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Nuclear fusion: from science fiction to ‘when, not if’

Tom Wilson

8–10 minutes

When Zoltan Tompa first presented a nuclear fusion company to his Canadian government development fund’s investment committee, he viewed the technology as a “moonshot” with “an outside chance” of success.

Fifteen years later, he says it is a matter of “when, and not if” fusion energy gets connected to grid.

“We believe it has a real shot at putting a commercial power plant on the grid within about a decade from now,” Tompa said of Canada’s General Fusion, where he now sits on the board.

General Fusion is one of around 35 private companies worldwide seeking to build on decades of experimental fusion research and deliver on its promise of near limitless, zero-carbon power.

This week that goal moved slightly closer with confirmation that scientists at the Lawrence Livermore National Laboratory had

achieved energy gain in a fusion reaction for the first time in history. The gain occurred for a split second and the energy produced was only greater than that in the lasers used to trigger the reaction, and not the total electrical energy use to power the system.

However, the breakthrough, first reported by the Financial Times, has focused global attention on a technology normally derided as constantly being 30 years away.

“It’s a huge shot in the arm and I think it’s a psychological signal to society at large, to investors, to policymakers, that fusion is no longer in the realm of science fiction,” said Tompa, who leads clean technology investments at the Business Development Bank of Canada. “It proves that fusion is real and that the time for fusion is now.”

really?

British astronomer Arthur Eddington first theorised in 1920 that the sun was powered by a fusion reaction that could be replicated on Earth to generate unlimited energy.

Since then, largely publicly funded laboratories have conducted hundreds of experiments, successfully heating hydrogen isotopes — normally deuterium and tritium — to such extreme temperatures that the atomic nuclei fuse, releasing helium and energy in the form of neutrons. But progress has been slow, littered with false dawns, and until last week no group had achieved energy gain.

Sceptics point to the many remaining challenges. The energy gain from the fusion reaction needs to be significantly increased from the levels obtained at the Lawrence Livermore National Laboratory. Furthermore, that result was achieved through a different, less common fusion approach to that of the most

advanced private sector projects.

Many of the current plans for potential fusion power stations will also require teams to overcome difficult engineering challenges and in some cases manufacture, at scale, complex new materials.

“A significant leap” is still required to get to commercial power but this is the role that private sector companies — which “work at a much faster clock speed” and “innovate much more quickly” — will now play, said Tompa.

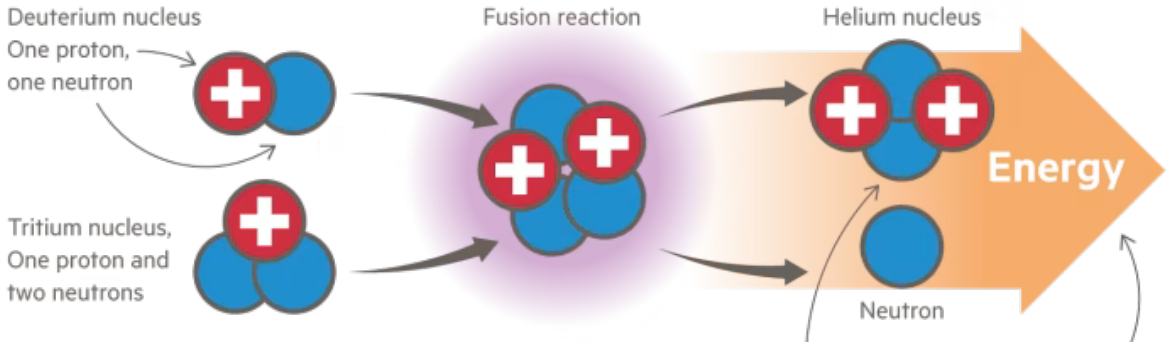
“We see this as a passing of the torch moment,” said Andrew Holland, executive director of the Fusion Industry Association, which was set up in 2018 to represent the nascent sector. “This is where it goes from the lab to the market place.”

