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More Missiles Than Megawatts

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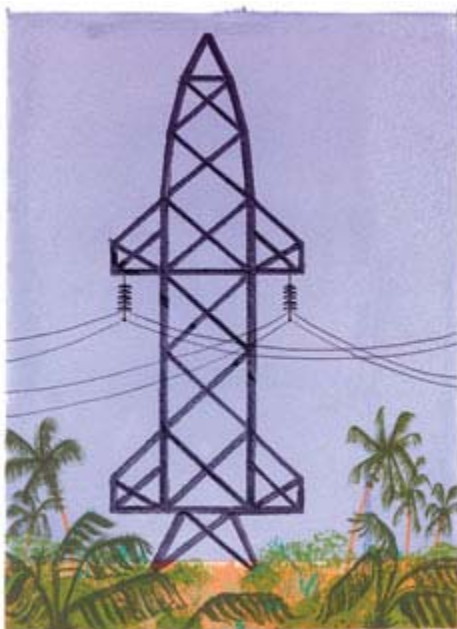


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For a developing country, India has pursued a uniquely ambitious and far-reaching nuclear technology program. During the last six decades, it has developed expertise and facilities covering the entire nuclear fuel cycle, from uranium mining and milling to reprocessing spent nuclear fuel. India also operates a pilot fast breeder reactor, one of seven countries to have built one, and it has started constructing an industrial-scale breeder.

The Indian government's long-held vision is that nuclear energy—and especially breeders, which are designed to produce more fresh fuel than they consume—will play a large part in the country's ambition of becoming energy-independent by the year 2030. But progress has fallen far short of that goal. Early on, the country's top nuclear officials forecast that by 1987 nuclear energy would generate 20 to 25 gigawatts of electricity. Later estimates inflated that figure to 43.5 GW by the year 2000. Today, India's 17 reactors generate 4.1 GW, a mere 3 percent of the country's total electricity-generating capacity. Although India is the fifth-largest producer of electricity in the world, in nuclear generation capacity it is not even among the top 15 countries. Despite 60 years of development and government support, India's nuclear establishment has failed to produce either the world-class technology or the large quantity of cheap electricity that it once promised.

One important factor that has impeded India's nuclear-energy ambitions is its preoccupation with nuclear weapons. When the country detonated its first nuclear explosive in 1974, it caught the existing nuclear powers by surprise. Up until then, Western countries had freely shared their nuclear technology and expertise with India. Afterward, the rest of the world largely disengaged from India's nuclear program, despite New Delhi's claims that the test's goals were "peaceful." Without access to international technology and collaborations, its plans to expand atomic energy went awry, as project after project suffered setbacks.

In spite of its status as nuclear outcast, India's determination to move ahead did not abate. In 1998, the world discovered why, when a set of nuclear tests at Pokhran, in northwest India, abruptly and officially ended the country's public stance of pretending to pursue only peaceful uses of nuclear technology. This time around, though, the outcome was decidedly different. Within two years of the tests, the United States decided to re-engage with New Delhi, laying the groundwork for strategic military partnerships. Now, nine years after the Pokhran tests, India and the United States are trying to embark on a nuclear collaboration of unprecedented scope.

The two countries signed a statement in July 2005 that commits the United States to "work to achieve full civil nuclear energy cooperation" and "adjust international regimes to enable..."

[nuclear] trade" with India, including letting the country import much-needed uranium. In exchange, India will separate its nuclear facilities into civilian and military sites and open up the civilian sites to international inspection. "What we are attempting today is to put in place new international arrangements that would overturn three decades of iniquitous restrictions," Prime Minister Manmohan Singh told his Parliament in August 2006.

Proponents of the deal have lauded it for, among other things, helping to move India away from fossil fuels and helping to stem the proliferation of nuclear materials and warheads. In fact, though, the pact will likely decrease India's reliance on coal and gas by only a nominal amount. What's more, the arrangement is unlikely to provide the much-needed boost to India's languid civilian nuclear program or fix the myriad problems that hobble it. Most troubling, the U.S.-India deal, which must still be approved by various international organizations, would in all likelihood free up India's uranium resources for military ends, facilitate the building of even more nuclear weapons and, possibly, lead to greater instability in South Asia.

