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Nuclear Power and Proliferation: A Nuclear Industry Perspective

Chapter 3 of *Abolishing Nuclear Weapons* focuses not so much on disarmament as on proliferation and some other concerns arising from increased use of civil nuclear technology, particularly the generation of nuclear power. My comments here are in response to that chapter. While the civil nuclear industry deems it important to point out when these concerns are misleading or overstated, the industry unequivocally supports the role of the International Atomic Energy Agency (IAEA) and of measures to counter the proliferation of nuclear weapons.[1]

In their paper, George Perkovich and James Acton competently canvass most of the proliferation-related issues arising from increased use of nuclear technology, including power generation. The paper does not suggest anything new, and its treatment of two issues in particular—uranium resources and reprocessing—needs supplementing, as discussed below.

Proliferation and Safety Concerns in Context

The chapter makes clear that there are two possible routes for material from the civil nuclear fuel-cycle to end up in nuclear weapons: from uranium enrichment (to levels well beyond those used in power generation today) and from reprocessing of normal used fuel (assuming that plutonium is separated and that it is weapon-usable). In the highly enriched uranium case, construction of a weapon is relatively simple; in the plutonium scenario, it is very complex.

So far, neither route has been followed, though there has been some ambiguity regarding plutonium recovery from low burn-up fuels in the United Kingdom (prior to 1960); in India; and probably in Russia (from RBMK, or Chernobyl-type, reactors). All are nuclear-armed states apart from their civil nuclear activities.

Regarding the global renaissance of nuclear power, the Chernobyl accident in 1986 certainly set it back (but, fortunately, did not put an end to it), and it has taken time for the atypical nature of that reactor and its operation to be widely realized. Certainly it is so profoundly different from the mainstream of world nuclear reactor technology as to be practically irrelevant. The accident was brought about by a unique coincidence of technical, cultural, and political factors.

The Drivers of the Nuclear Renaissance

Any discussion of the political compromises between developing or acquiring elements of the civil nuclear fuel-cycle and nonproliferation priorities needs to have sober regard for the drivers of the nuclear renaissance. Fifty years ago, the first generation of nuclear power plants were justified by the need to alleviate urban smog caused by coal-fired plants. Nuclear was also seen as an economic source of base-load electricity, which reduced dependence on imports of fossil fuels. France epitomizes the latter policy.

Today's drivers for building nuclear plants have evolved and can be summarized as follows:

- Energy demand. Global population growth in combination with industrial development will lead to a doubling of electricity consumption by about 2030. The increase will be greater if there is a major move to electric vehicles by then, as envisaged by Nissan and other automakers. Over the same period, a lot of generating stock, particularly in the United States and the European Union, will need to be renewed. The shortage of freshwater in drier regions calls for increased use of energy-intensive desalination plants; in the longer term, hydrogen production for transport purposes will need large amounts of electricity or high temperature heat or both.

- Climate change. Increased awareness of the dangers and effects of global warming and climate change has led decision makers, the media, and the public to realize that the use of fossil fuels must be reduced and, in the case of electricity generation at least, replaced by zero- or low-emission sources of energy such as nuclear power. Nuclear power is the only large-scale alternative to fossil fuels that is readily available to meet base-load demand by producing a continuous, reliable supply of electricity.

- Economics. Increasing fossil fuel prices have greatly improved the economics of nuclear power for electricity generation. Several studies and the market show that in many parts of the world, nuclear energy is the most cost-effective of the available base-load technologies. In addition, as various government incentives and trading schemes encourage the reduction of carbon emissions, the relative economic benefits of nuclear power will increase further.

- Insurance against future fuel price exposure. A longer-term advantage of uranium over fossil fuels is the low impact that increased fuel prices will have on final electricity production costs, because the expense in nuclear generation lies primarily in the original capital outlay for the plant. This insensitivity to fuel price fluctuations offers a way to stabilize power prices in deregulated markets.

- Security of supply. As countries realize their vulnerability to interrupted deliveries of oil and gas (the latter being of most relevance to electricity), the abundance of naturally occurring uranium, its relatively low cost, and the ease of storing a few years' supply make nuclear power attractive from an energy security standpoint.

Looking further ahead, nuclear energy is likely to find increased application for process heat, particularly in the areas of hydrogen production, synthetic oil (Fischer–Tropsch process), recovery of oil from tar sands and, potentially on a very large scale, desalination. However, none of these is likely to make a qualitative difference to the issues being addressed in relation to non-proliferation.

The Practicalities of Reactor Fabrication

As nuclear power moves away from small national programs and becomes an increasingly globalized industry, serial production of new plants is expected to drive construction costs down and further increase the competitiveness of nuclear energy. The economies of scale that nuclear power can be expected to achieve will counter the capital cost increases that have affected all major infrastructure projects in recent years.

