The Illusion of Fusion Power in 10 Years

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1. Introduction

Recently over $10B has been invested in private fusion companies [1], many of which promise nuclear fusion-generated electrical power within about 10 years. The investors include high-tech companies like Google and Microsoft, which ought to be well-informed.

However, these promises of near-term fusion energy are in reality a combination of fantasy, delusion, and deceit, since there are far too many intractable problems in fusion physics and engineering to resolve in just 10 years. The inevitable popping of this recent fusion "bubble" will likely discredit the longer-term governmental fusion programs and undermine the public's trust in the integrity of scientific research.

2. Some problems

Since the early 1950s scientists around the world have been trying to build an electrical power station fueled by the nuclear fusion of light atoms, the energy source of the sun and stars (and hydrogen bombs). This is quite challenging since it requires temperatures of over 100,000,000 ºC, at which point the fusion fuel becomes a "plasma" or ionized gas, a complex fourth state of matter (solid, liquid, gas, plasma). Although the basic nuclear physics of the fusion reaction is well known, the plasma physics and engineering needed to build a working fusion power reactor are not yet known and exceedingly difficult.

In the rest of this section three examples of these difficulties are briefly described: confining the hot plasma, extracting the fusion energy, and providing a long-term supply of fusion fuel. The larger scope of the difficulty is outlined in the last paragraph of this section.

Hot fusion plasmas are difficult to confine in one place since they are driven unstable by the huge temperature difference between the plasma and the outside world. This instability creates small-scale turbulence which causes energy to leak out from the plasma, and so increases the heating power required to sustain the fusion. The physics of this turbulent plasma transport is so complicated that it cannot yet be reliably predicted even using the world's largest computers [2]. In addition, more violent large-scale plasma instabilities can sometimes extinguish the whole plasma within milliseconds. Given these instabilities, the main path forward has been to build larger fusion devices to slow down the energy loss, but this makes them more difficult to build and more expensive.

The energy produced by fusion reactions is about 10 million times larger (per gram) than chemical reactions such as burning coal, but all this energy must be extracted from the plasma through the reactor's first wall. Any solid wall will become hot due to the plasma loss and so is preferably made from a high-melting point metal such as tungsten [3]. Even if the first wall doesn't melt it will slowly erode due to the plasma loss and will be damaged by high energy neutrons, which constitute the main fusion energy release mechanism. This is a major problem since this wall will be inside a highly radioactive vacuum vessel, so all maintenance must be done by robotic manipulators. Even a pinhole-sized leak in the first wall cooling system will immediately quench the plasma and require extensive repair and probably many months of downtime.

By far the strongest fusion reaction is between deuterium (D) and (T), both heavy isotopes of hydrogen. Deuterium is available at low cost from ordinary water, but tritium is not found naturally since it radioactively decays in about 12 years. The required tritium fuel can be obtained from fission reactors or *just barely* from a fusion reactor itself using a nuclear reaction of the D-T neutron with lithium in a "breeding blanket". This blanket must cover nearly the entire wall and would be a labyrinthine device with many coupled nuclear, chemical, thermal, and mechanical constraints [4]. No such blanket has ever been built, and it could not be fully tested without a working fusion reactor. This has driven some fusion designers to propose using the D-D or D-^{3}He fusion reactions, which are about 100 times slower than D-T but do not require tritium breeding. But this makes the already difficult confinement problem much more difficult due to the higher temperatures required.

Each of these three problems has been studied for over 40 years by hundreds of scientists and engineers, but no clear solutions yet are in hand. However, this short list only begins to describe of the difficulty of a fusion power reactor. The real difficulties can be appreciated by perusing the 8 papers in the 2025 Special Issue of the leading journal Nuclear Fusion, modestly entitled: "On the path to tokamak burning plasma operation" [5]. This work is focused only on a single next-step device ITER, which is a "tokamak", or donut-shaped magnetic bottle. ITER is an enormous 30 m high machine being built in France and is by far the largest and most ambitious fusion project ever attempted. This Special Issue comprises over 1000 dense pages, written by about 400 authors from around the world, with over 600 figures and almost 8000 references. ITER's designers hope it will make 400 MW of D-T fusion power by the 2040s, but if the power were converted to electricity (which it will not be), ITER could barely run itself due to the large electrical requirements of this huge facility. This study illustrates the real complexity of fusion problems and the multiple uncertainties in the proposed solutions.

