Nuclear Power: Brave New World or Same Old Nightmare?

Joy Facos
Sustainable Investing Research Analyst
Sentinel Financial Services Company
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Background

Nuclear power has been both praised as "clean" energy for the future and vilified as a looming environmental threat of titanic proportions. With the global call to reduce greenhouse gas (GHG) emissions, nuclear power, a near zero-GHG emitter, is getting more than a second look today. The Obama administration is building on the 2005 Energy Policy Act and has proposed trebling the current $18.5 billion federal loan guarantee program for the construction of new nuclear reactors in the U.S.[1] The Nuclear Regulatory Commission (NRC) is currently reviewing 17 applications to build 26 reactors.[2] However, the process is slow, uncertain, and no one is rushing to be the first in the pool.

While nuclear power has been widely accepted in Europe and Asia, the U.S. has not been so enthusiastic. The concerns are not new and range from public health and safety to nuclear non-proliferation and the long-term disposal of radioactive waste. In addition, experience has shown that the construction process is long, costly, and fraught with unexpected delays and regulatory challenges. There has not been a new construction license issued for a nuclear reactor in the U.S. since 1978.[3]

Currently, nuclear power generation is an exclusionary screen for Sentinel's sustainable investment funds. The question evaluated here is whether the risks and concerns which supported the original exclusionary position are still valid, or whether a new position is warranted. This is not intended as an exhaustive analysis of nuclear power in the U.S., but rather as an overview of the industry, highlighting the key issues for consideration in the investment process.

Current U.S. Fleet

Today there are 104 reactors in the U.S., with 103 of those currently producing approximately 20% of the power for the country.[4] These nuclear reactors are Generation II [5] light water reactors, and are boiling water reactors (BWR) or pressure water reactors (PWR), each with unique design and site specifications. Most of the fleet was brought on line in the 1970s and 1980s. With initial 40 year operating licenses, many of the reactors have received 20 year license renewals or are in the process of relicensing. To date, 53 reactors representing 51% of the U.S. fleet have been relicensed, with another 15 up for renewal in the next ten years. The remaining 36 are slated to be reviewed for relicensing after 2020.[6,7]

It is important to note that with the exception of the partial core meltdown of Three Mile Island (TMI) 2 in 1979, there have been no major nuclear events in the U.S. In fact, the U.S. fleet has performed relatively well. Since 2003, “the total number of kWh produced by the reactors has steadily increased [and] . . . the fleet-averaged capacity factor . . .has been maintained at about 90%.” [8] However, the fleet is starting to show its age. (Please see **Public Health and Safety** below.)

Key Considerations

With renewed interest in nuclear power generation at the federal level, public support seems to be gathering as well. A recent Gallup poll[9,10] found that U.S. support for nuclear power has risen to an all-time high since the Gallup organization started measuring the question in 1994, with 62% of respondents favoring nuclear power as a source of electricity. This was up from the nadir of 46% in favor in 2001. Conversely, 33% of respondents in this most recent poll were opposed to nuclear power, down from the high of 48% in 2001. While public sentiment appears to be warming, what remains to be seen is how this general support of nuclear power translates to acceptance of new reactors at the local level as the “not in my backyard” reaction tends to kick in when plans and sites become specific.

As the NRC considers the 17 combined construction and operating license (COL) applications for 26 new Generation III reactors, many questions and concerns must be addressed.

Public Health and Safety

The key public health and safety concern is associated with radiation exposure above naturally occurring levels. The health effects of exposure to radiation depend on the level and length of time of exposure, and can range from cancer and birth defects to death.[11] Although the partial core meltdown of TMI 2 in 1979 has not been linked conclusively to any deaths or adverse health effects, the 1986 catastrophic explosion at Chernobyl in Ukraine (then U.S.S.R.) resulted in as many as 4000 deaths.[12] While the chances of major nuclear events such as these are remote, they do still exist.

The real public health risk posed by the industry, however, is more insidious in that reactors currently in service in the U.S. are simply aging, some less gracefully than others. One result of aging reactors has been groundwater and soil contamination at several sites, most notably at Exelon's recently relicensed Oyster Creek facility in New Jersey and Entergy's Vermont Yankee plant, two of the oldest reactors in operation. In both cases, significant amounts of tritium, a radioactive form of hydrogen, had been released into groundwater through leaky underground pipes. In the case of Vermont Yankee, there has been additional groundwater and soil contamination by more dangerous cesium-137 and cobalt-60, both radioactive isotopes which result from nuclear fission. While the full impact of such contamination and its long-term effects on human health are still being debated, it is safe to say that the prevention of radioactive contamination at any level should be a top priority for the industry and the NRC.

