REVIEWS

Nuclear Energy: Present Technology, Safety And Future Research Directions: A Status Report from the APS Panel on Public Affairs

by John Ahearne, Ralph Bennett, Robert Budnitz, Daniel Kammen, John Taylor, Neal Todreas, and Bert Wolfe

Available at http://www.aps.org/public_affairs/popa/reports/nuclear.shtml

This Report, prepared under the auspices of the APS Panel on Public Affairs, provides an objective overview of nuclear power today with an emphasis on issues of reactor safety. The outstanding qualifications of its authors assure that the report is authoritative. As might be expected, its tone is more reportorial rather than editorial.

The starting point for the report is the 1993 APS Policy Statement that asserted: "A balanced energy policy…requires…strong programs to keep the nuclear energy option open." The Report's indicated purpose is to discuss "the current status of topics directly related to that 1993 APS position." About three-quarters of the document is devoted to nuclear reactors and their safety. Nuclear wastes and nuclear proliferation are also addressed, but less extensively.

Following a brief historical review of nuclear power, the report takes up two very general topics in the area of nuclear reactor safety. The first is an outline of the "key elements" in reactor design and operation that are necessary for safety. These elements are seen to be present in the nuclear programs of many countries, but for others - presumably some members of the former Soviet bloc - there are "significant gaps" that are now the subject of an international remedial effort.

The second general topic is the use of probabilistic risk assessments (PRAs) for evaluating reactor safety. There is general agreement that PRAs are useful for identifying weaknesses in reactor designs and evaluating the implications of changes in plant equipment and procedures, whether undertaken to improve safety or to improve economy. The report shows some ambivalence with regard to the absolute or "bottom-line" numbers given by PRAs for accident probabilities and consequences, indicating that these cannot be "highly accurate" but nonetheless that they can still be of "broad use." No direct mention is made of a particularly interesting use of the PRA method, namely the analysis of the rate of accident "precursors," as pursued by the Nuclear Regulatory Commission to track gains in reactor safety since the 1970s.

A highly informative overview is given of the main new reactors that have recently been built or are in prospect:

Advanced Light Water Reactors. All operating power reactors in the U.S., and most of those elsewhere, are light water reactors (LWRs), either pressurized water reactors (PWRs) or boiling water reactors (BWRs). One group of advanced reactors builds on prior experience to achieve simpler and safer designs, without radical changes. The report describes four such reactor types: the Advanced BWR (two already operating in Japan), the System 80+ (becoming the standard in South Korea), the Sizewell-B PWR (one unit, operating in the United Kingdom since 1995), and a recently completed quartet of French PWRs. Other LWR designs, somewhat further down the road in development, incorporate more substantial changes, particularly an increased reliance on passive safety features.

Gas-cooled reactors. Two helium-cooled, graphite-moderated reactor designs are described. One is the Gas Turbine Modular Helium Reactor, originally designed by General Atomics in the U.S. and now being developed by an international consortium in Russia. The

other appears to be the hottest, or at least the newest, game in town: the Pebble Bed Modular Reactor (PBMR), being developed in South Africa based on earlier German work and under consideration for possible licensing and construction in the U.S. Both feature small-size and also modular construction, and the possibility of passive cooling in case of an accident.[1]

Generation IV Reactors. The U.S. Department of Energy embarked in 1999 on an ambitious, if modestly funded, initiative to develop reactor designs that might be ready for deployment by 2030. The targets set for such reactors include safety, proliferation resistance, economical use of fuel, and low cost. The report provides an outline of the goals for these reactors.

Overall, the report indicates that advanced LWRs are safer and more economical than present LWRs, but still are not cost-competitive with natural-gas fired plants "assuming present gas prices and no environmental credits" – perhaps an important caveat. It cites some attractive features of the PBMR, but indicates that it is too soon for a definitive evaluation.

The report closes by addressing the chief concerns about nuclear power:

Reactor safety. The report states crisply that "the safety of operating reactors has been excellent since the TMI and Chernobyl reactors." New designs promise still greater safer.

Economics. This is subsumed under reactor safety, with lower construction costs anticipated for the new designs.

Nuclear Waste. The report briefly describes the present status of the handling of both high-level and low-level nuclear wastes, but does not undertake to consider the merits or weaknesses of the proposed Yucca Mountain repository.