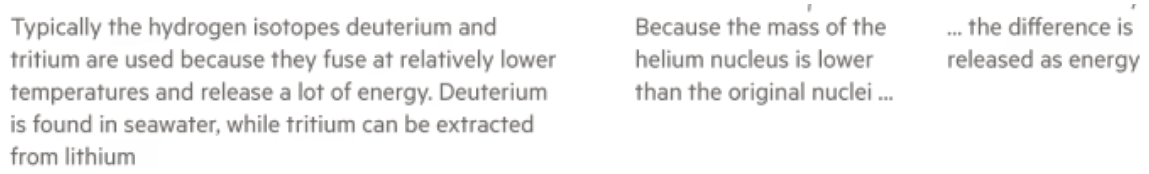
The oldest private company in the field, according to the association’s most recent report, is Princeton Fusion Systems, founded in 1992. California-based TAE Technologies came next in 1998, followed by General Fusion in 2002. But most of the private sector growth has come in the past five years after the 2016 Paris climate agreement committed countries to limit global warming to well below 2 degrees Celsius and supercharged interest in potential clean technologies.

good graphic for video

A nuclear fusion reaction

In a fusion reaction, the repulsive electrostatic forces keeping the nuclei of light atoms apart are overcome and they fuse together to form helium. This requires extraordinarily high pressures and temperatures.





Sources: IAEA; US Department of Energy; FT research
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“Four years ago, five years ago, the only people that were building real fusion machines that can make real fusion work were the public programmes . . . and now the next generation of things are things that are being built by the private sector,” said Bob Mumgaard, chief executive of Commonwealth Fusion Systems.

In a sign of increased private sector enthusiasm for fusion, CFS raised $1.8bn last year from 30 investors including Tiger Global Management and Google, in a round that equalled the declared private funding of the entire industry at the time. CFS is building a demonstration plant called Sparc, about half the size of a tennis court, which it hopes will achieve energy gain by 2025. It then has plans to demonstrate commercially viable power in the early 2030s.

Many public-sector scientists suggest that these timeframes are too optimistic. But Philippe Larochelle at Bill Gates’s Breakthrough Energy Ventures, which first backed CFS when it was founded in 2018, said the fund’s fusion investments should no longer be seen as speculative.

“The reason we’ve invested in CFS and our other fusion companies is that we apply the same standard to them that we do to all of our other electricity investments, which is do we think that this is a scalable way of getting carbon free dispatchable power at less than $50 per megawatt hour,” he said. “It seems like there’s a very plausible pathway here that this could be a dominant source

of energy on Earth, sometime this century, and I think maybe even in the next decade or two."

In total, at least $2.83bn was raised by private fusion companies in the 12 months to June, which was more than had been raised in the history of the industry and brought total funding at that point to $4.9bn, according to the Fusion Industry Association.

While early funders of fusion companies tended to be Silicon Valley venture capital firms and tech billionaires — Jeff Bezos has backed General Fusion — the investor universe has widened.

"A lot of new classes of capital are trying to get smart in the space and are ready to make investments, I think, sooner than most people thought they would have," said Larochelle.

TAE Technologies raised $250mn in July from investors including Google, Chevron and Sumitomo, bringing its own funding to date to more than $1.2bn.

"As the science and technology matures so are the types of investors that are investing," said General Fusion chief executive Greg Twinney.

However, fusion remained a "very small fraction" of the $2.4tn in global energy investment in 2022 forecast by the International Energy Agency. "If we're looking to speed things up or reduce the risk, more capital is the way to do that," he said.

More than half the private fusion companies, including CFS, are developing approaches based on magnetic confinement, in which huge magnets hold the deuterium-tritium fuel in place while it is heated to temperatures hotter than the sun.

At least eight companies are working on inertial confinement

approaches, similar to that used at the Lawrence Livermore National Laboratory, where a laser or high-speed projectile is used to trigger the reaction. They include the UK's First Light Fusion and Germany's Focused Energy. General Fusion's approach, sometimes described as magneto-inertial, combines aspects of both.

Seattle-based Zap Energy, which is also backed by Breakthrough Energy Ventures, hopes to achieve fusion using a pulse of electrical current, which Larochelle described as similar to a "lightning bolt".

Some of these approaches are bound to fail. "Any investor has to go in understanding that for any individual fusion company there is still binary technology risk," said Tompa.

However, there is growing confidence in the sector that several will succeed.

"Sometime in the next decade or two, we are going to build the first commercial fusion reactor and then humans are going to spend the next 10 million years building better fusion reactors because fusion is really just an amazing energy source," Larochelle said. "The fuel is infinite, carbon free and extremely cheap . . . you can build it anywhere and scale infinitely."