Worth noting is that "metal fatigue, embrittled concrete (and even rotting wood in the case of Vermont Yankee) have all plagued the nation's aging fleet. Counter-intuitively, though, the bulk of the problems with these reactors occurred during their first decade of operation - - a fact that bodes ill for the next round of nuclear power plant construction."[13]

Therefore, at a time when the NRC is being called upon for greater diligence in its oversight of aging reactors, it also is required to monitor construction of new and, for the most part, untested designs. The NRC is currently reviewing for certification the Generation III reactor designs that are part of the new wave of COL applications. To date, no new design being contemplated in the 17 applications has received final approval. Although Westinghouse's AP-1000 and GE's Advanced BWR (ABWR) had received preliminary certification, both are back under review based on further design modifications.[14]

Even with the safest designs, another factor in public health and safety that cannot be underestimated is that of human error. Both TMI and Chernobyl were the direct result of human error.[15] In the words of one NRC trainer, "'You cannot regulate against stupidity.'"[16]

Waste Management

Closely related to public health and safety is the issue of radioactive waste. U.S. nuclear reactors use a once-through open fuel cycle, meaning that once the nuclear fuel is spent, the entire fuel rod assembly is removed from the reactor core, stored, and cooled. The spent nuclear fuel (SNF) rods contain high-level radioactive waste which requires safe, permanent storage as it remains dangerous for millennia[17]. "[T]he nuclear industry has produced roughly 64,000 metric tons (one metric ton equals 1.1 U.S. tons) of radioactive fuel rods in total or, in the words of NEI [Nuclear Energy Institute], enough 'to cover a football field seven yards deep.' (Of course, actually concentrating rods this way would set off a nuclear chain reaction.)" [18]

To date, a solution to this critical problem of safe, permanent storage has not yet found. As a result of this failure, it is necessary for nuclear power plants to store spent fuel rods on site in storage pools or in some cases in dry cask storage until a federal long-term storage facility is developed. "All told, the nuclear reactors in the U.S. produce more than 2,000 metric tons of radioactive waste a year, according to the [Department of Energy] DoE - - and most of it ends up sitting on-site because there is nowhere else to put it."[19] On-site storage is becoming more challenging as "nearly all of the nuclear power plants in the U.S. have already run out of storage space, because these pools were not designed to be long-term containers and enough room needs to be preserved in case of a crisis such as a meltdown."[20]

Yucca Mountain has been an on-again-off-again permanent, deep geological storage option since 1987 and has cost the DoE approximately $11 billion to develop.[21] At present, it is no longer an option as President Obama has taken it off the table as a long-term storage solution.[22] The concerns surrounding Yucca Mountain and its suitability as a permanent nuclear waste repository include its proximity to geological faults and the potential for groundwater contamination. Another key concern is that of safety and security with respect to the transportation of high-level nuclear waste from reactor sites, most of which are located east of the Mississippi, to a single storage facility in Nevada. Based on these concerns, the DoE is seeking to withdraw its licensing application from the NRC for further development of the site, and the Obama administration has stated its commitment to reviewing waste management alternatives.

As noted in the 2009 *Update of the MIT 2003 Future of Nuclear Power* report: "There is no plan for high-level wastes . . . [and] the progress on high-level waste disposal has not been positive."[23] In the meantime, the DoE "continues to pay fines to the various nuclear power plants around the country for not providing storage for their waste."[24] These required fines paid by the federal government to the nuclear power companies total about $1 billion annually.[25]

The nuclear industry itself is also concerned about this lack of a coordinated waste management policy:

> 'there has to be some resolution to the high-level waste issue,' says Craig Nesbit, vice president of communications for Exelon. 'We don't think it's appropriate to build another plant in another community knowing that we are saddling that community for an indeterminate amount of time with high-level waste.'[26]

Reprocessing

In Europe and elsewhere, the question of waste has been addressed to a limited extent. Outside the U.S., closed-fuel cycles are employed. In a closed-fuel cycle, spent nuclear fuel is reprocessed and recycled into mixed oxide fuel (MOX) for use in certain reactors, with the residual high-level waste combined with borosilicate (Pyrex) in a process known as vitrification for safe, compact, permanent storage. However, no permanent storage facility has yet been commissioned for civilian nuclear waste anywhere, although "most countries intend to introduce final disposal sometime after 2010."[27]

