lA Honors

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Nuclear Fusion: An Anticipated Timeline

As humanity continues to develop and advance technologically, intake of energy and the depletion of natural resources has increased. With a limited supply and harsh ecological impacts, fossil fuels have been realized as a short-lived solution, with ever growing long-term problems. CmTent renewable energy somces are not cost effective or efficient, and the present energy conglomerate has grown so large it controls world politics. Hyper privatization of power leads to higher social stratification, and will inhibit any progress in the developing world (Grossnickle). Nuclear fusion is the only viable solution to the world's ever-increasing energy consumption; in cost-benefit analysis, there is no more available and renewable energy somce than the hydrogen that fuels it. Writer for *TIME Magazine* and contributing editor to *Smartplanet* Mark Halper said, "Many people regard fusion power as the Holy Grail of energy because in theory it would provide a safe, endless power source. Fusion mimics the process of the sun, hurling atoms together rather than splitting them apart as today's nuclear fission teclmology does." In essence, · the forthcoming achievement of sustainable fusion would provide the forces of the sun, and allow them to be harnessed efficiently.

According to statistics from Lockheed Martin Corporation, the world actively uses 17 terawatts of energy per year. Global demand is estimated to grow to 28 terawatts annually by· 2050, with a population double of what it is today; keeping in mind there are 1.3 billion people in

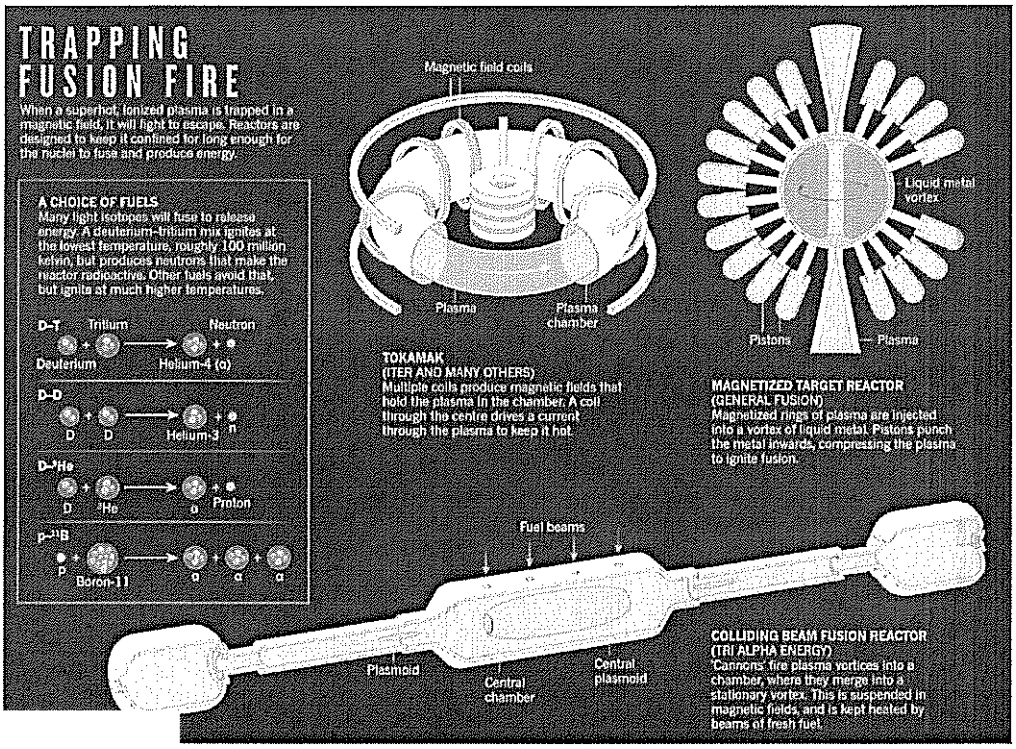
the world who live without electricity. There are approximately 1200 coal plants being plmmed with costs estimated at $4 trillion to accommodate this (Chase). The BBC reports:

> We cmmot rely on fossil f1.1els indefinitely. Firstly, supplies of oil, coal and gas are finite and will eventually run down. Secondly, the greenhouse gases produced tln·ough the burning of fossil fuels are a major driver of climate change, scientists believe...However, demand for energy is also increasing. In 1990, about 75% of the world's population (those in the developing countries) were responsible for only 33% of the world's energy consumption. By the year 2020, that 75% is likely to have risen to 85% and the energy consumption to mound 55%. Thus, there will be greater competition for the fuel resources available.

