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Nuclear Fusion Energy

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Problems with Energy Production Today

In our current world we have many ways of producing energy to run our modern world. With current technology we are able to harness energy from resources such as: coal, natural gas, wind, solar, geothermal, hydro, and nuclear fission. Our current forms of energy production, however, all have large issues facing them. These issues range from the amount of energy that can be created, safety involved in their use, and their ability to create power.

Limited Resources

Within our current setup for providing energy in America nearly all energy comes from sources with fixed resources. The U.S. Energy Information Administration states that only 34.6% comes from renewable resources (including nuclear fission). Nearly all other energy in America comes from fossil fuels [1]. This means that nearly all energy that is produced uses resources that will eventually run out. According to Our World in Data, at the current rate of use the world will run out of natural gas in 52.8 years and coal in 114 years [2]. While we won't run out of fuels for a few more decades it is likely that due to scarcity they will become too expensive to be a viable source of energy prior to that point. Our planet must find new ways to sustain its hunger for electricity in the coming years.

Harms of current methods of Energy production

Most of our current energy production could be viewed as creating electricity in exchange for harm to our planet and possibly to those that the electricity is provided to. Nearly all forms of renewable energy are virtually harmless, yet only 14.9% of American energy production comes from renewable sources [1]. The rest of energy produced comes from nuclear fission and fossil fuels which give off dangerous byproducts and have created issues like global warming.

Most people know at this point that the burning of fossil fuels, such as coal and natural gas, releases carbon dioxide into the air. This release of carbon dioxide into the atmosphere creates the effect of global warming which negatively impacts the environment of earth. Along with carbon dioxide burned fossil fuels also creates sulfur dioxide (causes acid rain and provokes respiratory / heart disease) and nitrous oxides, which creates ground level ozone (irritates/ damages lungs) [3]. Burning fossil fuels is extremely damaging to the environment, but they can be just as damaging before being burned.

Fossil fuels also create environmental problems prior to ever being burned. Fracking, a common method of extracting oil and natural gas from the ground, has been shown to damage the environment in multiple ways. For one, the method has been shown to contaminate ground water in surrounding areas [4]. Fracking has also been shown to cause magnitude two earthquakes and is correlated with magnitude four earthquakes toward middle America [4]. Even after the extraction fossil fuels, they can still damage the environment through spills in tanker boats or oil pipelines. Through all steps in the use of fossil fuels the environment is damaged and puts people in harm's way.

Nuclear fission release zero harmful emissions into the atmosphere while being used, but it isn't without its own dangers. The reactions within a reactor create two types of byproduct, low level radioactive waste, and spent nuclear fuel [3]. "Low-level radioactive waste is stored at nuclear power plants until the radioactivity in the waste decays to a level where reactor operators can dispose of it as ordinary trash or to a level where they can send it to a low-level radioactive waste disposal site" [3]. Spent fuel must be stored in pools or specially designed storage containers to keep in the radioactivity, but there is still a risk of leakage [3]. While highly uncommon Nuclear reactors have the potential to melt down such a in the scenarios seen at Chernobyl, Three Mile Island, and Fukushima. While nuclear fission is one of the safest forms of electricity production, with 90 deaths per trillion kilowatts produced (almost 100,000 less than coal), it still has its dangers [5].

Sustainable Power Unable to Meet Demands

Renewable energies such as solar may seem like a near perfect solution to energy problems. The solar farms have little to no impact on the environment other than space taken up and "Each hour 430 quintillion Joules of energy from the sun hits the Earth" all of which has the potential to be used as electricity due to solar panels [6]. Solar power has its own problems that could keep it from being able to replace what fossil fuels produce now. Solar power is dependent on the weather which is inherently not dependable. Along with not being dependable only certain regions of world are viable for solar power, and batteries aren't able to store enough energy to transfer to areas were solar isn't viable. There is very little current technology that can be used to replace what our current systems of energy production.

Nuclear Fusion Energy

The National Academy of Engineers (NAE) has compiled a list of the 14 largest problems facing our world today and has named them "the Grand Challenges of Engineering" [7]. One of these challenges that I feel will have the greatest impact on our society and can solve the problems I have already spoken about. This grand challenge that I am the most interested in is to "provide energy through fusion" [7].