For the U.S., closed-fuel cycle reprocessing and vitrification are currently not options. (Please see **Non-Proliferation** below.) While R&D in the area of closed-fuel cycle technology received attention in 2004 with the creation of the Global Nuclear Energy Partnership (GNEP), its future in the U.S. is far from promising. "Whatever the merits of this closed-fuel cycle vision, it will be more expensive than today's once-through fuel cycle, and involve a multi-billion dollar federal R&D and demonstration effort over several decades."[28] The National Research Council, the research arm of the U.S. National Academy of Sciences, concluded that "such reprocessing is impractical and expensive" and the work of GNEP in this area "should be halted, because the money could be better spent on other areas of nuclear power research, such as next generation reactors."[29]

Non-Proliferation

Plutonium, a key element used in nuclear weapons, is separated out in a method of reprocessing known as PUREX (plutonium and uranium recovery by extraction). With this separation of plutonium, the risk of nuclear proliferation was considered sufficient enough for President Jimmy Carter to impose a ban on spent nuclear fuel reprocessing in 1977.[30] The ban has been in place since that time.

Non-proliferation issues took center stage recently when President Obama convened a meeting of 47 world leaders in April 2010 to discuss nuclear non-proliferation and combating nuclear terrorism. Commitments were made by many countries to reduce or eliminate nuclear stockpiles and to secure more thoroughly nuclear materials. However, more work needs to be done in the coming months and years to ensure that meaningful progress continues.

Economic Feasibility

One of the main untested issues for the nuclear industry is that of economic feasibility of new reactors. The current COL applications are for Generation III reactors which are basically more advanced Generation II light water reactors. The question about what these new reactors will really cost is expected to remain unanswered "until one is actually built"[31] given that "delays, mistakes, and other holdups sent construction costs of the last round of nuclear reactors through the roof. Estimates range from at least $2 billion to $14 billion."[32]

"The nuclear power industry maintains that nuclear power plants must not cost more than $4,500 per kilowatt to build."[33] By comparison, the cost of a coal-fired facility is approximately $2,300 per kilowatt and a gas-fired facility is about $850 per kilowatt.[34]

"Westinghouse expects to deliver AP-1000 for somewhere around $3,500 to $4,500 per kilowatt . . . or more than $6 billion in total, assuming construction takes three years."[35]

> The U.S. Department of Energy (DoE), for its part, puts the average cost of a new nuclear power plant at $7 billion - - which is more than one quarter of the average stock market value of all public energy companies that currently own a nuclear power plant. 'Twenty-five-billion-[dollar] average market capitalization companies

cannot underwrite many nuclear plants,' noted Dennis Spurgeon, assistant secretary for nuclear energy at the DoE.[36]

This goes back to the $18.5 billion federal loan guarantee program, a program that President Obama would like to see tripled. The original plan for the program was to be able to support four applications.[37] However, a single application from Southern Company was recently granted a conditional award of $8 billion in federal loan guarantees for two AP-1000 reactors at its Vogtle site near Burke, Georgia.

> The federal loan guarantee is conditioned on the project's receiving an operating and construction license for the two units from the Nuclear Regulatory Commission, which Southern estimates could come as early as next year. . .The company has not provided a total cost for the new units, but estimates range from $7 billion to $9 billion per reactor.[38]

> 'The inability to project the true construction costs and timelines coupled with regulatory issues that plagued the nuclear industry in the past have not been resolved,' said Tyson Slocum of Public Citizen . . .'Not only is the final price tag for Southern Company's two new reactors unknown, but the reactor design that has been tapped for federal backing, the Westinghouse AP[-]1000, has yet to receive design certification from the NRC.'[39,40]

The U.S. is not the only country facing these challenges:

> An on-going effort to build a Gen III+ nuclear reactor in Finland - - the so-called evolutionary pressurized water reactor, or EPR, from AREVA - - is already three years behind schedule and around $2 billion (1.5 billion euros) over budget, initiating arbitration action between the Finnish utility and the French nuclear power plant builder over who will pay the extra cost.[41]

Even those entities that have submitted COL applications to the NRC are not committed to the projects should they receive final approval. It simply allows those companies to keep their options open and bide their time until it makes economic sense to dive in. One issue that Exelon, in particular, has been most outspoken on is the need for federal carbon cap and trade legislation which would make nuclear power more competitive with its less clean, but far cheaper, coal-fired brethren. Another issue to be considered is the potential impact of successful conservation efforts and advances in energy efficiency on overall power demand.

