FUSION: THE PATH TO LIMITLESS ENERGY

BY MATT LUNDY

Fusion power may not be literally limitless, but for all intents and purposes, it is. Nuclear fusion is the process of combining, or fusing, multiple atomic nuclei. This produces absurd amounts of energy; for scale, all of the energy output from our Sun comes from nuclear fusion. Yet, despite our best efforts, we have never achieved a fusion reaction powerful enough to serve widespread use. Because of the slow progress of commercially viable fusion, many have written it off as a pipe dream, but the immense potential behind this energy source has compelled decades of scientific work and continues to attract significant research efforts.

To understand just how powerful nuclear fusion is, consider the Sun. Our Sun is powered by fusion, and uses its most abundant element, hydrogen, as fuel for the process. The Earth's largest sources of readily available hydrogen are our oceans; as hydrogen constitutes two-thirds of water's molecular makeup, fuel derived from Earth's greatest bodies of water would be plentiful. If we could properly utilize fusion on Earth, the current hydrogen in the oceans would be able to power global human energy consumption at its current levels, for two billion years.[1] If we could access such a vast store of power, energy would practically cease to be a finite resource.

These huge amounts of energy are possible because the process of fusion converts mass to energy, and even a little bit of mass is equivalent to a massive amount of energy. When two atomic nuclei combine, the resulting atom has slightly less mass than the sum of the two individual atoms. This difference in mass is released as energy according to Einstein's famous equation, $E=mc^2$, which tells us that energy equals the product of mass and the speed of light (3 × 108 m/s) squared. This means that just one gram of matter—the mass of a paper clip—completely converted into energy could power a 100 watt light bulb for around 30,000 years, which is about five times longer than recorded human history.

Fusion has many benefits beyond its power. In contrast to fission—the reverse nuclear process that powers our modern-day reactors and bombs—fusion is a cleaner and safer alternative. Fusion solves the two major flaws of fission: radioactive waste and the possibility of meltdown. Any waste created by current methods of fusion has a half-life of only around a hundred years at most.[1] After a relatively short period of quarantine, the waste is completely safe. Additionally, a fusion meltdown is impossible. A fission meltdown, in which the reactor core or shielding overheats and melts, is possible because a fission reactor houses years' worth of energy-producing mass at any one time. It does this because it has to maintain a chain reaction of splitting atoms. On the other hand, a fusion reactor has to be constantly fed mass, meaning that the mass inside the reactor at any given time is tiny, equivalent to that of a few postage stamps. Thus, there is never enough mass for a meltdown to occur.[1]

If fusion surpasses fission, then fusion also beats out fossil fuels like coal and gas. It produces no CO2 or other harmful greenhouse gases. Fusion avoids the other most common fear of fossil fuels too: that one day they will run out. Even if we were one day able to drain every drop of our oceans for energy, hydrogen is the most common element in the universe. Fuel is not a worry for fusion.

For all its immense benefits, however, fusion is simply not currently usable as a power source. As of now, every other energy source discussed is more practical than fusion because those other sources have tangible results. A fusion reactor that can efficiently power any large-scale structure has yet to be built. Performing fusion on Earth essentially means creating a small sun in a lab. This requires immense temperature and pressure to force nuclei together, overcoming the Coulombic force repelling particles of like charge (i.e. the protons in the nuclei.)[11] This process takes a lot of energy. The goal of fusion research is to create a reactor that maintains the initial driving energy at levels high enough to sustain continuous fusion. This point is adequately named ignition, analogous to how ignition of a car engine starts a continuous process.