From the pouring of the first concrete to the generation of the first power, most reactors today are built in less than five years, with four years being state of the art and three years being the aim with prefabrication. Prior to construction, it typically takes several years to obtain preliminary approval for a reactor, but this time frame, too, should diminish.

The chapter seems to rely on inadequate sources in suggesting that "for the next decade, the world's nuclear industry can probably build no more than ten reactors per year." That figure is absurdly low. For the next few years, fewer than ten reactors exceeding 1,000 megawatts-electric (or perhaps 1,200 megawatts-electric for the Russian VVER pressurized water reactor) built annually might, perhaps, be credible. But already, demand is evident for new large forging presses and other equipment, and more will be commissioned as required.[2]

It is noteworthy that 218 power reactors started up in the 1980s, an average of one every 17 days. Among them were 47 in the United States, 42 in France, and 18 in Japan. Their average power was 923.5 megawatts-electric—fairly large even by today's standards. So at the very least, it is not hard to imagine a similar number of power reactors being commissioned over a ten-year period starting around 2015. In fact, with China and India getting up to speed with nuclear energy (not to mention heavy engineering) and world energy demand doubling in the next twenty years, a realistic estimate might be the equivalent of seventy 1,000-megawatts-electric units per year, or one every five days.

A relevant historical benchmark is that eighteen U.S. shipyards built more than 2,700 so-called Liberty Ships from 1941 to 1945. These standardized 10,800-metric ton capacity cargo ships were of a very basic British design but they became symbolic of U.S. industrial wartime productivity. Average construction time was forty-two days in the shipyard, often using prefabricated modules. In 1943, three were being completed every day.

The Evolving Nuclear Fuel Cycle

With respect to chapter 3's evolutionary approach to reducing the potential for diverting fissile materials, uranium is a fairly common element in the Earth's crust and no country is without ample supplies for a few nuclear weapons (one weapon requires as little as five tons of natural uranium). If cost is no object, uranium could be recovered in such quantities from most granites, or even from seawater—sources that would be quite uneconomic for commercial use. In contrast, world trade for electricity production is about 66,000 tons of uranium per year, all of which can be accounted for.[3]

Multinational ownership of enrichment and reprocessing facilities is already happening in some respects, led by reactor vendors and generating utilities. Urenco and Eurodif are government-owned (not essentially private) multinational enterprises. Global Laser Enrichment (GLE, née

SILEX) was set up by a U.S.-Japanese firm, GE Hitachi Nuclear Energy, and now has shareholding of General Electric 51 percent, Hitachi 25 percent, and Cameco 24 percent, giving it a U.S.-Japan-Canada spread before paying licence and royalty fees to Silex Systems in Australia. The International Uranium Enrichment Centre at Angarsk is already a Russian-Kazakh enterprise with equity interest from Ukraine, Armenia, South Korea, and Mongolia. These partnerships, however, are driven by commercial considerations. The radical approach of pursuing multinational control of all such facilities would be a far different matter.

Along those lines, a major omission from this section is the Global Nuclear Energy Partnership (GNEP), a U.S. initiative that has become an international partnership. While opinions differ as to GNEP's potential, and Congress has been slow to adequately fund it, 24 states representing all of the world's nuclear industry have signed up, and the technologies GNEP is designed to foster are certainly important.

GNEP envisages the development of comprehensive fuel services, including such options as fuel leasing, to address the challenges of assuring reliable fuel supply while minimizing the need for enrichment plants in new countries. The general premise that curtailing such expansion will have nonproliferation benefits is a dubious one. What weakening of the nonproliferation system would result from the creation of such facilities in Australia and Canada? Meanwhile, the few countries that are of proliferation concern are hardly likely to be influenced by kind offers of reliable fuel supply. When conceiving of elaborate systems, it is important to get the premises right.

This is not, however, to disparage the potential value of GNEP. The establishment of comprehensive and reliable fuel services, including options for the disposition of used fuel, is expected to create a more practical approach to nuclear power for nations seeking its benefits without the expense and difficulty of establishing indigenous fuel-cycle facilities. As yet, however, GNEP has raised expectations in many parts of the world regarding a rational approach to nuclear waste, without eliciting any corresponding offer from countries to actually dispose of waste from beyond their borders.