Regulatory Framework

The above referenced COL application is new for the NRC. Prior to this wave of applications, the NRC had evaluated construction and operating licenses separately, each with its own application and review process. The newly combined construction and operating license is intended to streamline the application and review process. As it is, the review process is expected to take approximately three and a half years from the time the application is accepted by the NRC.

The NRC also is working to standardize reactor designs, approving only a limited number of designs to be used in the next round of construction. This is to avoid the challenges of the 1970s and 1980s that resulted in 104 reactors and 104 unique designs. To date, only two designs have been certified, yet neither one is contemplated in the 17 COL applications under consideration. [42] Five designs are currently under review, and all five are represented in the 17 COL applications. No timeline for design certification has been indicated.

With the regulatory framework untested, final application approvals and construction timelines are fluid at best.

New Technologies

Even before ground is broken for these Generation III reactors, the NRC and the DoE are looking forward to next generation nuclear power plants. The new designs and technologies, referred to collectively as advanced reactor designs, lie between the Generation III and Generation IV reactors, and are expected to be submitted to the NRC for design consideration over the next three years. These designs go beyond the existing water-cooled reactors, employ more passive safety features, and are more compact. The advanced reactor designs include the helium-cooled Pebble Bed Modular Reactor (PBMR) (PBMR Ltd.) which uses fuel “pebbles” as opposed to fuel rods; the International Reactor Innovative and Secure (IRIS) (Westinghouse) which is light water-cooled; the Super Safe Small & Simple (4s) (Toshiba) which is a sodium-cooled underground reactor; the Power

Reactor Innovative Small Module (PRISM) (GE – Hitachi), a sodium-cooled reactor; and mPower (Babcock & Wilcox), a smaller light water-cooled reactor.[43]

Further down the road are the Generation IV reactors which are still in very early design stage, but are expected to be construction ready by 2030.[44] And then there is Bill Gates.

In late March of this year, it was announced that Toshiba, Gates, and TerraPower, a company in which Gates has already invested millions, have entered into an agreement to develop a next generation nuclear reactor.[45] "TerraPower is working to create nuclear reactors that generate hyper-fast nuclear reactions able to eat away at the dangerous nuclear waste,"[46] a type of breeder reactor. While there are many benefits to this theoretical design concept, including recycling radioactive waste while generating "effectively an infinite fuel supply,"[47] the design is considered "pie in the sky" as "researchers have been working on similar utopian ideas for more than 60 years . . . with no tangible result."[48] However, Gates believes that the "technology could be ready for testing in 20 years and ready for commercial use 20 years after that."[49] As with all the other issues related to nuclear power, there is that element of "wait and see."

Conclusion

While nuclear power achieves the laudable dual goals of low-carbon emissions and reduced reliance on fossil fuels, the costs of that power - - both financial and environmental - - remain incredibly high. Even with the support of the Obama administration and improving public sentiment, serious concerns call into question the wisdom of the renewed nuclear push. Without a long-term solution for the disposal of nuclear waste, moving forward with new construction seems both short-sighted and irresponsible. Public health and safety concerns have also not been adequately addressed as evidenced by the recent challenges to the license renewal of several reactors. Finally, the financial impact on nuclear operators, particularly those engaged in potential new construction, continues to be the great unknown.

In light of the fact that the risks and concerns which informed Sentinel's original decision to prohibit investment in nuclear power for the two sustainable funds remain, a change in the exclusionary position is not warranted at this time.

The industry, in some respects, is still in its infancy, with new, untested designs; long lead times for new construction; and a "work-in-progress" regulatory framework. As with any young industry, game-changing advances in technology are not out of the question. Sentinel will continue to monitor developments in nuclear power generation both in the U.S. and abroad. Should there be a significant breakthrough in any of the areas of concern, namely waste management, public health and safety, and environmental protection, the exclusionary position for the sustainable funds would be re-evaluated.

Sentinel Investments

ENDNOTES

[1] Ling, Katherine. "Can Fresh Funds Jump-Start a U.S. Nuclear Renaissance?" *Scientific American.* February 16, 2010. Retrieved from www.scientificamerican.com/article.cfm?id=nuclear-power-loan.