To understand why the seemingly benign proposal could lead to such dire unintended consequences, it helps to appreciate how India's nuclear efforts came to be in such a troubled state, starting with the unique history of the program. In 1954, seven years after the country became independent from Britain, the newly founded Department of Atomic Energy laid out a three-stage plan for nuclear power. The first phase was to construct and operate heavy-water reactors fueled by natural uranium and then reprocess spent fuel to separate plutonium, which could be recycled as new reactor fuel. But plutonium can also be used in weapons—a fact the DAE remained largely silent about. The second and third phases involved developing breeder reactors that could use thorium. Unlike the uranium-235 contained in natural uranium, thorium can't undergo fission at low energies. However, thorium is fertile; when bombarded with neutrons, it can be transformed into uranium-233, which can be used to fuel a reactor.

All of India's 17 existing reactors are part of the first phase, as are five of the six facilities under construction. Efforts to use thorium as a fuel have not gone far. An experimental breeder, the Fast Breeder Test Reactor at Kalpakkam, in southern India, constitutes the only functional part of the second phase. The Fast Breeder Test Reactor has been continually plagued with problems since its start-up in 1985. One glitch within the reactor vessel during a fuel-transfer operation in May 1987 forced the reactor to shut down for two years to undergo repairs. It wasn't until 2000 that the reactor managed to run continuously for more than 50 days.

In October 2004, after 20 years of planning and repeated delays, the DAE finally began building India's first industrial-scale fast breeder reactor. But it isn't expected to be completed until 2010—and only if all goes according to plan. Exorbitant costs, safety concerns, and engineering problems have effectively killed similar breeder programs in the United States, France, and Germany and set them back severely in Japan and Russia.

Even by the Indian government's optimistic timetable, breeders using uranium-233 as fuel won't start operating until the middle of this century, decades behind schedule. And nuclear power is unlikely to contribute even 10 percent of India's electricity generation in the next few decades.

Despite such shortfalls, the DAE continues to pursue its three-phase plan, and in particular the long-standing goal of developing reactors that use thorium and uranium-233. There is some logic to preferring thorium: by the International Atomic Energy Agency's estimates, India has about 225 000 metric tons of thorium, or almost a third of the world's reserves. Uranium reserves, by contrast, are more limited and of poor quality in India.

Under the circumstances, India will be compelled to rely primarily on uranium for some decades. Assuming that its reactors run at 75 percent capacity on average, India needs about 510 metric tons of uranium a year; recent figures suggest its annual production is about 200 metric tons. The DAE has been making up for some of the shortfall by using uranium stockpiled when India's nuclear generating capacity was much smaller.

Even so, reactor electricity outputs, as reported on the Nuclear Power Corp. of India Web site, fell to 56 percent in 2006–2007, down from 74 percent just three years earlier. With new reactors coming online and without uranium imports, this decline will continue. The department's best efforts to open new uranium mines and a new uranium ore concentrating plant have meanwhile met with stiff resistance from local communities, primarily because of the many health problems that existing mines have created, such as well-documented increases in birth-defect rates in nearby villages.

The DAE also maintains that nuclear power is much cheaper than other sources of energy, but the agency's budgets paint a different picture. When the DAE has compared the costs of generating electricity from nuclear reactors with those from coal-fired plants, India's staple source of electricity, it has assumed that the coal plants are located far from the source of their coal.

Obviously, that assumption inflates coal transportation costs and biases the comparison in favor of nuclear power.

In the early years, the DAE claimed that nuclear power was cheaper than thermal plants that were located more than 600 kilometers away from the coal mines. By the 1980s the distance had crept up to 800 km. A 1999 study increased the distance to 1200 km. In fact, though, one-third of India's coal plants are located right next to a mine pithead, and another quarter or more are within 500 km of one.

Even the 1200-km claim does not hold up to scrutiny. Two researchers from the International Energy Initiative and I compared the cost of producing electricity at India's most recently commissioned nuclear reactor, a 220-megawatt heavy-water reactor at the Kaiga atomic power station in the southern state of Karnataka, with electricity from a nearby coal plant that is 1400 km away from a mine. We found that the nuclear plant was about 8 percent more expensive at the government-determined rate of return on investment, which reflects the present value of future benefits and costs. At market rates of ROI, however, it could be 50 percent more expensive.