3. Some history

The quest for a fusion power reactor has been almost entirely funded by national governments from its beginning in the early 1950s, and since the late 1950s there has been extensive and friendly international cooperation. The initially high level of optimism about fusion was based on the obvious analogy with the rapid success of fission reactors. The first self-sustaining fission reactor was created in Chicago in 1942, and the first commercial fission power reactor was opened in the UK in 1956.

Many brilliant ideas for fusion reactors were proposed in the 1950s and 60s, but most initial experiments were disappointing due to unexpected plasma instabilities. A kind of Darwinian selection process ensued so that by the 1970s the tokamak emerged as the winner [6]. Three large (ca. $1B) tokamaks were started in the early 1980s as a potential solution to the "energy crisis".

One of these was the TFTR device at Princeton, which ran from 1982-1997. The other large tokamaks were in the UK and Japan.

By the late 1990's these three large tokamaks had not quite achieved their initial goals, and it became clear that any future tokamak reactor would be extremely large and expensive. Alternative fusion concepts were encouraged by national governments and small experiments were continued at universities and national laboratories. By about the year 2000 some private fusion companies began to promise short-cuts to fusion power, but these were largely ignored by the mainstream fusion community since their initial performance was significantly lower than the tokamaks of the mid-1970s.

At present (2026) several government groups are designing (on paper) demonstration electricity generating power plants based on the tokamak. For example, the European DEMO [7] would address serious engineering issues such as the breeding blanket, remote handling, safety, and RAMI (Reliability, Availability, Maintainability, and Inspectibility). This DEMO design has a staggering complexity far beyond that of ITER and probably beyond any engineering project in human history. Even assuming ITER success, a European DEMO would not start running before 2050 and would probably operate until 2080. There is no current plan for a US DEMO; however, the UK claims (surprisingly) to be planning a prototype spherical tokamak fusion power plant by 2040 (STEP).

4. Some private fusion companies

It seems as if every fusion concept of the last century has recently been reincarnated as a privately funded fusion power company. Most of these companies have a few reputable scientists and very colorful web sites, but in my opinion none of them will ever come close to building a fusion power reactor. A critical assessment of some of these companies is given below, listed in order of their founding.

4.1 TAE Technologies

TAE Technologies of Foothill Ranch, California was founded in 1998 and is one of the oldest existing private fusion companies [8]. It began as Tri-Alpha Energy to exploit the non-neutronic but very weak p-^{11}B fusion reaction, which makes 3 alpha particles. Their machine configuration has changed over the years, but their latest machine NORM uses high energy neutral beam injection to sustain a "field reversed configuration" (FRC) within a magnetized cylinder. An FRC is a floating plasma current ring originally discovered in the 1960's.

TAE's best fusion performance was in their machine C-2W, but this was only comparable to the tokamaks of the early 1970s [9]. They have recently (2025) published a physics paper in the Nature Communications with over 80 authors demonstrating a simpler method of field reversal and diagnosing the plasma [10], without showing improved performance. In Dec. 2025 TAE announced a planned merger with the Trump Media & Technology Group, which "expects to site and commence construction of the first utility-scale fusion power plant in 2026."

4.2 General Fusion

General Fusion of Vancouver, Canada was founded in 2002 and is focused on "magnetized target fusion" [11]. This is a high-density pulsed plasma compressed by an imploding metal liner, an idea originally developed in the 1970s at the US Naval Research Laboratory. General Fusion has recently (2025) published a paper in the journal Nuclear Fusion [12], claiming a D-D neutron yield lower than many of the earliest fusion experiments of the 1960s. Yet they promise to supply commercial fusion energy to the grid by the early-to-mid 2030s.

