China's 21st-Century Nuclear Energy Plan

by Marsha Freeman

The People's Republic of China is implementing an energy program which will bring online as many as to 30 new nuclear power plants over the next 15 years, and which has put China in the forefront of world research and development in nuclear science and engineering. This effort stands in stark contrast to the situation in the United States, where the Bush Administration's "pro-nuclear" energy plan is to try get *one* new commercial power plant built over the next decade, and to delay development of advanced reactor systems—some of which the U.S. tested decades ago—into the indefinite future.

The Chinese economy has been growing at an average rate of 8% per year, with electricity demand growing twice that fast. The Ministry of Electric Power has estimated that 15-20% of China's present energy demand cannot be met, and that 100 million Chinese have no access to electricity. Last year, China's State Electricity Regulatory Commission warned that the situation was worsening, as the country faced, in the Summer of 2004, a shortfall twice as large as that of the year before. To keep up with its rate of economic growth, China estimates that it will have to double its electric-generating capacity every decade. At 385,000 MW (megawatts) of current online capacity, China has an electric grid system second only to the United States.

Simply expanding the use of coal to meet this growing demand is not an option. Already 40% of China's railroad capacity is dedicated to hauling more than 1 billion tons of coal per year (two-thirds of China's energy is produced from burning coal). Alhough China is the world's sixth-largest producer of petroleum, it now imports one-third of its oil. As far back as the late 1970s, China knew it had to go nuclear; now it is systematically carrying out the multifaceted program that will make it a world leader in nuclear energy technology.

China Goes Nuclear

China's multi-pronged nuclear strategy follows the same strategy as its program in space exploration. First, rather than reinventing the wheel, China has imported commercial power plants from Russia, France, and Canada, to have the immediate benefit of nuclear energy, and to train its own cadre of engineers and operators. Today, China has nine reactors operating and two under construction, with nuclear energy accounting for about 2% of its total electricity output.

In the late 1990s, as the large-scale construction of nuclear plants was under way, Chinese officials were already planning for the 21st Century. China plans to choose one reactor design (and supplier) for its next group of nuclear plants, to enable it to standardize its nuclear operations, rather than continue with the widely varying designs now in place, from different suppliers. The goal is to have an increase of nearly sixfold in nuclear capacity, up to 40,000 MW by 2020, from 8,700 MW today. Due to the size of China's electric system, even this aggressive effort will bring nuclear's share up to only 6% of installed electric-generating capacity. This program requires that at least two new reactors come online each year, over the next 16 years. By 2050, China plans to have 150,000 MW of nuclear capacity, equivalent to 150 large power plants. There are about 440 nuclear reactors today, worldwide, and 103 in the United States.

Critics of all political persuasions have insisted that such "breakneck" speed in nuclear power plant construction cannot be achieved. John Moens, an analyst at the U.S. Department of Energy, begged to differ. On Jan. 15, he told the *New*

China's high-temperature gas-cooled pebble bed reactor (HTR-10) in Beijing. Right: Scientists at Tsinghua University power up the reactor for testing in December 2000. The reactor design is considered "inherently safe."

York Times: "In 1970 we had a net capability of 7 million kilowatt hours [of nuclear generating capacity in the U.S.], and by 1981 we had reached 56 million kilowatt hours. So the rate of growth [the Chinese] propose is not only conceivable, it has been done before."

According to officials from the China National Nuclear Corporation (CNNC), the decision has not yet been made as to how many reactors in the next group of imported plants will incorporate the newer, recently licensed next- or third-generation technology, and how many will use the current-generation designs, with "some improvements." CNNC estimates that for quick expansion, the most efficient approach is to add more plants at existing sites, using the same reactor design as the operating units. More advanced, next-generation reactors will likely be chosen for new power plant sites. This program is of such national priority that, according to *China Business Weekly,* delegations which included Chinese President Hu Jintao have been visiting existing and potential sites for nuclear plants, along China's coastal areas.

In July, the government approved the construction of four nuclear plants, and in September, CNNC director Yu Jianfeng said during an interview at the World Energy Congress in Sydney that China will soon award an $8 billion contract for the four nuclear reactors, with work to begin 2007. Each set of two reactors will be located in Guangdong and Zhejiang provinces, which have been suffering from power shortages, and are expected to come online in about 2012. Yu said that about 70% of the equipment for the reactors will be Chinese-made.

