Special report: In China the big nuclear question is "how soon"?

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By David Stanway

CHENGDU, China (Reuters) - The congenial Professor Duan Xuru doesn't look like a stereotypical mad scientist as he shows guests into a cluttered laboratory filled with canisters, vacuum pumps and patched-up pipes tied together with spirals of blue wire and rubber tubing.

But Duan, based in the southwest Chinese city of Chengdu, is working on an audacious project described as a "man-made sun". He hopes it will eventually create almost unlimited supplies of cheap and clean energy.

Duan is no maverick either, but a pioneer in one of the many expeditions that China has launched to map out its nuclear energy options in the future.

Old-fashioned atom splitting has been in the spotlight after Japan's biggest earthquake and tsunami left an aging nuclear reactor complex on the northeast coast on the verge of catastrophic meltdown.

While Germany and Italy have turned their backs on nuclear power, China is pressing ahead with an ambitious plan to raise capacity from 10.8 gigawatts at the end of 2010 to as much as 70 or 80 GW in 2020.

Many of the nuclear research institutes across the country are working on advanced solutions to some of the problems facing traditional reactors, from the recycling and storage of spent fuel to terrorist attacks.

But Duan and his state-funded team of scientists are on a quest for the Holy Grail of nuclear physics: a fusion reactor that can generate power by forcing nuclei together instead of smashing them apart -- mimicking the stellar activity that brought heavy elements into existence and made the universe fit for life.

Duan said fusion could be the ultimate way forward: it is far safer than traditional fission, requires barely 600 grams of hydrogen fuel a year for each 10-gigawatt plant, and creates virtually no radioactive waste.

"Due to the problems in Japan, the government hopes nuclear fusion can be realized in the near future," said Duan, the director of fusion science at the Southwestern Institute of Physics, founded in 1965 and funded by the state-owned China National Nuclear Corporation (CNNC).

While fusion has moved some way beyond the purely hypothetical after more than half a century of painstaking research, it still remains some distance away from being feasible. Critically, the energy required to induce a fusion reaction far exceeds the amount of energy produced.

Fusion might be the ultimate goal, but in the near future, all China's practical efforts will continue to focus on a new model of conventional fission reactors.

While China's nuclear industry awaits the results of a government review in the wake of the Fukushima crisis, all signs point to China pushing ahead with its long-term strategy.

The National Development and Reform Commission said last week China would continue to support the construction and development of advanced nuclear reactors and related nuclear technologies.

"Suddenly, China has become even more important to the world -- as other people ask whether they still want to go ahead, China still seems intent on going ahead at full speed," said Steve Kidd, deputy secretary general with the World Nuclear Association, a London-based lobby group.

If traditional nuclear power represents the civil application of the atomic weapons dropped on Hiroshima and Nagasaki in 1945, fusion is an extension of the hydrogen bomb, first tested by the United States in 1952.

Showing Reuters around a sweltering, hermetically-sealed lab designed to bring hydrogen isotopes to an unthinkable 55-million degree boil in a 1.65 m vacuum chamber, Duan said progress had been slower than first expected at the dawn of the nuclear age.

"It took about nine years to go from the atomic bomb to nuclear power, and we hoped it would take a maximum of 20 years to get from the first H-bomb to a fusion reactor," he said. "But in reality it was very difficult because there were so many technical and scientific challenges."

Described by one observer as an attempt to put the sun in a box, nuclear fusion has been derided as the province of cranks and charlatans -- the modern equivalent of the perpetual motion machines that plagued U.S. patent offices in the 19th century. Skeptics scoff the world is now 50 years away from fusion power -- and always will be.

Duan shrugged off the criticism. He has spent more than 20 years in the field, including eight years in Germany, and found reasons to be optimistic.

"Actually, the concept of nuclear fusion is very simple," he said with a wry smile. "The first thing is to generate the plasma. The second thing is to heat the plasma to a few hundred million degrees. And then you need to confine it."

The devil, of course, is in the details.

EXOTIC OPTIONS

As Japan's stricken Fukushima plant lurched from crisis to crisis in March and April, the safety of nuclear power was called into question -- including in China. Five days after the quake and tsunami knocked out the 40-year-old Fukushima Daiichi complex, China said it was suspending approvals for nuclear power plants pending safety checks of plants in operation or under construction.

