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Harvesting the Stars

Today much of what keeps the evolution of humanity back is our lack of sufficient cheap energy. Growing up in Ethiopia I saw this firsthand. Most nights the electricity in the capital city would go out and left in the dark. I could often see the stars. They glowed when our city didn't, yet I was fortunate to afford the time and luxury of admiring a power outage. Millions living in poverty sheltered in their fragile tin homes, with every power outage the city grew weaker. It slowed the progression of critical infrastructure, million would light fires for heating, which is dangerous in such a dense city. Millions more were left to starve, and the economy was left to slow. Every opportunity that could be afforded with power, online education, modern appliances, lights, and safety, was smothered out, as millions spent all the time they once had to just survive. Therefore, it is critical to find the power of the stars, fusion, and implement it efficiently, cheaply and safely. While it is expensive and the technology isn't reliable yet., Fusion is the only source of energy good enough to support our evolution because it is environmentally friendly., Its efficient and generates a lot of energy., and it has an abundance of fuel.[rb1] Germany which at a time was one of the leaders in nuclear energy recently closed their last nuclear reactor. Frank Jordans writes about this in an AP article titled "Germany bids farewell to its last nuclear plants, eyes hydrogen future." This is a testament of all the negative sentiment towards anything nuclear powered, with the mass destruction caused in nuclear reactions like Hiroshima and Nagasaki, as well as other nuclear disasters such as Chernobyl and Fukushima.

However, all such incidents have been Nuclear Fission, not to be confused with Nuclear Fusion. Fission is the process in which one atom separates into two smaller ones releasing lots of energy. In Fusion reactions atoms are combined to form a bigger one, in which lots of energy is also released. However, unlike fission, fusion is easily controlled. In fusion reactions it requires a lot of energy and work to catalyze a reaction, however with a fission reaction it takes a lot of work and energy to stop a reaction. Therefore, if something were to go wrong in Fusion the reaction simply wouldn't happen but in Fission if something were to fail it would mean mass destruction. Steven Cowley outlines this in his Ted Talk "Fusion Is Energy's Future." Yet the lack of education and the amount of political opposition from corrupt and ignorant politicians means humanity and the quest for better, more sustainable energy is coming to a halt.

Although Nuclear Fusion is necessary and desirable, it's worth comes with a price. Fusion energy is expensive and hard to control. In addition, it still requires a lot of theory and practice that is unknown and undiscovered. Furthermore, using various methods, it has been hard for any net energy output. The reason for this is because it's difficult to overcome the nuclear force when putting two atoms close together this is because protons are positive, and electrons are negative and its very difficult to overcome their repulsion when two atoms' protons come close to another. The suns crippling gravity helps overcome this, yet we are lucky that this problem exists, if not there's nothing to stop a nuclear explosion every time someone sets a pen down. This is discussed in McCracken and Stotts's "Fusion: The Energy of The Universe". Therefore, it requires a lot of energy to overcome this and induce fusion. This makes fusion reactors big, fragile, costly, and very difficult to implement, possibly limiting its applications.

First discovering fusion energy in the 10th grade, I was introduced to lots of sci-fi where it is seen thrown around and seems established. Mainly from one of my all-time favorite series "The

Expanse” by James S. A Corey, which brushes over the implementation of fusion in just about every way. It seemed to me however that Fusion was abstract and that the likelihood of dying before its ever used for commercial use seemed likely. Yet as I studied history with the likes of Rockefeller, Andrew Carnegie, Elon Musk, Albert Einstein, Oppenheimer, and Thomas Edison, it seemed to me that a lot of the time we doubt to much and that we already know the answer to many of the problems we have we just must find it and find a way to make money with it. In my research I will add to the discussion the possibility of merging technology we already have with technology that is currently limited in the fusion energy field to achieve cheap, realistic, and easily applicable fusion reactors.

In recent years Fusion is seen as the god of energy in the field yet outside of the energy field it seems a distant and dangerous theory. As discussed before this is far from the truth. In addition the applications of fusion energy far outweigh the potential side effects. For example, according to the MIT climate portal “Fusion energy, like fossil fuels, is a form of stored energy. But fusion can create 20 to 100 million times more energy than the chemical reaction of a fossil fuel.” Not only is it more efficient than fossil fuels it is much cleaner and better for the environment. In a fusion reaction only helium and some nuclear activated neutrons are created; the nuclear waste is small and can be safely stored underground whereas the helium released into the air is negligible since it is not an air pollutant and not harmful, according to Steven Cowley’s Ted Talk. Lastly, the nuclear future has some key applications further than just replacing old technology. Fusion Energy with a method called antiproton fusion in which muons are created in proton-antiproton annihilation onboard a spaceship in order to provide energy for propulsion. The specific impulse of this type of propulsion is almost 1000 times greater than any current technology. (SpaceX.com, Kammash) Therefore nuclear fusion being safe, clean, hyper efficient , and widely applicable is desirable to implement in universal settings, and should garner more public attention and funding.

