NUCLEAR FUSION—A HOPE FOR THE FUTURE

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INTRODUCTION: FUSION ENERGY AS AN ALTERNATIVE FUEL SOURCE

Humankind's continual growth, both in population and technology, has led to an exponential increase in energy consumption. Within the next few decades, we will be heavily strained in regards to our energy supply, and current alternative fuel sources have not yet proven to be a clear substitute for fossil fuels. However, one technology, if we can fully perfect it, may lead to a nearly infinite and clean energy source. Nuclear fusion, a topic that has been researched for over 50 years now, may finally hold the key to our energy demands.

Nuclear engineering has always interested me, along with energy production. As a kid, I would spend hours watching videos and reading extensive articles on nuclear reactors. It is no wonder, then, that the engineering behind nuclear fusion immediately caught my attention, both for its practicability and importance to society. Fusion is a clean and sustainable source of energy, which society is desperately going to need in the coming years. Billions of dollars have been invested in it over the past 50 years, and we are at the doorstep of the next breakthrough. Tokamak reactors, the most technologically advanced reactors for fusion energy, are currently being perfected to produce electricity from fusion reactions. Specifically, a long-awaited program, nicknamed Iter (International Thermonuclear Experimental Reactor), is wrapping up construction soon. This tokamak reactor is the largest of its kind and will prove whether nuclear fusion is truly feasible as a potential energy source.

I, along with countless scientists and engineers, have high hopes for fusion energy, provided several problems are worked out. Fusion has little to no disadvantages, excluding research and development costs, and can assume most of the worlds' energy needs. Therefore, I believe this type of energy production is an attainable solution to the energy crises rapidly approaching.

THE NEED FOR NUCLEAR FUSION-CLEAN, SUSTAINABLE ENERGY

Our Dwindling Energy Supply

In the past decade, awareness of our faulty reliance on fossil fuels has grown tremendously. Sustainable energy is being pushed to the forefront of scientific research, more so than in any other generation thus far. However, as Jef Ongena and Yuichi Ogawa stated in the scientific journal *Energy Policy*, "currently more than 85% of the primary energy production in the world is originating from fossil fuels" [1]. For such an unsustainable resource, this type of fuel is in dire need of a replacement. Yet, this replacement still needs to be found. Wind energy and solar energy are promising, but have clear disadvantages based on the weather. Nuclear fission provides energy year-round, regardless of external conditions, but catastrophic disasters and hazardous waste degrade its value.

Furthermore, not only do fossil fuels have severe environmental consequences, the world's supply of them is also rapidly shrinking. The world energy supply is projected to be incapable of keeping up with demand within the next 40 years, according to a report by Sing Lee and Sor Heoh Saw [2]. Engineers agree that the world needs a new source of fuel, or else we risk an energy crises by the end of the century. Therefore, I believe it is the perfect time in which nuclear fusion energy should be introduced to the energy market. A world run on fusion energy can be sustained for millions of years, without negatively affecting the environment.

What is Nuclear Fusion?

The concept behind nuclear fusion is quite simple. Two isotopes of Hydrogen – Deuterium and Tritium – fuse together to form a helium atom, which releases an abundant amount of energy. This energy is then harnessed in the form of heat by a blanket and changed into electrical energy to be used in almost all devices requiring power. However, the steps leading up to this fusion are the problem. As the world nuclear organization

describes, "Fusion fuel … must be heated to extreme temperatures of the order of 50 million degrees Celsius, and must be kept stable under intense pressure… and confined for long enough to allow the nuclei to fuse" [3]. These extreme conditions mimic those of the sun, which also runs on fusion energy. The main challenge with fusion energy is the containment of this plasma created by the heated matter, and keeping it at a high pressure, which has led to numerous trials and errors of reactor designs. Currently there are two types of reactors designs being tested. The more promising one, the Tokamak, is expected to become the main design build for all fusion reactors in the future.

The Tokamak Reactor Design- Advantages and Disadvantages

The Tokamak Reactor was invented in 1960s by the Soviet Union and has been improved greatly over the years. Currently, per the Culham Centre for Fusion Energy, it is "the most developed magnetic confinement system and is the basis for the design of future fusion reactors using this method" [4]. A tokamak consists of a vacuum vessel, in which hydrogen gas is introduced. The gas is then converted to plasma both by a neutral beam injector, which injects particle beams, and a strong current. The plasma is shaped and contained by a magnetic field, which acts as like a cage. Once fusion has begun, a blanket made of lithium catches emitted neutrons and makes more tritium. A water-cooling loop carries the heat to an exchanger which creates steam to drive turbines, producing electricity.

A reactor based on the tokamak design is extremely effective, mainly since it uses magnetic confinement. As John Greenwald of the Princeton Plasma Physics Laboratory says, "The spherical design produces high-pressure plasmas - essential ingredients for fusion reactions – with relatively low and cost-effective magnetic fields" [5]. Magnetic fields work excellently with charged plasma, since it follows the magnetic field lines, which can be adjusted at will. The helical path lines will cause the plasma to flow circularly around the toroidal device without striking the walls and losing energy.