[Click here for an animated timeline of India's nuclear history](#)

A 2003 study by researchers at MIT reached similar conclusions for the United States; it found that the cost of U.S. nuclear-generated electricity is about 60 percent higher than electricity generated from coal. Of course, it's difficult to make a direct comparison between India and Western nations because of differences in labor costs, as well as India's more lax licensing guidelines, which make all power plants generally cheaper to build and operate. Still, the trend is clear: both in India and elsewhere, the capital costs of reactors make nuclear power significantly more expensive than electricity from coal.

We deliberately made a number of assumptions in our economic comparison that favor nuclear power. For instance, the DAE did not factor in the costs of dealing with radioactive wastes from nuclear power, and so neither did we. The department's rationale for that exclusion is it reprocesses all spent fuel, segregating the waste according to its radioactivity. A colleague and I calculated that reprocessing would cost about US \$600 per kilogram of spent fuel. Including even half of that amount would make nuclear power's additional expense over coal jump from 8 percent to 27 percent.

Another factor artificially driving down the cost of nuclear power is that, unlike many other countries, India has no provision for insurance liability against nuclear accidents. In the United States, for instance, the Price-Anderson Nuclear Industries Indemnity Act, passed in 1957, requires that nuclear utilities cover each reactor they operate with the maximum available amount of insurance, which in 2005 was \$300 million per plant. Every company licensed to operate a reactor in the United States must also contribute to a fund to pay for cleanup and damages, should an accident occur. In India, the assumption seems to be that the government will deal with the consequences of an accident; in effect, this amounts to a subsidy to the nuclear sector and obscures nuclear power's true cost.

That is not to downplay the enormous environmental havoc wreaked by coal-fired power plants, which generate more than two-thirds of India's total electricity, according to India's Ministry of Power. The plants emit not only carbon dioxide but also large quantities of noxious gases and harmful particulates. Those pollutants urgently need to be reduced, but increased reliance on nuclear power is not a cost-effective way of doing so.

Although India's nuclear energy program today is mired in problems, its beginnings were filled with hope.

Many of the fundamental ideas about the role of nuclear energy in India can be traced back to Homi Bhabha, the architect of India's nuclear establishment, and Jawaharlal Nehru, the country's first prime minister. Bhabha and Nehru viewed nuclear technology as a way to jump-start the new nation's social and economic development. In Nehru's eyes, India's earlier failure to develop steam power had caused it to miss the Industrial Revolution, and nuclear power, he reasoned, was the modern equivalent of steam. In 1948, while in the midst of setting up India's Atomic Energy Commission, Nehru argued that, "if we are to remain abreast in the world as a nation which keeps ahead of things, we must develop atomic energy."

To realize that vision, successive prime ministers have set large budgets for the nuclear establishment. In the late 1950s, the DAE cornered more than a quarter of all resources devoted to science and technology development in the country, and not much has changed since then. In 2005-2006 the DAE's budget was roughly \$1.2 billion, compared with \$87 million for the Renewable Energy Ministry, which is responsible for 10.4 GW of installed electrical capacity.

For the first 25 years or so following India's independence, the international community was more than happy to assist the new country in its pursuit of atomic power. India's leading nuclear scientists asked for and received both technical and financial aid from the United States, Britain, Canada, and other countries. Between 1955 and 1974, more than 1100 Indian scientists were trained at U.S. nuclear facilities, while more than 250 trained in Canada. The first Indian reactor, built in Trombay, at what is now the Bhabha Atomic Research Centre, was based on a British design and used British-supplied fuel rods. The design for the first reprocessing plant for separating materials such as uranium and plutonium from spent fuel, also located at Trombay, came from U.S. blueprints. Canada donated a research reactor to the Trombay facility; called CIRUS (for Canada India Reactor United States), it used heavy water supplied by the United States. France, for its part, collaborated with India to build the Fast Breeder Test Reactor at Kalpakkam, based on the French Rapsodie breeder.