Nextbigfuture writer Brian Wang took these statistics a step further by analyzing the growth in demand with fusion's growth in capability. The leading projects have capabilities of delivering power in the zettawatts, a billion times larger than current terawatt measurements.
Even more impressive, are the target dates of commercialization for these projects ("Summary").

Currently, four of these projects have game changing potential and will be competing for the worldwide grid. The fastest growing entity with solely fusion purposes is Tri Alpha Energy. They have large financial backing from Goldmm1 Sachs, Rockefeller's Venrock, the govenm1ent of Russia, and Microsoft co-fotmder Paul Allen's venture capital firm Vulcan Inc (Wang, "Summmy"). Tri Alpha Energy specializes in aneutronic fusion, creating electricity through charged ions, rather than heat driven turbines. This approach may become important in the issue of nuclear waste and containm1ent, as it has a minimal output of discarded materials. The mechanism of action contributes to the aneutronic effect, having to do with the chemical components in the fusion reaction. Certain combinations of elements m·e used in these reactions

instead of the standard equations associated with fusion. As shown in Fig. 1 in the fourth listed choice of fuel, the products of the



boron-fueled reaction consist oftlu·ee alpha pa1iicles, (hence the name Tri-Alpha). Since the acquisition of energy will come from these charged particles, instead of a measureable amount of heat from the reaction, it is defined as aneutronic (Weller). They are testing and fmihering development on a linear designed reactor, which would be compact and utilize a carmon like method. In the design, a chamber fills with plasma, which due to magnetic fields forms into a vortex. Laser bean1s fire fuel into the reaction to sustain heat, and the reaction then sustains itself (Wang, "Alternative"). The company is relatively young, founded in 1998 in Rancho Margarita, California. Despite the young age, Tri-Alpha has accrued over $150 million in venture capital thanks in part to the design manager, Norman Rostoker. Along with co-founding the company, he owns rights to the patents filed in support of the project developments (Denekamp). Some·of the other big names affiliated with Tri Alpha's Board of Directors include astronaut Buzz Aldrin, Nobel Prize wim1er Arno Penzias, Rusnano Executive Anatoly Chubais, and NASA software engineer Dale Prouty. Not much else is known about the company, as it is secretive and reluctant to release inf01mation (Kanellos).

Lawrenceville Plasma Physics is an even younger start-up based in New Jersey, founded in May 2014. The mission behind the group is to remove the fossil fuel dependent energy

system, and is the only crowd funded source competing in the future fusion reactor market. Similar to Tri-Alpha Energy, LPP is the only other firm pursuing an aneutronic pathway as the approach to power generation. President of LPP Eric Lerner said,