The development of advanced reprocessing technologies and fuels will enable further developments in advanced reactor technology. Developments in fast reactor technology center on the need for their cost to become competitive with that of current light-water reactors. Countries such as France, Russia, and Japan have experience in the design and operation of fast reactors, and the United States is working with them to accelerate the development of advanced fast reactors that are cost-competitive, incorporate sophisticated safeguards features, and are efficient and reliable. Russia has led the way in this with its BN-600 reactor, and it has voluntarily opened this reactor to IAEA inspectors so they can gain experience of safeguarding such units. A further driver of fast reactor development is their prospective use for burning all actinides, which otherwise form the main long-lived component of high-level nuclear waste.

Any discussion of reprocessing needs to disaggregate some ideas. It seems to be assumed (apart from fleeting reference to Urex+) that reprocessing means separating plutonium. In discussing the broad question of abandoning reprocessing, a distinction must be made between chemical reprocessing (which would inevitably have some potential of separating plutonium even if advanced aqueous processes do not) and electrometallurgical reprocessing in a fused salt bath (which does not have this potential).

The other issue that must be addressed concerns the inputs to reprocessing. If it is all high burn-up fuel, the plutonium is not much use for weapons anyway. The comment about Japan's "bomb in the basement" ignores the fact that Japan has no power reactors that could produce low burn-up material without massively and conspicuously compromising power output. Another way of assuaging concerns about the potential for weapon proliferation would be to institute some means of assuring that all material that is reprocessed had on average 20 percent non-fissile isotopes in its plutonium content.[4]

Regarding research reactors and their use of highly enriched uranium, security concerns have grown since the early 1970s, especially since many research reactors are located at universities and other civilian locations where security is much lower than at military weapon establishments which house much larger quantities of highly enriched uranium. Since 1978 only one reactor, the FRM-II at Garching in Germany, has been built with this fuel, while many, in at least sixteen countries, have been commissioned using low-enriched uranium fuel.

Most research reactors using highly enriched uranium fuel were supplied by the United States and Russia, so ongoing efforts to deal with the problem remain largely in their purview. The Reduced Enrichment for Research and Test Reactors program concentrates on converting reactors that exceed 1 megawatt-thermal and have significant fuel requirements to use low enriched uranium fuel. In 2004 the U.S. National Nuclear Security Administration subsumed this program in setting up the Global Threat Reduction Initiative, which more broadly focuses on tackling the disposition of highly enriched uranium fuel (fresh and used) as well as other radiological materials. The initiative has accelerated the removal of Russian-origin fuel to Russia and U.S.-origin fuel to the United States. In total, almost a metric ton of fresh and spent HEU fuel has been repatriated.

Regarding naval reactors, there does appear to be a dilemma in reducing enrichment levels because doing so would remove the key advantage of lifetime cores, but details of these plants are hard to obtain and verify. However, the technology is far from widespread—and is nonexistent outside the inner sanctums of weapon-capable states—so as a proliferation concern this can be deemed minor.

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A concluding and sweeping comment is that the authors, in their concern to rid the world of nuclear weapons, have downplayed some factors that others, including myself, would find paramount:

- It is highly unlikely that complete nuclear disarmament would even become an issue until all nuclear-armed states have reduced their arsenals to quite low levels. Identifying the diplomatic and strategic practicalities of achieving that precondition might have been a better recommendation for action.

- If climate science, as reflected in the findings of the Intergovernmental Panel on Climate Change, is correct, the greatest peril in the history of humankind lies in the damage to biospheric stability that may occur in the twenty-first century unless greenhouse emissions are drastically curtailed.

- Contrary to the authors' expressed agnosticism about whether the nuclear renaissance will retain momentum, most major governments in the world have embraced nuclear power as integral to their long-term plans for energy independence and environmental responsibility. The few lingering exceptions such as Germany prove the rule, while Italy's recent emphatic about-face on the question underscores the trend.

As the nuclear renaissance gains momentum, propelled by factors directly related to international security, security analysts must be practical, nonideological, and precise as they weigh plans to guide its progress.

Notes

1 World Nuclear Association Charter of Ethics, http://www.world-nuclear.org/about/ethics.html?ekmensel=185bf1b1_12_0_74_2.

2 A recent WNA Information Paper *Heavy Manufacturing of Power Plants* addresses the question, http://www.world-nuclear.org/info/inf122_heavy_manufacturing_of_power_plants.html.

3 On page 87 of the current volume, the paper refers to "yellowcake (refined uranium ore)." The relevant category is natural uranium (i.e., unenriched), whatever its chemical form. As shipped from a mine, it is normally U_3O_8 or uranium oxide concentrate (essentially the same thing).

4 The question of whether reactor-grade plutonium with around one-third non-fissile isotopes (mainly Pu-240) is "weapon-usable" is contentious. What is not in serious dispute is that such material has never been made to explode and that any attempt to make a bomb with it would be fraught with serious hazard to those preparing it.