Security. On-going efforts to increase plant security against terrorist attack are mentioned. In its discussion of weapons proliferation the report touches on the reprocessing of spent fuel, taking the position that reprocessing is not economical and creates "a serious proliferation concern."

Overall, this report is a very useful document, although one may regret that two significant topics were apparently outside its intended scope. One is a review of the technical issues surrounding the Yucca Mountain project—arguably the most immediately critical matter relating to nuclear power in the U.S. today. Another is placing the possible need for nuclear power in the context of a comprehensive energy strategy. A single report, however, cannot address all relevant matters. In the areas it does cover, the report gives a very good picture of the current situation, with an impressively balanced perspective.

Reference:

[1]A slightly different pebble-bed design is being independently developed by a Massachusetts Institute of Technology group. See Andrew Kadak, "A Renaissance for Nuclear Energy?" *Physics and Society* January 2002, pp. 13-17.

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Hubbert's Peak: The Impending World Oil Shortage

Kenneth S. Deffeyes, Princeton University Press, ISBN 0-691-09086-6

In 1956 M. King Hubbert, a geologist, made one of the very few good forecasts in the energy field.[1] He fitted US oil production to a bell-shaped curve (with hindsight, a Gaussian is best) which predicted that oil production from wells in the lower 48 states would start to decline

about 1970; and it did. The prediction has continued to have astonishing accuracy. By the late 1990s production had fallen by half from its all-time high of thirty years ago, and is still roughly on the curve.

Based on Hubbert's success, Deffeyes, a petroleum geologist now retired from Princeton, applies this method to world oil production. He forecasts that oil production will reach its maximum and begin to decline in about 3 years (yes, in 2005, give or take a little)! If true, there would be shortages of oil and great increases in oil prices. That would shake US Mideast policies to the roots, turn on its head the marketing of huge gas-guzzling "trucks" to households, and more. This "Hubbert-type" forecast is based on the assumptions that cumulative oil production will eventually turn out to be about 2 trillion barrels, and that a smooth symmetric (bell-shaped) curve will describe the overall history of oil production. The US Geological Survey has predicted instead that cumulative oil production will be about 3 trillion barrels,[2] which would move the Hubbert-type peak to about 2025. These are both geologist's predictions. The language of economists is different. They say there is no limit to the resource, that production is only limited by the price people pay. On one point there seems to be general agreement: There are almost certainly no very large new oil fields left to discover. The most recent excitement concerns the Caspian Sea region of the former Soviet Union. But while the estimated resources are huge in dollars, they are modest in terms of annual world consumption.

Some feeling for these numbers is given by the total consumption to date of roughly 0.9 trillion barrels. Pessimists like Deffeyes say that just over half the eventually available oil is still in the ground, and optimists say 70%.

But the oil still in the ground is not the only controversial aspect of a Hubbert-type forecast. Hubbert's bell-shaped curve implies that production will begin to fall when cumulative production reaches half of the original resource. The assumed shape of the curve is a way of estimating how the economic system and society will deal with the impending exhaustion of petroleum. Hubbert says that there will be a moderate decline in production starting long before exhaustion is imminent. The USGS and the US Department of Energy place the reversal about 5 decades in the future by assuming that production will continue to grow almost until the resource collapses. The reader's opinion is as good as the experts' on this.[3]

In my opinion, some feeling for the shape of the curve can be obtained by theorizing about the transition away from oil. Most of the oil is used for transportation, and, in the US, most of that by automobiles.[4] Four possibilities for fueling automobiles in the next few decades are: (1) development of unconventional oil resources such as tar sands from Alberta or very heavy oil from Venezuela or synthetic oil from coal; (2) the easier conversion of remote natural gas to a convenient liquid;[5] 3) switching to vehicles directly fueled with hydrogen; and 4) provision of household vehicles that are 50% to 100% more energy efficient than at present.[6] New supply technologies, like (1), (2) and (3) involve huge up-front costs and would take a lot of time. In the US, the scale of fossil fuel use is roughly 23 kilograms per person per day. The capacity to provide a substitute vehicle fuel could grow only gradually, probably only by a small fraction in 20 years. How would this slow development affect the shape of the curve? On the other hand new vehicles could be mass-manufactured in less than a decade and replace most of the fleet in another decade.