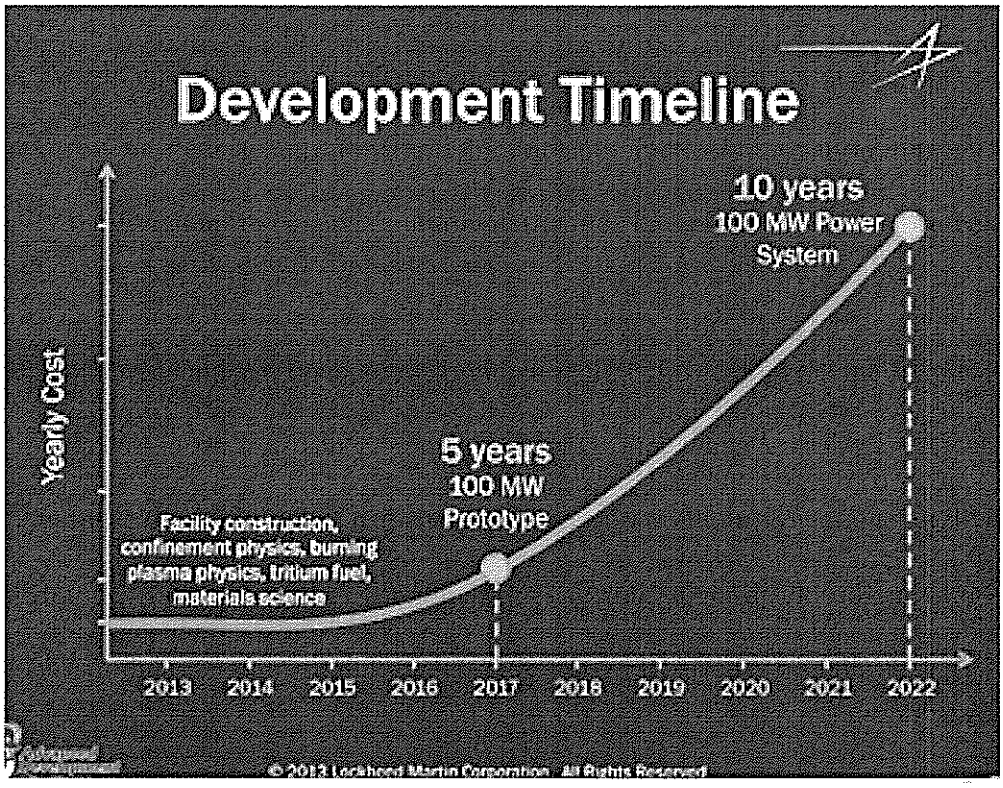
> The nuclear industry is stuck using the same method for making electricity that utilities have used since the days of Thomas Edison -generate heat to make steam to drive a turbine and generator.... We can change all that. We can convert energy directly into electricity and slash costs.

LPP is currently seeking an additional $200 thousand in funds, working at a fraction of the size of its cOlmterpart Tri-Alpha. Despite the early hurdles, Lerner is optimistic about future financing due to LPP's new beryllium based design (Helper, "Startup").

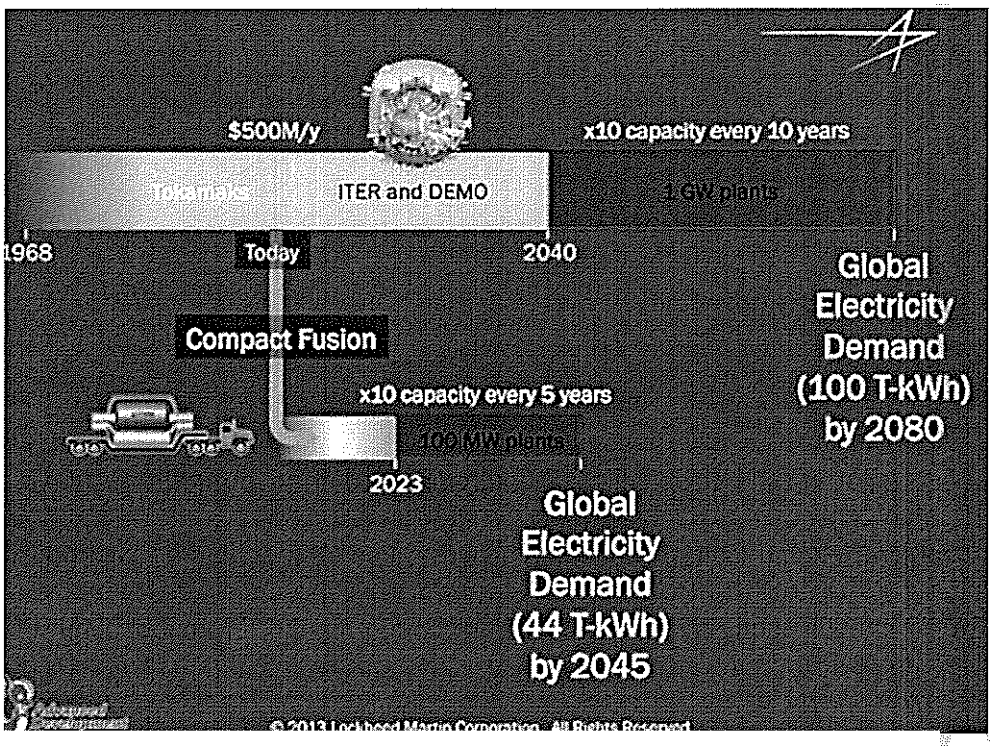
General Fusion is based in Vancouver, receiving funding from Amazon CEO JeffBezos and the Canadian Government. Their plan has the soonest release date, and they aim to cut energy costs to four cents per kilowatt-hour (Wang, "Sununary"). The average American uses 10,000 kilowatt-hours of continuous power per year, including electricity and gas, so the estimated cost to supply that energy for an entire year to an individual would be four hundred dollars (Murphy). General Fusion is seeking an approach that utilizes a piston compression system driven by explosives. So far the company has raised $50 million in venture capital, and in the next two years those funds are looking to grow more as they can improve plasma compression to reach levels needed for fusion. Any realistic power plant would still appear a

