus of about fifteen years, several reactors were either shutdown or have announced their early shutdown in the past few years. Based on an analysis of the reactor licenses including the renewed licenses and the age of the reactors, projections for a plausible scenario show a sharp upswing in the cumulative total of reactors in the decommissioning phase in the next twenty five years. However, the current industry shift towards deferred decommissioning where the plant could sit in a shutdown state for decades is no longer the acceptable option in many cases due to state intervention, future regulatory actions, and public opposition.

As the decommissioning scene expands, a looming crisis is unfolding as experienced decommissioning managers and engineers are expected to retire in large numbers. Industry estimates parallel the alarm sounded by other technology based professions and the workforce projections in general by the government agencies. In the nuclear industry, with no overlapping programs to transfer knowledge and experience to a younger generation, this issue has the potential to severely impact the decommissioning of future reactors as well as the future of nuclear power development in general.

A market analysis of the nuclear power, reactor decommissioning status, decommissioning trends, the factors influencing the trends, and projections for the future has been presented in this paper along with a discussion of the workforce challenges facing the industry. The issue of the shrinking workforce of decommissioning managers, engineers and other professionals is analyzed and recommendations are made in this regard. The overall activities in the nuclear field including nuclear power plants, nuclear decommissioning, and nuclear remediation m the US and overseas require development and training of a younger generation of nuclear workers on a large scale. A critical aspect is also the succession planning that allows for an adequate transition overlap between the new and the old nuclear crew.

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