General Fusion is unusual in that it seems to be motivated by fantasized engineering rather than by fantasized plasma physics. It plans a thick liquid lithium/lead liner to try to solve the first wall and tritium breeding problems *before* solving the plasma physics, which is at least an interesting idea. However, its use of huge mechanical pistons to compress the liner appears bizarre and highly unrealistic. In 2022 General Fusion announced a major partnership with the UK Atomic Energy Authority (UKAEA) to build their demonstration power plant at their large fusion lab in Culham, England. However, this collaboration was cancelled in 2024, and by 2025 General Fusion reduced its staff and appealed for additional funding.

4.3 Tokamak Energy

Tokamak Energy near Oxford, England was founded in 2009 as a spin-off from the UKAEA [13]. Their goal is to develop the technology and build the partnerships to deliver fusion energy in the 2030s. Their spherical tokamak device ST-40 has the best fusion performance by a private company [9,14], but this not surprising since ST-40 is very similar to existing government-funded spherical tokamaks in the US, UK, and Russia. Tokamak Energy's plan for a high temperature superconducting tokamak reactor appears to overlap significantly with the UKAEA STEP program. It is not clear what added value a small private company can bring to this well-funded UK government research program.

4.4 Helion Energy

Helion Energy of Everett, Washington was founded in 2013 and claims: "We're building the world's first fusion power plant" to supply Microsoft with 50 MW of fusion-generated electricity by 2028 [15]. Like TAE its design is based on a field-reversed configuration (FRC), but here two FRC's are supposed to collide and merge about once a second. Novel features of the Helion design include the use of D-^{3}He fuel and the direct conversion of plasma energy into electricity. They publish very little beyond theory [16].

It is well known that a single FRC is highly unstable, so the collision of two FRCs is unlikely to be stable long enough for significant fusion to occur. The D-^{3}He reaction requires much higher temperatures than D-T, and the ^{3}He must be created from D-D reactions in the plasma itself, since there is almost none on earth. Direct energy conversion is an idea from the 1970s which has never been implemented. The best experimental results from Helion are comparable to tokamaks of the early 1970s, so their claim to make a fusion power reactor within 3 years is absurd, at best.

4.5 Zap Energy

Zap energy is a company founded in Seattle, Washington in 2017 which aims to build a small-sized DT fusion reactor based on the "Z-pinch" [17], one of the first fusion ideas tried in the 1950s. This is perhaps the simplest fusion concept: a high current spark driven by pulsed high voltage in a single (Z) direction, with no external magnets or auxiliary heating. Z-pinches were largely abandoned in the 1960s due to their strong instability, but this company claims that plasma flow shear can stabilize this configuration, at least in theory.

The company publishes extensively and has a beautiful web site. But the fusion performance of their FuZE plasma experiment is comparable to tokamaks of the mid-1970s [9,18]. The extremely high power-density of a reactor-level Z-pinch would damage solid electrodes and nearby walls, so it would require liquid metal components. The engineering of these components is being tested on their Century prototype device [19]. This company seems to be technically competent but deluded by a theoretical idea.

4.6 Commonwealth Fusion Systems (CFS)

Commonwealth Fusion Systems was founded in in Devon, Massachusetts in 2018 as an offshoot MIT [20], whose government funded tokamak program was cancelled in 2016. CFS (with MIT collaboration) is presently building the SPARC tokamak, which is a compact high-field superconducting machine which they hope to operate by 2026. The SPARC design is like earlier USDOE proposals (CIT, BPX, FIRE) but with high temperature superconducting magnets which may allow a higher field strength than ITER-type magnets. CFS has also announced plans to build a larger ARC device after SPARC to deliver 400 MW of fusion-generated electricity to Virginia in the 2030s.

