

Clean Nuclear Fusion: Could This Be The Future?

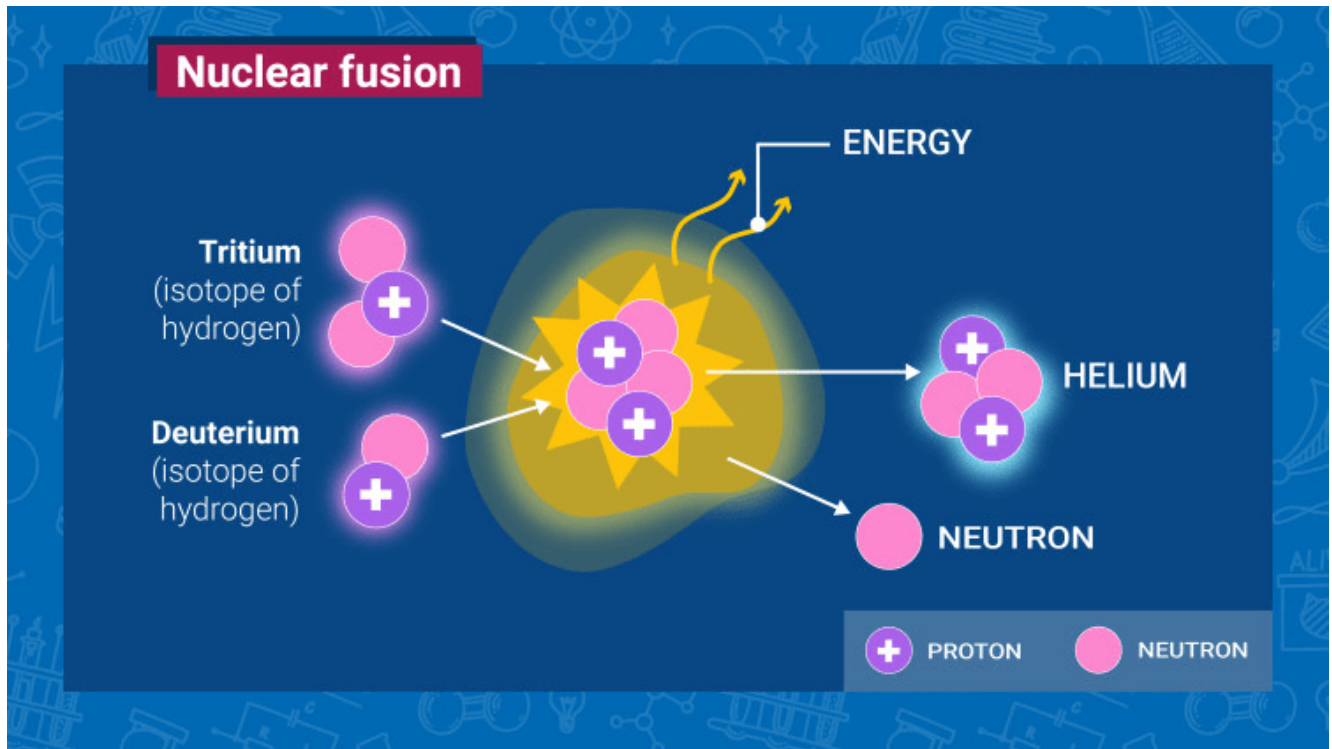
Category: Energy, Environment, Science, Sustainability

written by Ben Shaw | November 10, 2023

Global awareness of [climate change](#) has been continually increasing since the start of the 21st century. Conventional energy sources (e.g., fossil fuels) emit significant amounts of [GHGs](#), primarily Carbon Dioxide. Nuclear energy, specifically nuclear fusion, is a clean, [low-carbon energy source](#) that could offer a solution to our future energy needs. Although we have yet to truly crack the code on this amazing technology, the future of clean nuclear fusion seems promising, with [many countries involved](#) in the ongoing research efforts.

Understanding Nuclear Fusion

Nuclear fusion is the [process that powers the Sun](#) and other stars in the universe. Fusion occurs when two small atomic nuclei [merge](#) to create a single, more massive nucleus. For example, the Sun fuses hydrogen atoms together to form helium, releasing large amounts of energy in the process. Scientists are hoping to recreate the process that powers the Sun by creating nuclear fusion within a [fusion reactor](#). These reactors facilitate the transition of hydrogen atoms to a [plasma state](#). This is a superhot state of matter in which electrons become separated from their atomic nuclei.