[2] U.S. Nuclear Regulatory Commission. "Expected New Nuclear Power Plant Applications." Updated March 23, 2010. Retrieved from www.nrc.gov/reactors/new-reactors.html.

[3] U.S. Nuclear Regulatory Commission. "Information Digest, 2009-2010." (NUREG-1350, Volume 21). Appendix A: Commercial Reactors. Retrieved from www.nrc.gov/reactors/operating.html.

[4] Lake, James A., Ralph G. Bennett, and John F. Kotek. "Next Generation Nuclear Power." *Scientific American*. January 26, 2009. Retrieved from www.scientificamerican.com/article.cfm?id=next-generation-nuclear.

[5] Kindle, Fred, Pierre Gadonneix, and Thulani Gcabashe. "Issue Brief: Nuclear." World Business Council for Sustainable Development. October 2006.
Generation I – Prototypes and first reactors
Generation II – Current water-cooled reactors
Generation III – Post-Chernobyl (safer and more economical)
Generation IV – Currently in R&D stage

[6] See note 3.

[7] Retrieved from www.exeloncorp.com/energy/generation/nuclear.aspx

[8] Deutch, Professor John M., Dr. Charles W. Forsberg, Professor Andrew C. Kadak, et al. *Update of the MIT 2003 Future of Nuclear Power.* Massachusetts Institute of Technology. 2009. p. 5.

[9] Ibid.

[10] Jones, Jeffrey M. "U.S. Support for Nuclear Power Climbs to New High of 62%." March 22, 2010. Retrieved from www.gallup.com/poll/126827/Support-Nuclear-Power-Climbs-New-High.aspx.

[11] U.S. Environmental Protection Agency. Retrieved from www.epa.gov/radiation/understand/health_effects.html

[12] Biello, David. "Atomic Weight: Balancing the Risks and Rewards of a Power Source." *Scientific American*. January 29, 2009. Retrieved from www.scientificamerican.com/article.cfm?id=nuclear-power-plant-safety.

[13] Ibid.

[14] U.S. Nuclear Regulatory Commission. "Design Certification Application for New Reactors." Retrieved from www.nrc.gov/reactors/new-reactors/design-cert.html

[15] See note 12.

[16] Ibid.

[17] Biello, David. "Spent Nuclear Fuel: A Trash Heap Deadly for 250,000 Years or a Renewable Energy Source?" *Scientific American*. January 28, 2009. Retrieved from www.scientificamerican.com/article.cfm?id=nuclear-waste-lethal-trash-or-renewable-energy-source.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Ibid.

[22] See note 8. p. 11.

[23] Ibid.

[24] See note 17.

[25] Ibid.

[26] Biello, David. "Reactivating Nuclear Reactors for the Fight against Climate Change." *Scientific American*. January 27, 2009. Retrieved from www.scientificamerican.com/article.cfm?id=reactivating-nuclear-reactors-to-fight-climate-change.

[27] World Nuclear Association. "The Nuclear Fuel Cycle." April 2006. Retrieved from www.world-nuclear.org/education/nfc.htm.

[28] See note 8. p. 16.

[29] See note 17.

[30] Hannum, William H., Gerald E. Marsh, and George S. Stanford. "Smarter Use of Nuclear Waste." *Scientific American*. January 26, 2009. Retrieved from www.scientificamerican.com/article.cfm?id=smarter-use-of-nuclear-waste.

[31] See note 26.

[32] Ibid.

[33] Ibd.

[34] See note 8. p. 6.

[35] See note 26.

[36] Ibid.

[37] See note 1.

[38] Ibid.

[39] Ibid.

[40] See note 14.

[41] See note 26.

[42] See note 2.

[43] U.S. Nuclear Regulatory Commission. Retrieved from www.nrc.gov/reactors/advanced.html.

[44] Ibid.

[45] Sato, Shigeru. "Toshiba, Bill Gates's TerraPower May Develop Reactor (Update 1)." *Bloomberg.Com*. March 22, 2010. Retrieved from www.bloomberg.com/apps/news?pid=20670001&sid=aIyjkvNPEjjc.

[46] Sutter, John D. "Bill Gates and the 'Nuclear Renaissance.'" *CNN.com.* February 17, 2010. Retrieved from www.cnn.com/2010/TECH/02/17/bill.gates.nuclear/index.html.

[47] Ibid.

[48] Ibid.

[49] Ibid.