The United States' involvement was motivated in part by a Cold War-era desire to enlist India in countering China's growing military might. Inspired by U.S. strategic thinkers' rationalizations for massive nuclear arsenals, some of India's hawkish defense intellectuals began advocating nuclear weapons as a stabilizing force between the two countries. This stance, in turn, prompted neighboring Pakistan's quest for nuclear weapons. In 1965, Zulfikar Ali Bhutto, then the foreign minister of Pakistan, famously declared that if India developed an atomic bomb, Pakistan would follow, "even if we have to eat grass or leaves or to remain hungry."

Nonetheless, the United States' hostility toward China during the period led to some extraordinary ideas about what the U.S. government deemed to be acceptable levels of nuclear cooperation. Senior officials in the U.S. State Department and the Pentagon considered preparing troops in India to use low-yield tactical nuclear weapons supplied by the United States, according to a state department memo cited by George Perkovich in his book, *India's Nuclear Bomb*. The U.S. Atomic Energy Commission, the predecessor of the Nuclear Regulatory Commission, also contemplated helping India conduct "peaceful nuclear explosions," purportedly for excavating mines and canals. On 18 May 1974, India detonated a nuclear device with an official yield of 12 kilotons, a bit smaller than the "Little Boy" bomb that the United States dropped on Hiroshima in 1945. The plutonium that fueled the Pokhran blast came from reprocessed spent fuel from the Canadian-supplied CIRUS reactor. As a result, as the Canadian minister of trade and commerce, Mitchell Sharp, put it, "Trust between the two countries was gone." Years later, Raja Ramanna, the architect of the 1974 test, said at a public meeting, "The Pokhran test was a bomb, I can tell you now." Prodded by journalists, he added: "An explosion is an explosion, a gun is a gun, whether you shoot at someone or shoot at the ground."

India's test triggered serious international repercussions. Most significantly, it prompted various Western countries to form the Nuclear Suppliers Group, which restricts the export of nuclear technologies and materials to countries such as India that refuse to sign the Nuclear Nonproliferation Treaty. To some degree, the NSG's restrictions achieved their desired effect. All nuclear facilities built in India since 1974 have experienced delays and have repeatedly been scaled back. Replacement parts became harder to acquire, and Indian nuclear engineers found their foreign counterparts far less willing to help them solve technical problems.

But the sanctions did nothing to discourage India from surreptitiously continuing its research and development of nuclear weapons. In 1998, the country finally came clean. On 11 and 13 May, it conducted two tests that each consisted of multiple explosions, including one that India claimed was a 45-kiloton hydrogen bomb—though independent analyses of seismic data indicate that the bomb's yield was actually a fraction of the size. Two weeks later, Pakistan followed suit with its own nuclear tests. South Asia had become, in the words of U.S. President Bill Clinton, "the most dangerous place in the world"—and also the focus of renewed U.S. strategic interest.

A diplomatic transition did not take place overnight. Although Clinton traveled to New Delhi in 2000 to meet with Indian Prime Minister Atal Bihari Vajpayee and discuss "strategic" partnerships, his administration refused to resume civilian nuclear cooperation, despite much interest from the Indian side. It was only when President George W. Bush came to power in 2001 that a different perspective on India took shape.

The previous year, Bush's national security advisor-to-be, Condoleezza Rice, had argued in a *Foreign Affairs* article that the United States should recognize India as a counterweight to China. This idea was echoed by other strategists, including Ashley Tellis, who helped design the civil

nuclear agreement with India. "If the United States is serious about advancing its geopolitical objectives in Asia, it would almost by definition help New Delhi develop strategic capabilities such that India's nuclear weaponry and nuclear forces could deter against the growing and utterly more capable nuclear forces Beijing is likely to possess by 2025," Tellis wrote in a report for the Carnegie Endowment for International Peace, in Washington, D.C., where he is a senior associate.

For the Bush administration, India's emergence as a de facto nuclear weapons state was to be embraced, not punished. That shift in attitude was formalized in December 2006, when Bush signed a bill amending the U.S. Atomic Energy Act—the first step toward reversing a three-decade ban on nuclear trade with India. Robert Blackwill, a former U.S. ambassador to India and deputy national security advisor, summed up the administration's thinking in a March 2005 *Wall Street Journal* opinion piece: "Why should the United States want to check India's missile capability in ways that could lead to China's permanent nuclear dominance over democratic India?" And why, he might have added, should U.S. companies forgo lucrative opportunities with Indian customers, when suppliers in other countries—indifferent to New Delhi's nuclear weapons status—would be rushing in to do business?