The process of clean nuclear fusion generates power within a fusion reactor.
Source: ([IEAA, 2023](#))

To emulate the conditions necessary for fusion, a fusion reactor must operate at temperatures of over [100 million degrees Celsius](#). It also requires enormous amounts of pressure, approximately [10 times](#) that of the atmospheric pressure at Earth's surface. Maintaining these conditions for prolonged periods of time requires enormous amounts of energy. This has proved to be a [significant roadblock](#) in nuclear fusion research for some time.

Trapping the plasma within the reactor also requires sophisticated confinement techniques. In the current day, researchers are actively studying two leading methods of confinement: [inertial confinement and magnetic confinement](#). Inertial confinement systems utilise laser beams to rapidly heat and compress a small pellet of fuel until sufficient temperatures and pressures are achieved for fusion to occur. On the other hand, magnetic confinement utilises strong magnetic fields to trap and control the fusion fuel, while powerful electrical currents are used to heat the plasma. To be a viable energy source, a fusion reactor must also generate more energy from its fusion reactions than it requires to initiate and sustain the fusion process.

The Benefits Of A Clean Nuclear Fusion

Energy generation from nuclear fusion offers numerous benefits. People often hail

fusion as the '[Holy Grail of energy](#)'. Nuclear fusion has an abundant fuel supply. The best bet for current fusion reactors is [deuterium-tritium fuel](#). These are both isotopes of hydrogen, [the most abundant element](#) in the universe. Apart from the [indirect emissions](#) involved with power plants and reactor construction, nuclear fusion produces energy without releasing any [emissions](#). Nuclear fusion produces minimal waste. The main by-product of nuclear fusion reactors is helium, an inert, non-toxic gas. This is unlike [nuclear fission](#), which has the disadvantage of producing long-lived radioactive waste. Also, dissimilar to nuclear fission, nuclear fusion has no risk of [nuclear meltdown](#).



Energy generation from nuclear fusion offers numerous benefits.

Source: [Mariah Feria](#)

These advantages, along with others, show the potential of the future of clean nuclear fusion. This amazing technology can provide a future powered by reliable, clean, and renewable energy. So, how close are we to actually achieving this goal?