Deffeyes advises John McPhee on his series of popular books on geology. While he devotes the first chapter and chapters 7 and 8 to the Hubbert curve analysis, he also discusses how and where oil is formed, and how it is discovered and extracted. There are many interesting

anecdotes about the oil industry, and many easy doses of geology along the way. He must have been a delightful lecturer.

Notes and References:

[1]The list of forecasts that were grossly in error includes virtually all energy quantities of interest. For example, a review in preperation by Jon Koomey at al. (Lawrence Berkeley National Laboratory), of forecasts made in the 1970s of US energy consumption, shows they were all too high. For 2000, many were too high by a factor of two or more.

[2]This difference is due mainly to a contribution called "reserve growth" in already discovered fields, which has justification in the on-going improvements in mapping and extraction technology--although the size of the effect may have been exaggerated by the U.S. Geological Survey.

[3]There are examples for production-until-collapse behavior, for example in whaling. In whaling it is claimed that the optimal business strategy is to exhaust the resource as fast as possible, followed by moving whatever capital is left to another business.

[4]Making materials like plastics is an activity which would continue economically at oil prices much higher than at present; and substitutes could be found for by-product uses like power plant burning of "residual" fuel from refinery processes.

[5]Fouda, Safaa A, "Liquid Fuels from Natural Gas," *Scientific American*, March 1998.

[6]Ross, Marc, "New Automotive Technologies," *Physics & Society*, April 1999.

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The Bulletin of Atomic Scientists

Published bi-monthly by the Educational Foundation for Nuclear Science (not-for-profit), edited by Ms. Linda Rothstein

This review is based on an exploration of *The Bulletin of Atomic Scientists* from 1995 to the present. By surveying selections from the past five years, I hoped to develop a sense of *The Bulletin's* common topics of discussion, the style of writing and the depth of coverage.

At first glance, the title, *The Bulletin of Atomic Scientists*, suggests a magazine that discusses topics that are germane to those who work on nuclear/atomic weapons or power-related issues. I was pleasantly surprised to see that *The Bulletin* contains discussions of a broad range of current affairs. I found articles on bioterrorism, chemical weapons, and primers on international relations for a diverse selection of countries in addition to discussions of nuclear-related issues.

The Bulletin is divided into different sections, which as a whole balance expert opinion with clearly presented information. These sections are: the main articles, "Bulletins," "Reports," "Opinions," book reviews, "The Nuclear Notebook," and "The Last Word." Each issue has a main topic of discussion that is covered by two or more main articles. The articles I read provided in-depth introductions to issues I had not read about before. Each article was a friendly primer on its respective subject. Shorter "Bulletins" read like news briefs on current, sometimes entertaining, events not mentioned in the mainstream press. "Reports" provided detailed exposition on specific political and technical issues. By construction, "The Nuclear Notebook," which is prepared by the Natural Resources Defense Council, is an almanac of international facts

and figures regarding national nuclear stockpiles. Each entry in the notebook focuses on a specific nation, providing publicly the latest information available. These sections of *The Bulletin* were nicely balanced by opinion pieces found in "Opinions" (called "Perspectives" in past issues) and "The Last Word."

The style of the journal appears geared toward educating both technical and non-technical audiences about current affairs in international politics, nuclear-related or not. The articles that I read were not shallow in their coverage, in contrast to mainstream media. They were not filled with unnecessary technical details, but rather provided details as a means of understanding the issues at hand or expanding one's prior knowledge on a specific subject.

Many mainstream media sources are terse in their presentation, elementary in their vocabulary or writing style, and shallow in their coverage. Based on the material that I had read, I felt that *The Bulletin* covered topics in an intelligent and polished style. Overall, *The Bulletin* was a refreshing alternative to traditional news sources.

More information, including back issues, can be found on their website: http://www.thebulletin.org

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A Beautiful Mind
by Sylvia Nasar (Simon and Schuster, 1998; paperback reprint with new Epilogue, 2001)
A Beautiful Mind
a film directed by Ron Howard (DreamWorks-Universal Studios, 2001).

"Insanity is often the logic of an accurate mind overtasked." (Oliver Wendell Holmes, Sr.)