Should the pact be sealed, India will allow inspectors from the Vienna-based International Atomic Energy Agency to regularly survey its civilian nuclear facilities. India, in turn, will be eligible to import uranium to fuel those civilian reactors that undergo inspection. It will also be able to purchase light-water reactors, the most popular reactor type worldwide. However, the country is under no obligation to allow safeguards on all of its civilian reactors. U.S. companies, for their part, will gain a foothold in a newly opened economy.

Some hurdles, however, remain. India and the United States are still negotiating the terms for importing uranium. The IAEA must nail down the details of the India-specific safeguards, and the Nuclear Suppliers Group will need to agree to amend its rules to permit trade between the United States and India.

Even before the deal has gone through, the U.S.-India pact has revived the DAE's hopes for a large-scale expansion of nuclear power. But the actual economics of the deal may prove sobering for the DAE. Light-water reactors are expensive: a 1-GW light-water reactor costs roughly \$1.5 billion to \$2 billion, compared with about \$1.2 billion for a heavy-water reactor of the same size—which increases the unit cost of electricity generation by up to 25 percent. Unless foreign companies offer cheap loans, Indian electricity consumers are unlikely to be able to afford many imported light-water reactors.

What's more, the agreement is likely to increase—not decrease—India's capacity to produce nuclear weapons and material. By importing uranium, India will be able to channel its native supply toward military purposes. In fact, K. Subrahmanyam, a former head of India's National Security Advisory Board and, since the 1960s, India's most prominent nuclear weapons advocate, has openly called for giving as many power reactors as possible civilian designation in order to conserve domestic uranium for the production of weapons-grade plutonium. My colleagues and I estimate that India already has approximately 500 kg of weapons-grade plutonium, sufficient for roughly 100 nuclear warheads—and Indian nuclear weapons advocates are clearly interested in stockpiling more.

There is also the possibility that those nuclear reactors not subject to IAEA inspection will be converted to military ends. Any power reactor not under safeguards can be used to make weapons-grade plutonium by limiting the time the fuel is irradiated. This prevents the build-up of higher isotopes of plutonium, which are undesirable in a weapon. When a typical heavy-water reactor is operated normally, fuel remains inside the reactor seven times as long as when it is producing weapons-grade plutonium. Heavy-water reactors are particularly suited to making bomb-grade material, because new fuel is continuously added (and old fuel continuously removed); this type of reactor could produce the same amount of electricity every year but would use seven times as much fuel to do so. In theory, a 220-MW heavy-water reactor, run at 60 to 80 percent capacity, could produce 150 to 200 kg per year of weapons-grade plutonium.

Meanwhile, Pakistan has demanded a similar deal from the United States. The U.S. government has refused, ostensibly because of Pakistan's poor nonproliferation record—in particular, the Pakistani scientist Abdul Qadeer Khan's long-running illicit trade network, which provided nuclear technology to Libya, Iran, and North Korea. Undaunted, Pakistan's agency in charge of nuclear weapons, the National Command Authority, issued a statement saying it will expand its own arsenal, which currently is estimated to have between 65 and 75 nuclear warheads, in response to India's increased capacity for generating weapons.

In other words, what happens in India, and the choices it makes, will resonate both regionally and globally. India's myopic focus on expanding its civilian and military nuclear program threatens to

exacerbate the arms race with Pakistan while ignoring the urgent local need for clean, affordable electricity.

Instead of digging deeper into the nuclear rut, India should invest even more heavily in renewable electricity generation and improve its energy efficiency in many sectors. For instance, India could expand its use of wind power—it already has the world's fourth-largest installed wind capacity—as well as solar, biomass and small-scale hydropower. There's huge room for improvement in its coal plants, which are significantly less efficient than those in other countries; losses during electricity transmission and distribution are typically about 25 percent, compared with 10 percent in many countries. And the environmental impact of coal, both in terms of carbon emissions and the health effects of pollution, must be addressed.

Between its burgeoning economy and a population that is projected to eclipse China's by 2050, India has difficult choices to make regarding its energy future. Nuclear power, however, is not an affordable—or desirable—answer for India.

About the Author

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