China by most calculations is already the world's biggest energy consumer, and demand for power is set to soar in the next decade. But its dependence on fossil fuels have also turned it into the world's biggest source of greenhouse gas.

Duan's fusion reactor could be the answer to China's energy conundrum. It does not require acres of space or tones of scarce fuel or water resources. It produces no CO2 emissions or waste, and is completely safe, even if struck by an earthquake.

A large part of China's fusion research is now focused on the tokamak, a Russian acronym meaning "toroidal magnetic chamber". It is a doughnut-shaped vacuum vessel wrapped in superconducting magnetic coils that confine and control the ultra-high temperature soup of ions and electrons known as plasma.

But tokamaks can only run a few seconds in experiments conducted every five months or so, creating a brief 500-megawatt burst of energy before fizzling out.

Unlike the tokamak, new conventional technologies are on the cusp of being commercialized, including "third-generation" designs imported from U.S.-based Westinghouse, owned by Toshiba, and France's Areva.

Also on the horizon are fourth- and fifth-generation technologies that go by names like fast-breeder, traveling wave, or high-temperature gas-cooled, as well as small and versatile "modular" reactors with shorter construction times.

"(China) has investments in the more exotic reactor designs and they also have got cooperation on fast reactors with the Russians," said Kidd of the World Nuclear Association. "They are keeping their options open, and Fukushima will encourage that tendency toward next-generation reactors."

The allure of the next generation reactors is they can eliminate, or at least defer, the problem of fuel shortages by reprocessing spent uranium into plutonium and other actinides and boost the amount of usable fuel by a factor of 50.

Like fusion, some of these advanced reactors remain a long way from the market, said Adrian Heymer, executive director at the Nuclear Energy Institute in Washington, D.C. High-temperature gas-cooled reactors are unlikely to be ready until 2030, and fast breeders could have to wait until the 2040s.

"When we say future, we are really looking at the distant future -- they not only need a step forward in technology but certainly also a step-up in operator acumen," Heymer said.

The nuclear debate, Kidd says, needs to focus more on the commercial application of current technologies.

"The nuclear industry's reaction, whenever there is a problem, is to try to find technical solutions rather than business solutions, which is the way any other industry would deal with it."

Non-mainstream technology is a diversion, he said, and China needs to focus on the task in hand: getting a new generation of reactors into commercial operation for the first time.

"What the industry has to do now is build a large number of third-generation units around the world, bring costs down and establish a global supply chain that will allow costs to be cut."

FISSION MISSION

All the discussions about Duan's "artificial sun" seemed ironic in the April gloom of Chengdu in China's rainswept Sichuan basin, where industry representatives met to talk about the long-term prospects for nuclear power.

They were originally lined up to celebrate the country's rapid capacity build-up and the extraordinary leaps expected over the next decade. Now they had to come to terms with the worst crisis to hit the industry in a quarter-century.

For the first time in years, China's bullish nuclear firms were on the back foot. Tang Hongju, the head of the nuclear division of the Chengdu-based Dongfang Electric, one of China's biggest nuclear equipment manufacturers, tried gamely to put it in the best light.

"The fact that we could have this conference and invite so many experts after the Fukushima accident shows how much confidence there still is in the Chinese nuclear sector."

Some worried about profits in the coming year.

"We are actually quite worried about a slowdown in orders," said a representative with another supplier. "There is still a lot of uncertainty because in the end it all depends on what the government decides. Right now we have no idea what it will be."

Before March 11, the world was awaiting a bold 2020 capacity target of 85 GW, more than doubling the previous 40 GW figure. The two big plant builders, CNNC and the China Guangdong Nuclear Power Corporation (CGNPC), said 100 GW would be possible.

Even before Fukushima, some urged caution. The State Council Research Office published a paper in January saying China needed to rein in the overexuberant nuclear sector and keep the target at around 70 GW.

"There was a lot of hot air about a 'nuclear renaissance' in the last few years and the credibility of it was getting lower -- Fukushima actually provides an excuse to slow down a bit."