CFS has published an extensive set of papers on the SPARC design and its physics basis [21,22]. Among the physics problems with SPARC/ARC are excessive localized heat flux to the wall, the need for costly RF plasma heating, and huge tungsten radiation power loss at high density. Among many engineering problems are extreme wall and magnet stresses during large-scale plasma instabilities, minimal access for routine wall maintenance, lack of a tested design for tritium breeding, and stresses due to pulsed operation. Each of these problems can be a showstopper for their ARC reactor. ARC also shares many other tokamak reactor problems with the much larger ITER device, but has a totally unrealistic goal and timeline.

4.7 Type One Energy

Type One Energy, founded in 2019 in Madison, Wisconsin, is designing the Infinity One stellarator to be built near Oak Ridge, Tennessee, in collaboration with Oak Ridge National Laboratory (ORNL) and the Tennessee Valley Authority (TVA) [23]. They claim this will be the world's most advanced stellarator with optimized magnetic fields and high temperature superconducting magnets. Stellarators were invented in Princeton in 1951 and have gradually achieved fusion performance nearly comparable to tokamaks. Infinity One is viewed as test bed for Infinity Two, a 350 MW D-T fusion power reactor to be built at a former TVA fossil fuel plant, which "...could provide a baseload electrical generation for the region as early as the mid-2030s".

Type One Energy includes some recognized experts on stellarators and has chosen good technology partners in ORNL and TVA. Their designs were published in a series of seven papers in a special issue of the Journal of Plasma Physics [24]. Stellarators are more complicated than tokamaks but have some advantages such as improved large-scale plasma stability. However, the world's leading stellarator, the German government-funded W7-X device, was initiated in 1994, constructed during 2005-2014, and operated between 2015 and the present. This long maturation period of W7-X strongly suggests that even the first Infinity One test device could be not operated by the mid-2030s.

4.8 Pacific Fusion

Pacific Fusion was started in 2023 in Fremont, California to achieve "net facility gain" (producing more fusion energy than it consumes) by 2030 [25]. Their fusion concept is based on a magnetically driven imploding liner developed primarily at Sandia National Laboratory, who's pulsed power program since the 1960s has been funded by the US National Nuclear Security Administration. NNSA's mission is to "enhance national security through the military application of nuclear science".

Pacific Fusion has obtained $1B in private funding with only a very small staff and no existing hardware. They hired as founding CEO a high-profile biologist with no experience in fusion research. Their pretentious white paper "Opportunities in pulsed magnetic fusion energy" [26] states that: "Pulsed magnetic fusion must be a key component of the fusion landscape to realize the U.S. bold decadal vision for fusion energy." Their Founder's Letter explains: "The funding is all committed upfront (to mitigate financing risk), and it’s unlocked as we achieve predefined milestones (to ensure accountability). We’re enormously grateful to Hemant, the GC team, and our founding syndicate for their creative partnership in structuring the financing."

5. Conclusions

Unfortunately, the recent promises of fusion electricity within 10 years are a toxic mixture of fantasy, delusion, and deceit. There are just far too many intractable problems in physics and engineering to meet such a deadline. Even if a first demonstration reactor could be built late in this century it would almost certainly not be a practical source of electricity due its enormous cost and unreliability.

Why do smart people continue to promote and support the illusion of fusion power in 10 years ? First, many fusion advocates lack experience with real machines, which seldom behave as we would like. Second, initial experimental success can lead to overconfidence and failure at later stages. Third, plasma theory has proven to be an unreliable guide for improving fusion performance. Forth, peer pressure in large fusion groups discourages healthy dissent. Finally, smart people are willing to exploit the gullibility of others in the service of their goals.

Looking back at the slow pace of fusion progress since the 1990s and the immense difficulties on the path toward a fusion reactor, it should be clear that fusion research is at best a long-term scientific endeavor and will not a practical source of electricity within the next 50 years, if ever. We know that energy from fusion is possible, but sadly the dream of fusion power within 10 years is just an illusion.

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