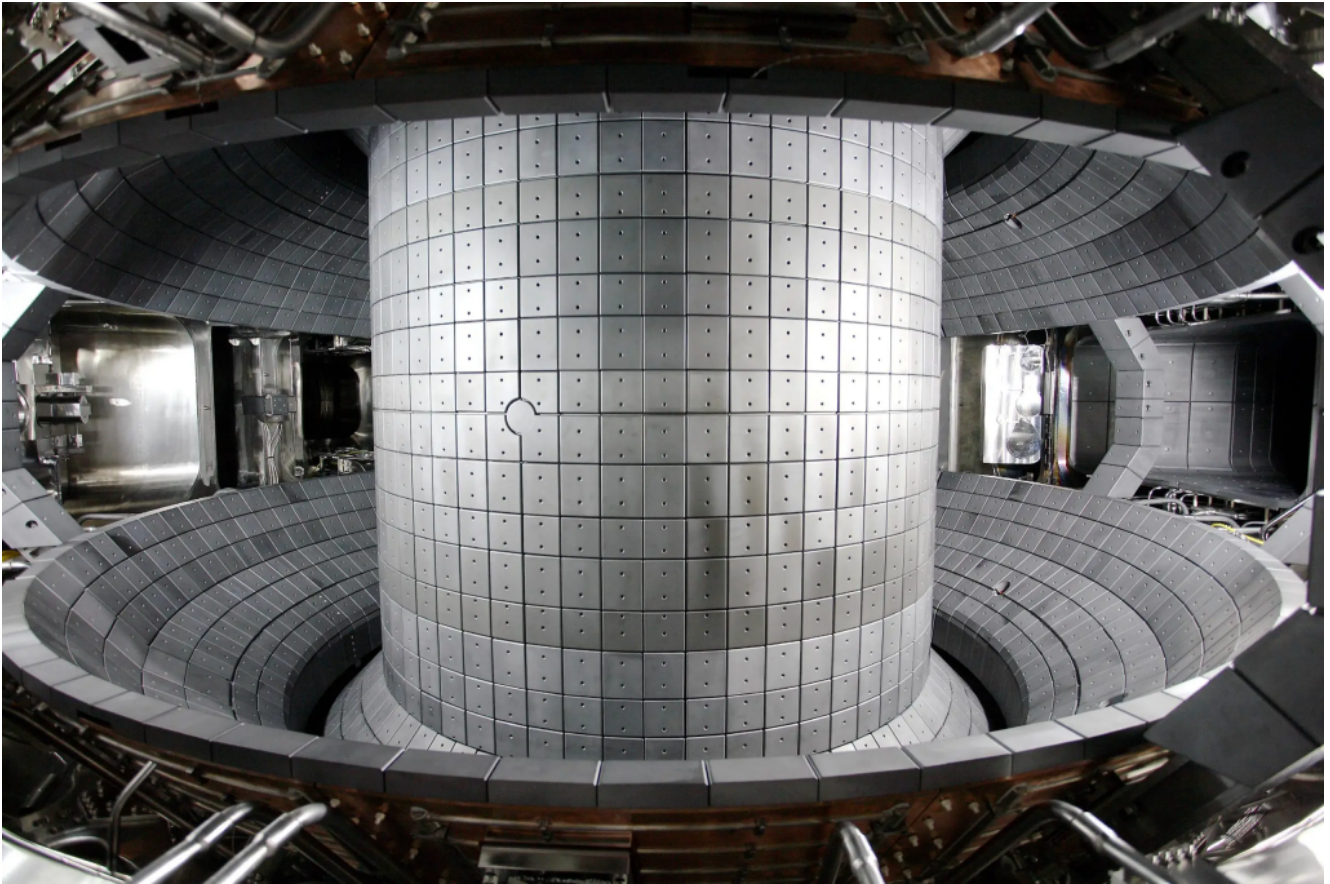
The current state of Nuclear Fusion

Nuclear fusion research has come a long way since the technology was first

revealed to the world [in 1958](#). This revelation sparked [global collaborative research](#) efforts that are still ongoing today. The [tokamak](#) fusion reactor design currently dominates as the [most commonly utilised](#) fusion reactor. The tokamak contains its hot plasma in a doughnut-shaped chamber using strong magnetic fields. Alongside the tokamak is the [stellarator](#). The stellarator has a more complex design, relying on a magnetic field generated by external coils. Stellarators employ external coils to create a twisting magnetic field for plasma control, as opposed to the method used in tokamaks, which involves inducing electric currents within the plasma.

The Tokamak Reactor

There are a number of tokamak reactors operating around the globe. The Korean Superconducting Tokamak Advanced Research ([KSTAR](#)) is a superconducting fusion device also known as the Korean artificial sun. In 2021, it set a new world record, maintaining a temperature of 100 million °C for 30 seconds. The team is aiming to increase this time to 50 seconds in October 2023. In China, the Experimental Advanced Superconducting Tokamak (EAST) is also setting its own records. It was able to operate at 160 million °C for 20 seconds in 2021. In that same year, China's artificial sun was able to maintain a temperature of 70 million °C for 1,056 seconds. In 2022, the Joint European Torus ([JET](#)) reactor smashed the 1997 record of energy output, producing [59 megajoules](#) of energy over five seconds.



Clean nuclear energy: the interior of the KSTAR Tokamak.

Source: [KSTAR](#).

The Stellarator

Stellarators offer [various advantages](#) compared to tokamaks. The stellarator requires lower injected power to maintain the plasma, enable the streamlining of certain aspects of plasma control, and provide more design adaptability. Nevertheless, these advantages are accompanied by [heightened complexity](#), particularly in the case of magnetic field coils, which is why the tokamak design is more commonly utilised. The most successful stellarator fusion reactor currently in operation is the Wendelstein 7-X ([W7-X](#)). The W7-X began operating in 2015 in Greifswald, Germany. As of February 2023, the W7-X team has achieved a record energy turnover of 1.3 gigajoules, maintaining the hot plasma for [eight minutes](#). Another notable competitor is the Helically Symmetric eXperiment ([HSX](#)) in Wisconsin, U.S.A. The HSX is currently capable of confining plasma at temperatures higher than 10 million °C.

Fusion Challenges

Controlled nuclear fusion research has been underway for about [half a century](#). So why is it that we aren't currently reaping the rewards of this wonder technology? There are a [number of challenges](#) that stand between us and clean nuclear fusion being a viable energy source. It is an inherently complex problem. After all, we are essentially attempting to create an artificial version of our Sun. Emulating the conditions of a star's interior on Earth requires massive amounts of energy.