Beijing has not yet published new targets, but Xue Xinmin, a researcher with the NDRC's Energy Research Institute, said it was now likely to be scaled back to around 70-80 GW.

He said a slowdown would give China time to improve its regulatory system, train personnel and build manufacturing capacity, thus ensuring the industry's long-term strength.

Official corruption is another concern. Last November, the CNNC chief was jailed for life for taking bribes and abuse of power, raising questions about the integrity of policy-making at the top of the industry.

Despite the uncertainties, optimism continues to prevail -- and some insiders suggested Fukushima could actually cement China's future dominance of the sector.

"The Japan accident could be good for China," said one industry official who didn't want to be identified in order to speak more candidly.

"It will force China to move forward technologically and pay even more attention to safety. But it will also lead to a bigger slowdown in nuclear development in other countries. China can really gain the upper hand."

China has already committed itself to investing $1.5 trillion in seven strategic industries, including nuclear and high-speed rail. Its plans to push into high-tech sectors prompted U.S. President Barack Obama to call for a "Sputnik moment" aimed at ensuring that the United States doesn't fall behind.

Even the lower target of 70 GW is still a huge leap from 10.8 today, and China could very quickly return to "business as usual Kidd said.

While many predicted the safety review after Fukushima would cause project approvals to be suspended for at least a year, now the expectation is for the pipeline to start moving again in August.

Dozens of plants are waiting to be built.

"Obviously, there will be some delays, but I don't think there are any implications for those projects already under construction -- and there are 27 of those, which is enough to be going along with," said Kidd.

FUKUSHIMA NIGHTMARE

Parts of China are prone to earthquakes, such as the 8.0-magnitude quake that flattened several towns in Sichuan in 2008, killing 80,000 people.

The quake did no harm to nuclear power plants, sparing China a Fukushima-style nightmare. But it damaged beyond repair a turbine manufacturing unit belonging to one of China's biggest nuclear equipment makers, Dongfang Electric, at a loss of 1.6 billion yuan. Since then, the company has recovered, building and expanding facilities in quake-damaged Deyang and elsewhere.

Despite misgivings among the general public, the quake didn't stop nearby cities -- including the megapolis of Chongqing -- from pushing ahead with their own reactor plans.

Chinese netizens have expressed concerns about the projects, and after Fukushima some accused local officials of putting prestige and profit ahead of public safety.

"The people of Sichuan should unite and together resist the shameful act of building a nuclear power station in Sichuan," said one comment on an Internet site (www.mala.cn) used to discuss local issues in the province.

Existing nuclear projects are clustered on China's eastern coast, but the government has identified nuclear power as a crucial part of efforts to reduce coal dependence and boost energy supplies in poor and polluted interior regions.

Beijing said shortly before the Japan crisis that China's first inland plant would begin construction within two years, and Sichuan was among a number of provinces hoping to be in the first pick.

A lot is at stake. Sichuan officials said apart from Dongfang Electric, more than 30 companies in the province were preparing for the projects, which have not been given the final go-ahead by the central government.

Critics of nuclear power suggest all the "inland" nuclear plans should be torn up in light of the Japan crisis, and not just because of the potential earthquake risks.

"China has a huge variety of natural disasters -- this is a country vulnerable to extreme weather and the government needs to take into consideration all the worst-case scenarios," said Li Yan, China campaign manager with Greenpeace.

Nuclear supporters see a massive overreaction to Fukushima.

"The safety requirements for inland nuclear power plants are no different from those on the coast -- the key consideration is water supply and environmental capacity," said Li Xiaoxue, an official in charge of new reactor projects at CGNPC.

Kidd of the World Nuclear Association said plants in earthquake-prone regions could be scaled back, but that was no reason to ban all inland projects.

"Some of the regions have seismic problems and as a consequence of Fukushima there may be less of a rush to go to some of these areas, including Sichuan, but otherwise there's no particular good reason not to build them," he said.

GENERATION GAP

Li of CGNPC caused a stir at the Chengdu conference when he said China could halt approvals for new second-generation plants -- similar to the Fukushima Daiichi plant -- after Japan's disaster. He also wondered whether China was ready to make the big leap into third-generation technology.