Fusion only naturally occurs in the centers of stars. The cores of stars are the only place in the universe in which there are conditions of enough heat and pressure to sustain a fusion reaction. These conditions allow for the nuclei of atoms to merge together creating heavier atom and releasing a neutron. An example of the process would be for two hydrogen atoms to fuse into a helium atom. During the reaction when a new element is formed a small amount of mass is lost. That is not to say that the mass goes off in the form of another particle, but that the mass is directly converted into energy. This change from mass into energy is quantifiable through one of the most well-known equations in physics in Einstein's $E=MC^2$ [8]. Fusion reaction release an absolutely staggering amount of energy with one liter of water having the capability of giving off the same amount of energy as 500 liters of gasoline, according to the Culham Center for Fusion Energy [9].

Replicating the conditions of the core of a star is a difficult task, but we can get around mimicking exact conditions. It would be impossible to recreate the pressures experienced in the center of a star, but we can compensate for the lack of pressure by increasing the temperature to levels far greater than our own sun [9]. Another way to change the conditions to make it easier to induce fusion is control over the atoms being inserted to reactor [9]. These requirements are still difficult to achieve, but they offer a method for us to have any ability at creating a fusion reaction.

In order to compensate for the lack of pressure on earth compared to the interior of a star the particles must be heated to over one hundred million degrees Celsius [9]. To achieve this the reaction takes place in what is known as a Tokamak, the Tokamak has a torus shaped compartment within it that contains the hydrogen particles for fusing. The cavity of the machine is surrounded by a series of magnets that are used to heat the hydrogen, insulate it, and control the movement of the plasma. From the point plasma is formed a fusion reaction should start. Once the fusion reaction starts it will continue, self-sustained, until it runs out of hydrogen to fuse. When the reaction is taking place high energy neutrons are given off which, not being electrically charged, escape the plasma and collide with the walls of the Tokamak. This will create heat energy in the walls which will be used to heat water into steam, that turns a turbine thus making electricity [10].

Fusion can be made to more readily occur if certain types of hydrogen are used. Fusion more readily occurs when it takes place between the hydrogen isotopes deuterium (one neutron) and tritium (two neutrons) [7]. "Deuterium represents approximately 0.015% of hydrogen in water. Even so, there is enough deuterium to generate present levels of energy consumption for billions of years" [9]. Tritium is more difficult to obtain, but it is needed in very small amounts compared to deuterium. Tritium doesn't occur naturally, so it must be synthesized from lithium using a nuclear fission reaction [7]. Even so there is enough lithium in the ground and oceans to fuel fusion reactors for "millions of years" [7].

Why Fusion is Important

As of the writing of this paper there has yet to be a fusion reactor that has created more energy than it took to begin a fusion reaction. New steps are being made towards this goal every day though, currently in France the larges fusion reactor ever is being constructed for experimental purposes to test the viability of the power source. The name of this internationally funded research reactor is ITER and it is set to run its first tests creating plasma in 2025[11]. This reactor has multiple goals for testing, but the most important of which is testing its ability to create more energy than it takes to start the process. Currently it is predicted that the reactor will make 500 megawatts of power from the 50 megawatts it takes to start the process.

The research and creation of these fusion reactor has cost billions of dollars and thousands of man hours over the past few decades without the creation of positive energy. This fact leaves some opposed to the furthering of spending on something that we don't know will actually work or be commercially viable [12]. I am of the opinion, however, that we must keep trying to make this

a viable source of energy production. When the possible result is a nearly limitless supply of energy that is safer than any type of energy production we have today we must keep striving to make new discoveries. This kind of technology has the potential to raise the quality of life of the entire planet bringing electricity to those who have never had it, while simultaneously putting an end to the mass dumping of carbon dioxide into the atmosphere.

It's not just what we can do with the technology either its knowing that we have the ability to create such things. We as humans may soon be able to recreate something that has only ever previously occurred in the centers of stars, some of the most awe-inspiring structures of our universe. I believe that solving this grand challenge of engineering can make the lives of everyone on this planet better directly through the electricity it provides, but also by giving human race a sense of accomplishment that we as a species can harness the power wielded by the stars. That is why this technology is important to me I feel that it can help bring this world together under a grand accomplishment.

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