There are three main ways in which Fusion can be achieved or used. The first method is described in Isaac Asimov's “Reason” , a book that was published in the 1950s. It talks about robot space stations that beam energy from the sun back down onto earth with highly concentrated rays of light and plasma. This somewhat idealistic way of getting Fusion energy is often looked over as confining plasma is costly and certainly impossible with such great distances. Therefore making it impossible to use this method, in this science fiction sense. Another possible way to collect the sun's fusion energy would be to collect the radiation, and then beam it down through the atmosphere. Currently any high energy radiation or particles that hit the atmosphere are quickly dissipated into many lower energy particles. Yet collecting them before they get through the atmosphere and then concentrating them enough and perhaps changing their form we could get the energy back down on earth. Currently there are lots of companies that work on small scale radiation wave energy where instead of plug ins and wires they transmit energy through electromagnetic waves.(source) Recently a satellite was able to beam solar energy down successfully to Earth. The CalTech based researchers said “the wireless transmission of energy through space is based on a quantum phenomenon called “interference.”” If you have multiple sources that are operating in concert, in the same phase, you can actually direct energy in one direction so all of them will only add in one direction and will cancel each other out in all other directions," Hajimiri said. This is how they were able to achieve “beams” of energy. However the energy that comes down to earth is relatively low and inefficient. Therefore importing fusion from the sun is not yet feasible, requiring megastructures bigger than our earth. It will be millenia until we can collect the sun's plasma for energy. However, beaming down other energy like radiation from the sun is possible, it is also very inefficient.

Right now the most common and successful way of achieving Fusion is Magnetic or inertial confinement, where a plasma hotter than the sun is confined and forced to fuse two atoms of deuterium together. Although this way of achieving fusion works, it is also not very cost efficient. In addition the amount of energy put in is greater than the energy produced. In "Fusion the Energy of the Universe" the author says that in a desirable fusion reaction a chain reaction takes place, so that the energy from the previous reaction can fuel the next one. Yet this is only possible in a reaction where there is net positive energy gain. In 2023 a research team in Great Britain was able to produce 5 MW net power. This marked the beginning of the age of fusion and it suddenly seemed all the more in reach. However with this great achievement, they weren't able to create a chain reaction and, with a low success rate of getting a fusion reaction in the first place, it meant that the net energy gain from fusion could still be considered negative. For example if one reaction uses 2.5MW of power and produces 7.5MW in a successful fusion reaction, but only one of four reactions is successful then technically that powerplant would still be losing energy and be of no use. This is why current fusion technology using these methods isn't very hopeful for the next 10 to 15 years, because they still need to fine tune and develop new technologies to aid in making the reaction more consistent. In this method huge electromagnets create a strong magnetic field that holds the plasma in place, and the room for improvement on this technology is strictly held by the laws of thermodynamics and therefore improvement on this method itself seems difficult.

The last method of fusion this paper will discuss is muon fusion. In this method muons which are like electrons but much bigger, replace electrons inside of an atom. Their much greater mass makes them go closer to the nucleus of hydrogen isotopes, greatly reducing strong nuclear forces which repel atoms away from each other. Yet when an atom has a muon instead of an electron atoms can get way closer together and require much lower temperatures in order to fuse. This means that instead of making Inertial and Magnetic Plasma Confinement Fusion Reactors more efficient we can actually just get rid of a lot of the giant electromagnets used to confine the plasmas since the temperature is so much lower. Yet Muons themselves take a lot of energy to create. There are multiple ways in which they are created. One way is crashing particles into each other at highspeeds, the energy and joining of electrons with more energy create muons. Pions which are like muons but even bigger are also created in a similar way, creating pions through proton annihilation that decay into muons almost instantaneously. Yet creating Pions also takes a lot of energy and much is lost when it decays. Finally this paper focuses on the final way in which Muons are commonly created: through muon neutrinos. When fusion happens in the sun millions and trillions of neutrinos are released from the sun. neutrinos behave a lot like light flying and super high speeds and with almost no interaction with other matter. Yet if they do interact with an atom they can create muons. Now the chances of a neutrino interacting with an atom are extremely low. Yet with concentrated rays of neutrinos it is possible to create some muons. Even more interestingly neutrinos are everywhere, millions pass through the earth every minute and with concentrating them and manipulating them it is possible to direct the stream to atoms in order to create muons. Then when these muons are created, quickly before they decay, we can induce cheap fusion.

Using current technology to capture and manipulate muons we will be able to get cheap efficient fusion anywhere. This means we won't have to use big delicate magnetic and inertial confinement chambers that are expensive and require a stable power grid yet instead this reactor can be deployed anywhere at much less of a cost and with much greater applications.