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# Nuclear Fusion & Sustainability: How Far Are We?

Lam Sai Lok Adrian

Research Scholars Program, Harvard Student Agencies, In collaboration with Learn with Leaders

**ABSTRACT**

**This paper is a conceptual and qualitative finding of nuclear fusion as a whole, its limitations, ongoing problems and possible outlook in the future. It explores the question of stability in confinement of plasma, which maintains the reactions between deuterium and tritium, to achieve a net gain in energy and in turn evaluate the difficulties in achieving sustainable nuclear energy generation. The paper proposes scenarios and associated conditions which humans must fulfill to enable a smooth transition from fossil fuels to sustainable nuclear fusion energy. It was found that it is vital that scientific efforts be focused on improving the stability and confinement properties of plasma and nuclear fusion respectively, which will allow it to become a sustainable source of energy. The study provides a very surface, qualitative understanding of the broad field of nuclear physics.**

**Keywords: Plasma, nuclear fusion, deuterium, tritium, helium, confinement.**

**Subject: Nuclear Physics**

## INTRODUCTION

While the Sun's enormous gravitational energy forces fusion naturally, it is extremely hard to duplicate the same effect on Earth due to practical differences. Intense pressure, along with high temperatures, which can be up to hundreds of millions of degrees, are both crucially needed to accomplish such results. As such, the efficiency of nuclear fusion generation on Earth becomes an issue when fusion reactors are not consistently able to contain and maintain the fusing between deuterium and tritium long enough for a positive gain in energy generated. Improved confinement properties, ranging from different materials to techniques, along with stability of plasma reaction, must be guaranteed, for nuclear fusion to become a viable source of energy generation.

As global warming and environmental issues arise and intensify, it is a universal goal for humans to come up with a new source of energy generation to mitigate such problems. Nuclear fusion has been a hot topic in recent years, with strong held beliefs for parties both for and against the proposal. Regardless of the debates, the possible benefits of nuclear fusion have always been widely recognized, as it could provide virtually limitless, clean, safe, and affordable energy to meet the world's demand.

However, countries are struggling to achieve effective nuclear fusion due to problems such as instability during its generation and other safety concerns. This study intends to gain a perspective on the process of nuclear fusion, address some of its core challenges and hence evaluate the potential difficulties when solving these issues, which could prove to be vital to the forward development of sustainable energy generation. Future scientific efforts should be focused on improving the stability and confinement properties of nuclear fusion, which will allow it to become a sustainable source of energy.

### Nuclear Fusion Generation Process

Nuclear fusion is the process by which two light atomic nuclei combine to form a single heavier one while releasing massive amounts of energy.[1] In the modern day and age, deuterium and tritium are the main fuels, the fusing of which creates a helium nucleus. This releases an energetic nucleus that can be later converted to energy by nuclear fusion plants. This process is particularly hard as the nuclei of atoms must collide in the right orientation with each other at high temperatures to outweigh the repulsion and hence allow them to fuse. As energy is generated through the nuclear plants, high energy is emitted, estimated to be exponentially higher than that of conventional energy generating methods.

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[1] Matteo Barbarino, International Atomic Energy Agency "What is Nuclear Fusion"

As hard as the extraction of energy may sound, nuclear fusion is widely believed to possess the potential for humans to achieve limitless, safe, and harm-free energy supply around the globe. The main fuels for nuclear fusion power plants today are deuterium and tritium. Deuterium, being an isotope of hydrogen, is abundant in seawater and can be distilled using well-established separation processes. Its abundancy establishes that it can be a vital ingredient for long-term sustainability achieved via this process. Conversely, tritium is a radioactive isotope with very limited supply - with a global stockpile of only around 30 kg available for commercial use worldwide[2]. Tritium is expected to be produced in conjunction with lithium, which is comparatively a lot more abundant in nature. It is the 33rd most abundant element in nature and is distributed widely in trace amounts in rocks, soils, and surface, ground, and sea waters[3]. By extension, it is estimated that energy generated by nuclear fusion would be 4 million times compared to conventional burning of fossil fuels. This kind of abundancy in the extraction of foundational fuels provides a positive outlook into the future of the industry amidst the challenges that lie in the generation of nuclear power. Apart from its abundance, the prospect of clean energy also entices us into the potential of the industry. With helium being its main product, nuclear fusion does not emit carbon dioxide nor any other kinds of harmful gases. On this front, the activation of all components in a fusion reactor is anticipated to be also low enough for the materials to be recycled or reused within 100 years[4]. This provides great potential for reduced radioactive waste. Ideally, nuclear fusion can make a positive contribution due to its abundancy and the pollution-free nature of its generation process.

**Limitations of Current Nuclear Fusion Technology**

There are several major issues and concerns that must be addressed before nuclear fusion becomes a viable sustainable energy source. Firstly, as nuclear fusion takes place in plasma - which is a very distinct and unique state of matter with hot, positive, and free electrons - the particles must collide at a very high temperature. It must reach approximately ten million degrees Celsius in order to overcome the electrical repulsion and complete the reaction. The risks involved in ensuring a smooth and safe operation in such high temperatures are immensely high, with a stable plasma needed in the process. Although plasma physics research has been studied in a lot of countries and institutions, there still exists no concrete solution to stabilize the plasma long enough for the output energy generated to demonstrate a net gain. In addition, the confinement properties of the nuclear reactor must also be addressed before nuclear fusion can consistently be an energy source in order to sustain the immense pressure of gravity. Other than magnetic confinement, which was a widely explored confinement method, other alternatives, such as laser fusion, which comes with inertial confinement, are being explored. Laser fusion does come with its shortcomings, though, an intense heating of the capsule, around 30 times more energy than they absorb, must be achieved in order to create enough inertia that keeps the fuel confined long enough for fusion to take place, with a net gain.[5]

Therefore, it can be seen that current technology does not fully support all the requirements needed for a complete and consistent nuclear fusion reaction. Problems regarding the safety, stability of plasma, reactor confinements and more, must be solved and understood before humans have the capabilities to proceed with the sustainable generation of nuclear fusion energy.

## CONCLUSION

This paper analyses the probable issues that prevents human from moving forward in the generation of consistent nuclear fusion energy. The potential solutions are promising and encouraging, given the current development and advancement in technology, figuring out successful methods to utilize nuclear fusion as a means of generating clean, safe and sustainable energy are imminent. It is very probable for nuclear fusion to become a viable source of energy generation in the near future and help combat the world's energy crisis.

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