The company later denied Li had made those statements. But even if China does go ahead with some second-generation plants among the many projects pending approval, the Japan crisis is likely to strengthen its prior commitment to third-generation reactors such as the AP1000 and Areva's EPR.

"China was heading that way anyway," said Kidd. "They see the AP1000, or derivations of the AP1000, as the way forward. I think they have looked at it and said if they can build it properly, it will be cheaper."

At Sanmen on the east coast, China is building the world's first AP1000, a model designed by Westinghouse to withstand the sort of catastrophic strains that struck the Fukushima complex.

China isn't just building Westinghouse's new third-generation model, it is also absorbing the technology in a strategy aimed at seizing the global initiative in the industry and building an entire industrial chain with a global reach.

Technology transfers from Westinghouse and others will allow China to create its own reactor brands. CNNC is talking to foreign partners about selling them abroad.

"Many of the technologies have already been basically localized," said Xue, the NDRC researcher. Reactors now under construction could rely on domestic manufacturers for around 80-85 percent of their components and equipment, he said.

"We are localizing advanced technologies in order to enter the global market -- China must become a nuclear exporting country and exporting reactors must be a part of our national strategy."

China is emulating South Korea, which signed a similar technology transfer agreement in 1987 and is building its own reactors in the United Arab Emirates.

"With the transfer of technology, the Chinese will have the wherewithal to move ahead with similar designs, and by the time they get to unit 10 they are going to be pretty much self-sufficient," said Heymer of the Nuclear Energy Institute.

"It could mean that by 2020-2025 they will be up and running themselves and could be a competitor," he said.

BREAKING EVEN

Back at his lab in Chengdu, Professor Duan remains optimistic about the long-term prospects for fusion, particularly when the pressures of climate change begin to intensify.

Duan heads a team of 200 people, up from just a few dozen in the 1980s when fusion researchers were struggling to convince their paymasters the technology was feasible.

In recent years, Beijing has offer more funds, partly to meet its commitments to a fusion project known as the international thermonuclear experimental reactor, or ITER.

"Now it is much better than before," Duan said. "One reason is energy security. Another is political: we joined the ITER project."

China joined the European Union, Russia, Japan and the United States in ITER in 2003. With India and South Korea also on board, the project aims to produce a working fusion reactor by 2019. The countries will share the project's costs, expected to run to 10 billion Euros.

Fusion is far behind fission in terms of development and far more reliant on international cooperation, at least while the technology is in its infancy. China, which has shown it can leverage its nuclear might to get know-how from Westinghouse and Areva, could be equally hard-headed if fusion looks like is paying off.

While the fusion research community has no secrets now, Duan said, labs like his could start to go their own way if big breakthroughs are made.

A number of labs -- including the Joint European Torus (JET) in Abingdon near Oxford in the United Kingdom -- have come close to a crucial breakthrough: getting more power out of the reactor than they put in, a ratio known as Q or "breakeven". ITER is likely to lift Q from less than 1 to more than 10 within 20 years.

The Q ratio is a starker, more scientific version of the sort of cost-benefit analysis that is brought to all forms of energy, including conventional nuclear power.

For the industry's inveterate opponents, benefits will always be outweighed by costs. But as China scours the planet for the scarce resources needed to meet the energy demand of more than 1.3 billion people, nuclear is seen as fundamental.

During his travels around the nuclear conference circuit, Kidd said he had identified as many as 20 separate excuses why nuclear power shouldn't be developed, but in the end, the fundamental problem facing the sector is cost.

It is a problem China is in the best position to solve.

"They have a wonderful opportunity to show what they can do and the key thing they can bring to the world is lower costs."

Whether China can eventually do the same for fusion remains to be seen, and until it is finally commercialized, China and the rest of the world have little choice but to endure all the costs and risks that arise from splitting the atom.

Duan has dedicated his adult life to fusion research, and he still isn't sure if he will see a commercially viable reactor in his lifetime.

"It is difficult to say," he said ruefully.

"I believe we will have a fusion power plant within fifty years, but I don't know if I will still be here to see it."

(Editing by Bill Tarrant)