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South Korea Fires Up Its 'Artificial Sun'

KSTAR nuclear fusion project passes milestones as mankind seeks the magic bullet of clean and unlimited energy

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The "holy grail" of energy – clean, safe and virtually limitless – is being generated in a six-story building in a science park on the outskirts of a city south of the capital Seoul.

Nestled among buildings marked Korea Institute of Advanced Science and Technology and the Korean Institute of Nuclear Safety in Daejeon, one hour from central Seoul by KTX bullet train, lies a superconducting fusion power plant – or, if you prefer, "artificial sun."

It is this facility that set a record that generated excited headlines across global scientific media at the end of last year.

On November 24, the KSTAR project of the Korea Institute of Fusion Energy (KFE) announced it had continuously operated plasma for 30 seconds with an ion temperature higher than 100 million degrees Celsius – more than double its previous time record.

To the uninitiated, this is gobbledegook. To the initiated, it is an encouraging milestone on the path to workable nuclear fusion – the power source that ignites the sun and the stars.

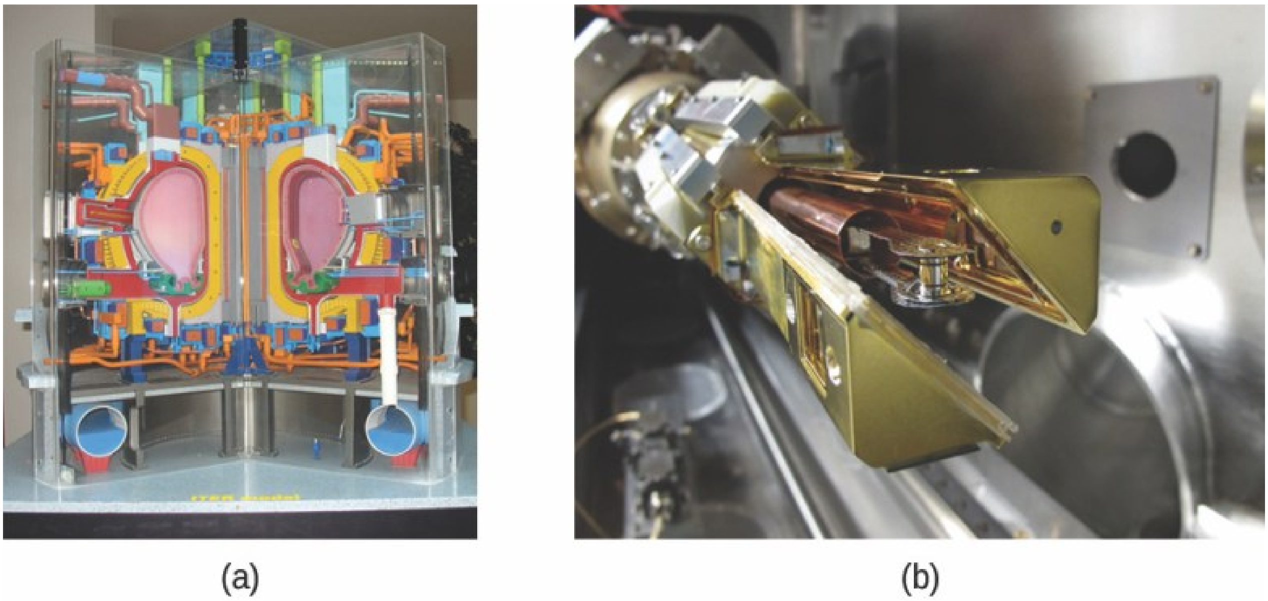
> "We successfully sustained [fusion] for 30 seconds last year," Yoo Suk-jae, the president of the KFE, told reporters visiting the KSTAR facility this week. "We usually say that fusion energy is a dream energy source – it is almost limitless, with low emission of greenhouse gases and no high-level radioactive waste – [but] this means fusion is not a dream."

And in a world racked by distrust, hatred and conflict, KSTAR is part of a different dream.

It is a key player in one of mankind's most ambitious scientific programs, albeit one that is little known outside its own sector: ITER. The International Thermonuclear Experimental Reactor, which is rising in southern France, could feasibly overcome what many see as humanity's greatest challenge – the energy and climate change crisis.

Remarkably – unlike other paradigm-smashing scientific mega-programs, such as the Manhattan Project and the Apollo Program – it is truly international in scope, crossing the world's most hostile ideological and political frontiers.

ITER's 35 member states include China, the EU (including the UK), India, Japan, Russia, South Korea and the United States.



A model of the International Thermonuclear Experimental Reactor under construction in the south of France, with an expected completion date of 2027. Photo: WikiCommons

KSTAR turns up the heat

The KFE was founded in 1995, employs 437 staff and has an annual budget of US$200 million. Its flagship project is the KSTAR, or Korea Superconducting Tokamak Advanced Research, in Daejon.

Despite its acronym, the KSTAR facility has nothing to do with K-pop, but everything to do with nuclear fusion.

Most energy sources consume a non-renewable resource: Biological sources such as wood or biomass, or fossil fuels such as coal, oil and gas.