This energy problem is the main roadblock that scientists are currently facing. They spend more power initiating and sustaining a reactor than they receive from the fusion process itself. To assess the ratio of power in to power out, scientists use the '[fusion energy gain factor](#)' (denoted as Q). A Q value of 1 or higher is the ultimate goal. This represents a reaction in which the thermal power output is equal to ($Q = 1$) or higher than ($Q > 1$), the thermal power input. In December 2022, the threshold of $Q = 1$ was broken for the [first time](#). This breakthrough occurred at the National Ignition Facility ([NIF](#)) in California, U.S.A. Scientists at NIF were able to achieve net energy gain [again in July](#) of this year, proving that the first result was more than just a fluke.

For clean nuclear fusion to be a viable energy source, fusion reactors must at least have a Q value of one. In reality, however, this value of Q will actually need to be much higher. If we hope to produce enough energy to sustain the operation of the plant and to convert the resulting heat into energy, we'd likely need a Q value [between 10 and 25](#).

What does the future hold?

Although we have yet to truly crack the code of nuclear fusion, the future seems bright. Come 2025, the massive international fusion project [ITER](#) is expected to start operations in France. The ITER tokamak is expected to produce plasma with a Q greater than 10, smashing previously held records. ITER is the result of collaboration between 35 nations and will cost about [US\\$20 billion](#). However, if successful, it could pave the way for future fusion reactor designs, bringing us closer to a world powered by fusion.

Nearly two dozen start-ups are actively developing a new range of devices, fuels, and approaches, including alternative [confinement techniques](#). In late 2021, the Massachusetts Institute of Technology (MIT), in partnership with the Commonwealth Fusion Systems start-up (CFS), produced one of the [most powerful magnets](#) to ever exist on Earth. This amazing magnet is capable of producing strong magnetic fields using far less power than previously thought possible. To achieve this, the magnet is layered with massive amounts of [high-temperature superconductor](#) tape. The tape can retain its superconducting properties even at high temperatures, which results in a more intense magnetic field. The potential of this superconducting magnet will be demonstrated in the [SPARC fusion reactor](#). Once operational, the SPARC reactor also expects to achieve fusion gain, Q , greater than 10.

The future of clean nuclear fusion might not be as far away as we think.

Source: [MIT](#), [Youtube](#)

Why is it essential that we focus on The Future of Clean nuclear fusion?

[One single kilogram of fusion fuel](#) can produce as much energy as 55 thousand barrels of oil or 10 million kilograms of coal. Additionally, the energy produced by fusion is [four times](#) greater than nuclear fission reactions. It is clear that nuclear fusion will be an amazing energy source for the future of humankind. In developed nations, fusion technology holds the potential to reduce carbon emissions in transportation, heating, and industrial operations. In developing nations, fusion power could provide much-needed energy to those facing critical [energy shortages](#).

A future in which humans thrive alongside the Earth and its life will need to be fueled by clean, renewable, and reliable energy. Renewable energies, such as [solar](#) and [wind](#), will undoubtedly have a role to play. Although it will still be [some time](#) until commercial fusion plants become operational, it is clear that nuclear fusion holds the potential to contribute greatly to this future. It is essential moving forward that we focus on fusion research and development to ensure that this future can become a reality.

achieving the United Nations Sustainable Development Goals (SDGs) and how they link to The Future of nuclear fusion

This month, the [THRIVE Project](#) focuses its sights on the United Nations sustainable development [goal number 7](#). This goal is to “ensure access to affordable, reliable, sustainable and modern energy for all”. Nuclear fusion can help us achieve this goal. The development of nuclear fusion technologies will also help us achieve other SDGs, including [goal 13](#) (climate action) and [goal 9](#) (industry, innovation, infrastructure).

A Thrivable Framework

[The THRIVE Project](#) stands to create a future in which humans can not only survive but also thrive. Our mission is dedicated to securing the enduring welfare and ‘[thrivability](#)’ of all species on Earth. The [THRIVE framework](#) examines issues and evaluates potential solutions through analysis of technologies such as nuclear fusion.

Clean nuclear fusion will assist with this vision of thrivability by assisting us with our transition away from finite energy sources. Fusion has the potential to provide a stable and abundant energy supply, which can also contribute to [reducing energy poverty](#) in areas where access to reliable electricity is limited or unavailable.

If you would like to learn more about how our research works at [The THRIVE Project](#) visit our [website](#). Additionally, you may follow our educational [podcast series](#) and [blog articles](#), and also [sign up for our newsletter](#) for regular updates.