John Forbes Nash, Jr. is a brilliant mathematician who, remarkably, overcame paranoid schizophrenia and won the Nobel Prize in Economics in 1994. By now most readers are familiar with this story, largely due to the enormous success of the film which has garnered numerous awards including the Golden Globes' Best Picture and, by the time this review appears, perhaps the Academy Award. The film is based upon the book of the same title by Sylvia Nasar, a former NY Times economics reporter and now Professor of Journalism at Columbia University. The book, which won the 1998 National Book Critics Circle Award for biography, has now become a best seller. It also won the Communications Award of the Joint Policy Board for Mathematics (a collaboration of the three major American mathematics societies).

Nasar's biography is "unauthorized" in the sense that Nash did not cooperate in its writing ("I adopted a position of Swiss neutrality"). Nevertheless in the epilogue added to the 2001 reprint (which bears on its cover a picture of actor Russell Crowe, who portrays Nash in the film, rather than of Nash himself) he expresses satisfaction with the result, especially retrieving some of his past. It resulted from an enormous labor of hundreds of hours spent interviewing hundreds of people who knew Nash at various phases in his life (the footnoted acknowledgments run to 40 pages), sifting through correspondence and records, and assembling all into a coherent whole. What results is a fascinating portrait not only of Nash, but also of the nature of mathematical America in the 1940's and 50's, the Nobel process and, perhaps most importantly, of the mysterious mental illness called paranoid schizophrenia and how the medical

establishment dealt with it. She contrasts the genteel anti-Semitism that blighted the paragons of American higher education, like Princeton and Harvard, with the dynamism of universities like MIT, NYU and CCNY. The Nobel Prize in Economics comes in for some withering criticism. Many leading mathematicians played roles in Nash's life and career and are portrayed here.

The film version is quite a different thing, although I must add that Nasar and Nash both approve of it. At the outset, let me say that the film is excellent entertainment, and I am told that the portrayal of schizophrenia is the best ever done in a major motion picture. The acting is excellent, except that I found that Russell Crowe, as Nash, tended to mumble too much--perhaps an accurate rendition of Nash or perhaps to mask the Australian actor's difficulty with the West Virginia accent. The problem I have with the film is that it is too far removed from the story as presented in the book. Some liberties reflecting the difference between the two media are to be expected. And, as screenwriter Akiva Goldsman has emphasized, they were not making a documentary.

The only real-life major characters in the film are Nash and his wife Alicia, played outstandingly by Jennifer Connelly. The film opens with Nash's arrival as a beginning graduate student at Princeton. We are introduced promptly to his roommate and lifelong friend--who does not exist in reality. The film implies that Nash's schizophrenia began much earlier than in Nasar's book. There is no record in the book of the early extremes of eccentricity at this stage, such as writing his calculations in soap on the windowpanes. The portrayal of the other mathematicians is perhaps too "over the top" as well. Hollywood has a perverse view of scientists in general, and especially of the cerebral mathematicians!

In reality, after Nash finished his Ph.D.--it was his dissertation on game theory that won the Nobel Prize--and spent a year at Princeton, he moved to MIT as a C.L.E. Moore Instructor. He spent a few summers at the RAND Corporation in California, doing classified research, spending much of his time applying his ideas on non-cooperative n-person games to military and geopolitical situations, until he lost his clearance after a homosexual incident. The film makes no hint of the homosexuality, and transplants the secret research to "the Wheeler Institute" on the MIT campus, so that the secret research can be an ongoing thread in the story. This aspect comes to dominate much of the film, giving it a pronounced cloak-and-dagger aspect that is quite exciting but entirely fictional.

The film accurately portrays the meeting of Nash and his future wife, Alicia. But one does not learn that Nash previously had an extended affair with a nurse, Eleanor Stier, who bore him an illegitimate son. Alicia is the long-suffering wife who stands by Nash through his tribulations. In actual fact they were divorced after six years of marriage, but remarried in 2001.

As for Nash's schizophrenia, while the film may be an accurate depiction of the illness and of the treatments Nash underwent, the delusions he suffers in the film are in many ways different. The real Nash saw himself in various bizarre roles: as a Palestinian warrior, as the "emperor of Antarctica," as someone in contact with extraterrestrials. He went to Europe and tried several times to renounce his U.S. citizenship. Like the majority of schizophrenics, his delusions were often in the form of voices. But auditory delusions are not very cinematic, so they become primarily visual in the film.

There are other items in the film absent in the book, such as a bizarre ritual involving pens among the Princeton faculty. I hope a reader will tell me that this is nonsense! But all in all, I would say that the film is worth seeing if you do not care about the real Nash story. If you do, the book is much more rewarding

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