Renewable energies, such as solar, wind and hydro are clean and unlimited, but, lacking consistent generation, are unable to sustain the level of operations required for industry.

And nuclear fission, the process used in atomic power plants, creates dangerous waste.

Nuclear fusion suffers none of these drawbacks. In the heart of a star, hydrogen nuclei collide, fuse into heavier helium atoms and release tremendous amounts of energy. A star generates this fusion organically through its extreme gravitational densities and temperatures.

On Earth, the most promising "fuel" for nuclear fusion to occur has been found to be two hydrogen isotopes – deuterium and lithium. These can be sourced from the oceans' virtually unlimited supply of seawater.

But while the fuels may be easy to source, their fusion is a fiendishly complex process. It requires huge, specialized devices that fuse the lithium and deuterium, turning them into a hydrogen state, where electrons separate from ions and gas becomes plasma.

Stars are aided by densities that the Earth's atmosphere does not possess. So, for fusion to occur here, temperatures must be raised and maintained at extraordinary heat.

It is this maintenance, or "confinement," of super-heated plasma that KSTAR does. Its tokamak – an experimental fusion reaction – is a mansion-sized device that would make a perfect set location for a science-fiction film.

Inside the KSTAR reactor room. Photo: Andrew Salmon

The tokamak uses powerful magnetic fields to confine the plasma in a donut-shaped vacuum ring. The plasma within reaches such ludicrous heat that thermal devices cannot measure it: Instead, scientists analyze its temperature by dissecting its light waves.

> "We can generate tritium on-site from seawater," KSTAR Director Yoon Si-woo told reporters as he showed them around the machinery. "We have to heat up the plasma up to 100 million degrees otherwise this [fusion] concept will not happen."

November's 30-second operation at 100-million degrees – a huge advance over KSTAR's first experiment in 2008, which lasted only one second – was a critical milestone, Yoon said. But that length of time needs to be far exceeded for fusion to become viable as a power source.

Next steps

> "This is not the end of the story, we must move on to 300 seconds – 300 is the minimum time frame to demonstrate steady-state operations, then this plasma can work forever. If we can't achieve that – we have to do something else," he said.

Things will be heating up at KSTAR in the next coming years. KSTAR's deadline to hit the 300-second mark is 2026. Multiple hurdles lie ahead.

> "To increase the fusion rate, you have to increase the temperature and the density," Yoon said. "Now we are focused on temperature, but we must also focus on density."

Another issue is cooling, which is now done by chilling the superconducting magnets with liquid helium. "We have to think about how to remove the exhaust from this high-temperature plasma," he added.

Even so, the South Korean team is now the toast of the fusion world. Given that there are multiple tokamaks in operation around the world, what has made KSTAR so successful of late?

Its superconducting magnets suffer no heat loss, Yoon said, while KSTAR also boasts excellence in its ion-heating systems, and offers world-class diagnostics to monitor the plasma.

Unlike the fears surrounding nuclear fission, Yoon says fusion offers no such risks. "When it comes to safety, nothing can beat fusion," Yoon said. "The issue is sustainability."

One reason why South Korea is so advanced in this field is the specializations offered of local industry, which can produce the kind of super-high stress metals and machinery a tokamak requires

> "We have a well-developed industry for this," Yoon said. "Based on that, we have a lot of advantages."

Indeed, Korea leads the world in shipbuilding technologies, and is also a key player in steel, construction and engineering.

He noted that while KSTAR is a government project – and as an experimental reactor, is not focusing on commercialization – major companies have worked on the reactor and its components.

Nameplates on the wall in the KSTAR building include the world's leading shipyard, Hyundai Heavy Industries, as well as Samsung Engineering and Construction and Samsung Advanced Institute of Technology.

Looking EAST

Still, KSTAR is hardly alone: A nearby competitor is also winning kudos.

Since the South Korean team's success, a Chinese fusion program, EAST – the Experimental Advanced Superconducting Tokamak, in Hefei Province – accelerated past what looks like an even more impressive landmark.

On December 30, it confined plasma for 1,056 seconds – more than 11 minutes – at 70 million degrees Celsius.

> "The recent process of EAST is quite amazing," Yoon said. "But there are two routes here."

He explained that with plasma being a combination of ion and electrons, KSTAR works on heating ions, EAST on electrons – the dynamics of which are different.

> "These are different routes to get to high-performance, steady-state operations," Yoon said. "We are working together with EAST … this is a competition, but it's a good thing."

This element of complementary competition is clear; Chinese personnel are working at the KSTAR site, said Yoon.

Both the Chinese and South Korean projects are components in the larger global project that will be the make or break of fusion energy generation.

> "This is not secret," Yoon said. "We are all sharing the ITER project."

In part two of this story, Asia Times will examine how KSTAR contributes to the ITER project, the spin-off and commercial potential of fusion energy technologies and the overall feasibility of this massively ambitious sector.

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Featured image: KSTAR Director Yoon Si-woo in front of the tokamak that is the heart of the nuclear fusion project. Photo: Andrew Salmon

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