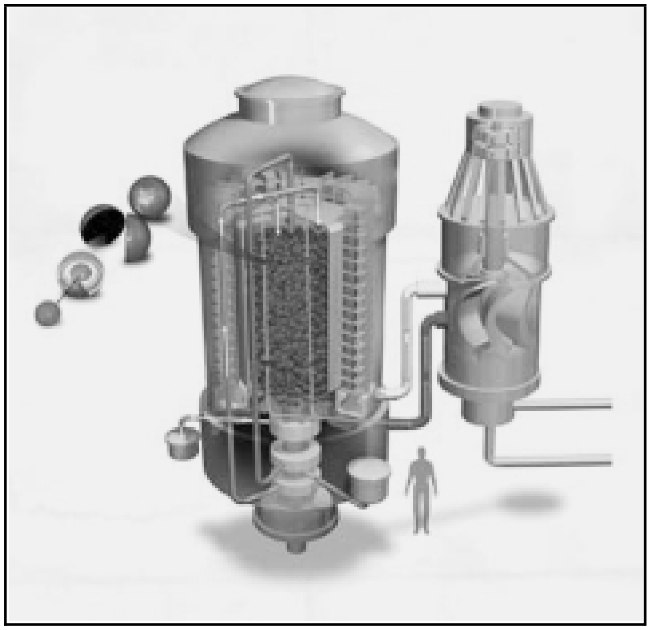
China has invited Westinghouse, French-based Areva, and Russia's AtomStroyExport to bid on the first four plants. In September 2004, the government also approved construction of another four reactors.

As a second aspect of its overall effort, at the same time that China has been importing commercial-scale nuclear plants to add to its electricity grid, domestic programs have been under way to develop indigenous conventional nuclear power plant designs, in order to give China an independent production capability for domestic use, and also for export. The 300-MW reactor at Qinshan, designed in China and built with 70% of its components produced domestically, began operation in 1991, and helped create a Chinese nuclear industry. In Phase II of its domestic R&D program, two 600-MW indigenously developed reactors were installed at Qinshan, and became operational in April 2002 and May 2004.

In July 2004, Ye Qizhen, chief designer of the second phase of the Qinshan nuclear project, and a member of the Chinese Academy of Engineering, said that Chinese engineers could "easily develop" a 1,000-MW-class reactor, based on the 600-MW design, if they introduced foreign-developed design software. *China Business Weekly* reported in February that China plans to build its 1,000-MW reactor before the first foreign third-generation nuclear reactors are built, around 2012.

China's program to develop its own nuclear power plant production infrastructure is aimed at export, as well as domestic deployment. In 1999, the Chashma-1 nuclear reactor became operational, 167 miles south of Islamabad, in Pakistan. The 300-MW reactor had been completed with help from China. In 2004, China's First Heavy Industries Company won a public bid to supply the Chashma-2 reactor's pressure vessel, which will be built in Dalian and completed in 38 months.

The international nuclear non-proliferation mafia has tried to bully China into reneging on the latest Pakistan nuclear plant project, but since that reactor will be under the inspection regime of the International Atomic Energy Agency, and the U.S. is eager to procure at least part of China's $8 billion construction program, no threats have yet been made.



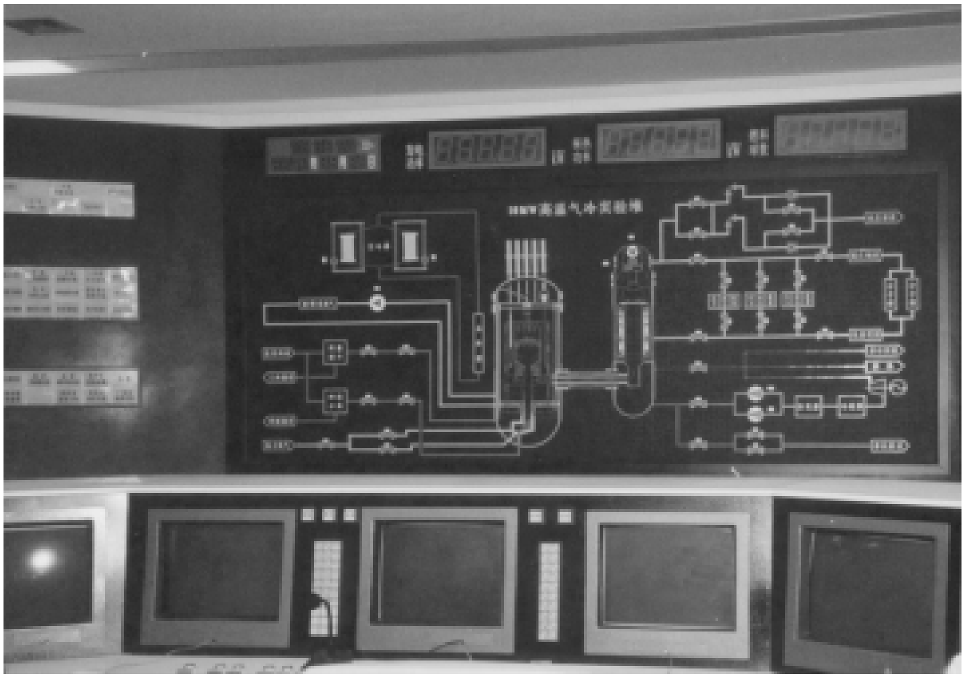
Sources: Andrew Kadak, MIT; Institute of Nuclear and New Energy Technology, Tsinghua University; World Nuclear Association.