While ignition has not yet been achieved, prom-

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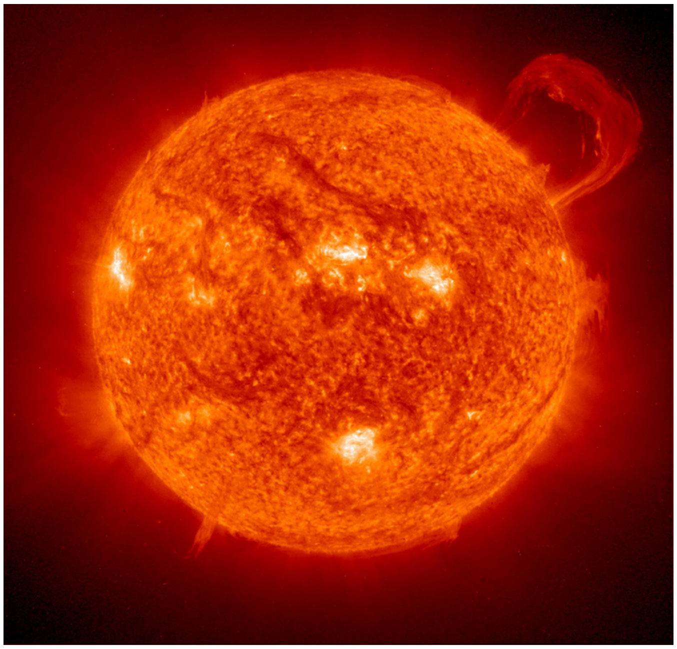

Figure 1: Our Sun is a superb example of the power of nuclear fusion, which serves as the Sun’s main energy source.[12]

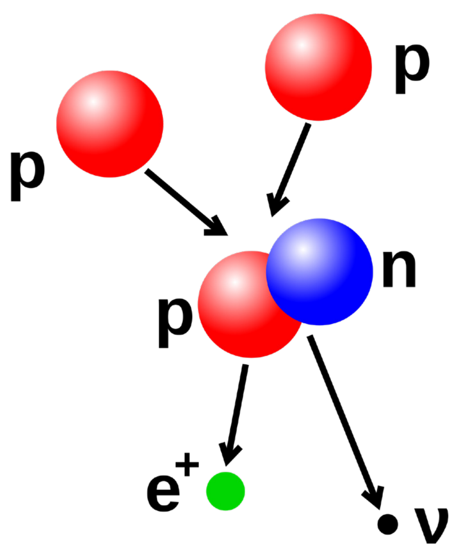

Figure 2: A simple diagram of the physical process of fusion with two hydrogen atoms.[13]

ising progress is being made in the world of fusion research. Recently, the breakeven point was finally reached. In 2013, a team at the US National Ignition Facility achieved an energy gain from “an inertially confined fusion implosion” which surpassed the energy required to start the reaction.11

Although it has taken decades to get to this point, and commercial viability has yet to be achieved, the research and applications for fusion power are only growing. Fully refined power plant designs that would be put into use once ignition is achieved have already been developed, such as the Lawrence Livermore National Laboratory’s “Inertial Fusion Power Plant Concept of Operations and Maintenance.”[4] A Fusion Nuclear Science Facility (FNSF) that could be built within the next decade has been designed to facilitate progress towards fusion energy in many ways, such as to obtain information on “reliability, availability, maintainability, and inspectability (RAMI) of fusion nuclear components.”[8]

Fusion power has some large scale applications. In fact, the clearest need for fusion power is found in space travel. Long-range space missions require significant leaps in minimizing fuel mass and maximizing energy use. An insignificant amount of lithium (with regards to overall mass) could serve as sufficient fusion fuel. More so, the Fusion Driven Rocket design from NASA makes use of a direct energy-to-propellant fusion system that would not require energy to be transferred into electricity, preventing any loss of energy that would be found in such a step.[9]

While fusion energy is not currently viable, continual progress in research is being made, which reassures the validity of fusion power in the future. As our society pushes further and further technologically, we will need a power source that can handle the exponential growth of energy demands and that can also innovate to allow future fields like space exploration to develop unhindered by energy constraints. With immense benefits in terms of abundance, power, and cleanness, fusion energy is arguably the best candidate for long-term energy needs.

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IMAGE SOURCES

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