Despite their favorability, tokamaks are far from perfect. The world nuclear association points out that engineers have discovered these reactors to be subject to large losses of confined energy, which causes severe mechanical and thermal stress to the structure [3]. This type of accident can result in the failure of the entire reactor, but no damage to outlying areas, much unlike fission reactors. Consequently, extremely strong materials are being researched, to try and find one which can handle the extremes within the reactor. If these stronger materials can be synthesized, I believe the tokamak reactor design is best suited for fusion energy production, due to its cost-effective nature.

The Benefits of Fusion Power

Even though fusion energy is still in development, experts agree that there are many advantages to nuclear fusion. For example, fusion is an extremely clean fuel source. As Ongena and Ogawa explain, "the primary fuels and the direct end product are not radioactive, do not pollute the atmosphere, and do not contribute to the greenhouse effect or the destruction of the ozone layer" [1]. Nuclear fusion differs greatly from fission in this aspect. Fission produces harmful radioactive waste that needs special disposal. Fusion has no such issue. This lack of pollution is incredibly important, both to me and society. I am an avid climate change activist and believer, and have tried to find ways to reduce my own carbon footprint. In fifth grade, I even did a project solely on household ways to cut energy consumption. My own desire to keep the earth habitable matches society's need. Mankind cannot hope to continue to emit so much carbon into the atmosphere without serious repercussions.

Not only is nuclear fusion eco-friendly, it is also remarkably sustainable. Per the Iter website, deuterium, one of the fuels, is readily available in all forms of water. Specifically, about 33 milligrams are available in every liter of seawater. Tritium, on the other hand, is very rare, yet can be made through a reaction with lithium. Lithium can be extracted from seawater also, and can be sustained for around 6 million years [6]. Sustainability is essential in a fuel source on which the world is to rely. I to believe we should all attempt to make the lives of future generations easier in whatever ways we can. Supplying them with a near infinite fuel source is an excellent way to do just that. Furthermore, Sing Lee and Sor Heoh Saw, in the *Journal of Fusion Energy*, claim that "without nuclear fusion energy the scenario depicts a severe downturn unavoidably in the fortunes of Mankind with world population shrinking below 5 billion and eventually even lower" [2]. All of society would better with a switch to nuclear fusion, and that is exactly my goal in becoming an engineer. I believe it is an engineer's job to better the world, and nuclear fusion is an excellent avenue with which the world can be improved.

Fusion Power- Is It Feasible?

For over 50 years now, fusion technology has been researched. The technology and physics associated with this process have almost been fully worked out, with only a few minor challenges remaining. The most pressing issue, however, that questions the validity of fusion power is economics. As Oxford Professor Chris Llewellyn Smith said to *The Guardian*, "with enough

money we could probably build a fusion reactor now but it would not be economical. The challenge is to make it reliable and competitive" [7]. This type of issue is exactly why this technology pertains to engineers. Engineers not only have to make things work well, but they also must make them economically efficient. Researchers have been testing economics models of fusion reactors for years now. However, recently researchers at Durham University, namely Professor Damian Hampshire, have concluded that "while there are still some technological challenges to overcome, we have produced a strong argument, supported by the best available data, that fusion power stations could soon be economically viable" [8]. This analysis offers a great deal of hope to me that nuclear fusion may one day be used supply the world's energy needs. Clearly, as they have proven, it is economically efficient. Thus, businesses may step in and try to make a profit. Competition in this market will increase fusion technology even more. Through this, I believe fusion energy may be the smartest option for a sustainable energy source.

ITER- "THE WAY" FORWARD FOR NUCLEAR FUSION

Albeit a great deal of research has gone into fusion energy, large-scale power plants are still based solely in theory. Iter hopes to change that. This program, consisting of 35 nations, is testing the viability of a commercial sized fusion plant. It will be the world's largest tokamak reactor when construction is finished, and allow scientists and engineers to accurately gauge how much energy they can produce from fusion. Iter's website details its main goal: "to be the first fusion device to produce net energy … [and] … to maintain fusion for long periods of time" [6]. Net energy just means that the process will produce more energy than it requires to run. The experiments run here will determine the fate of nuclear fusion in the future. As Professor Steve Cowley, director of the Culham Center for Fusion Energy, says, "when Iter gets to self-sustainment that will be one of those moments in science that happen very rarely. I think we will then be able to say it's completely scientifically possible to make a commercial fusion reactor" [9]. Hopefully, successful tests from Iter will reinforce my belief that fusion energy is essential for meeting the energy demands of the future.

FINAL THOUGHTS- FUSION IS OUR BEST OPTION

In a world run on energy, a diminishing fuel source can cause severe consequences, if it is not addressed. Economies will collapse, wars will begin, and society will take a turn for the worst, all because we relied too heavily on fossil fuels. Nuclear energy offers an outstanding chance to prevent such a future from ever occurring. By using non-hazardous materials and non-polluting products, fusion is the better alternative to fossil fuels, environmentally. Also, with such sustainability (~6 million years), fusion energy can power the lives of many generations in the years ahead. Without it, their lives will be incredibly hard, with energy demands quickly outpacing its supply. Any engineer worth their merit should see the value in this energy source. I personally believe this energy source is vital to our future, and has already proven itself to work remarkably well, in theory. Iter will provide the final proof as to whether nuclear fusion is truly able to support our energy needs. I hope to one day be a part of a revolutionary fusion plant, working with like-minded engineers, creating the energy to safely power the world for millions of years to come.

SOURCES

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