A schematic of the pebble bed reactor. Thousands of billiard ball-sized fuel pebbles power the reactor, each coated with impermeable silicon carbide and packed with 15,000 tiny uranium dioxide flecks, each of which is encased in its own silicon carbide shell. The pebbles flow through the reactor vessel, heating helium gas, which in turn flows into the water-cooled conversion unit and pushes a turbine (right), generating electricity. The gas then cycles back to the reactor vessel to be reheated.

Versatile High-Temperature Reactors

A third facet of the program, occurring at the same time that the Chinese are importing commmercial nuclear plants, and developing their own capacity to build and export them, is the research and development program in which China is engaged, intended to push forward on the next-generation nuclear technologies.

Energy produced from the fission of nuclei is typically



The HTR-10 control room in at Tsinghua University. The HTR is the leading edge of China's long-term nuclear program, which includes also the import of conventional fission plants, and the development of indigenous production capability for domestic use.

captured as heat and used to boil water for turbine-generator sets to produce electricity in a power plant. This is the least efficient use of the energy from nuclear fission: Two-thirds of it is wasted in the thermal-to-electricity conversion process.

If the temperature that can be extracted from a nuclear reactor is higher, in the 800-1,000°F range—perhaps three times that of a conventional reactor—that higher-quality heat can be used to produce hydrogen from water to be used for fuel, direct electrical production, and desalination.

China started a high-temperature gas-cooled reactor research and development program in the 1990s at Tsinghua University in Beijing, often described as China's MIT. Tsinghua also has a very active space engineering program, and has designed satellites and space experiments.

A $30 million, 10-MW high-temperature gas-cooled pebble bed reactor (HTR-10) began construction in 1995, and started thermal testing in December 2000. In 2003, the reactor was incorporated into the power grid. In the Fall of 2004, Chinese scientists proudly displayed their HTR-10 to an international group of nuclear experts, and carried out a demonstration, showing that it is "passively safe." In other tests, the coolant for the reactor has been switched off, and it cooled down by itself.

The "pebbles" in the reactor are the 27,000 graphite billiard-sized balls that enclose the fissionable uranium, insulating each particle and dispersing the fuel. Instead of circulating water, with its miles of pipes, the reactor is cooled by the circulation of helium gas, which can withstand higher temperatures. The reactor does not have to be shut down for refuelling, since the spent fuel balls can be automatically removed, and new ones inserted.

China is not the first country to build or test this advanced-design high-temperature reactor. Rudolf Schulten designed a pebble bed high-temperature gas-cooled reactor prototype that was built in what was then West Germany, in 1985. The United States also had a high-temperature test reactor in that period, in Colorado. But anti-nuclear hysteria and the decline in energy growth, due to growing depression economic conditions in the past 30 years, left those, and other, experimental reactors, shuttered or dismantled.

In the mid-1990s, the government national utility company of South Africa licensed the German pebble bed reactor design and has been developing a prototype modular small reactor. China chose Tsinghua University to be its center for the development of the technology.

China plans to have a full-scale 195-MW version of its HTR-10 on line by the end of this decade, at an estimated cost of $300 million. Half of the financial stake in the joint venture building the plant has been taken by one of China's largest electricity generators, Huaneng. Concrete will be poured in the Spring of 2007.

China's nuclear industry plans to sell these 200-MW-sized reactors to utilities and in rural areas as modules which can be mass-produced and assembled quickly, with additional modules grouped together as electricity demand grows. Wang Yingsu, an official of Huaneng, told the *Financial Times* during a recent tour of the HTR-10: "If it succeeds, we can then spread this technology both at home and to the whole world."

Some policymakers are concerned that China may make progress in its space program fast enough to send their citizens to the Moon before George Bush's go-slow Moon-Mars mission gets the United States back there. In the nuclear field, China has already pulled ahead.