decade from realization (Wang, Alternative). These estimates still surpass any estimation made for internationally fi.mded projects at fractions of price margins. For instance, the International Thermonuclear Experimental Reactor, a multinational government backed development, has $18 billion budgeted in the next decade with no results until the 2040s. Nathan Gilliland, CEO of General Fusion said, "We liken it to the Human Genome Project or SpaceX, where larger govenm1ent programs were ultimately outrun by more nimble and practical ilmovation in the private sector." Clearly the free market is appearing to win the race in a plausible fi1sion source (Helper, "Stmtup).

Leading the pack increasingly in fusion development behind closed doors is the US defense contractor Lockheed Mmiin's Advanced Development Group. Managed by Charles Chase, the aerospace defense corporation has had sheltered exposure to their project, the High: Beta Fusion Reactor. In one of the few times ever which Lockheed has ever disclosed one oflt's advm1ced projects, Chase took to Google's think-tank, Solve For X, to discuss his companies· vision for the world's power usage (Helper, "Nuclear"). Rich in funding and devoted time, the lab popularly known as Skunkworks,



estimates a prototype by 2017 with production beginning in 2022. The design has little long lived nuclear waste, is compact (about 2x2x4 meter dimensions), and can meet the worldwide power demand by 2045. Each reactor has an out put of 100 MW, to put that in perspective, 75 of them would be required to run the city of Las Vegas. Lockheed hasn't concerned itself with other private fusion entities; however, it has set its sights on the International Thermonuclear



Experimental Reactor, or ITER. Initiated by United States President Ronald Reagan and Soviet President Mikhail Gorbachev, the long running internationally funded project has just recently began construction, and will consume another $20 billion by 2040 when it becomes operational. This would not achieve global power until 2080; however, the project receives more US federal attention (Chase).

Steve Jurveston, a successful Silicon Valley ventnre capitalist, wants to drop "nuclear" from the developing technologies name. Despite a remarkable safety record and outperforming other renewables, nuclear energy has a stigma surrounding it thanks in part to events like the U.S.S.R's Chernobyl, and the modern-day Fukushima incident in Japan. The non-proliferation of

fusion's fl!el, and very nature of its reaction and design, does not operate under a set of physics which would allow a meltdown. Jurveston said, "Looking for a better name, I suggested that they call it sequestered solar" (qtd. in Helper, "Nuclear"). Separating tbe foundational differences between fusion and fission is one necessary step for it to expand, as the general public doesn't understand the reality of its safety. Arguments about the renewability of the fuel sources have been more of a concern among those within the field, rather tban giving attention to proliferation and disaster potential, a general consensus on the safety of the reactions has been reached. Two isotopes of hydrogen, deuterium and tritium, fuel tbem. Deuterium is quite common, occurring naturally in one out of every 6,500 water molecules in the ocean, enough for millions of years'of operation. Tritium however is uncommon, having a radioactive decay half-life of 12 years it is quite rare in nature. Tritium is amassed by striking lithium with neutrons, using the lithium as a wall surrounding the reaction. Neutrons are a byproduct, fueling it continuously, as observed:'

$^{6}Li + n \quad {}^{4}He + T$

$D + T \quad {}^{5}He \quad {}^{4}He + n$

The neutron collides with lithium, leaving a helium atom and tritium atom. The deuterium and tritium then fuse into another helium, which releases a neutron and 17.6 MeV in power (Chas ;-Murphy).

The two main concerns that arise in this process, is the limited source oflithium on EKl-th, and what impact the neutrons will have on the device. The true amount of lithium is debatabl ,' with no clear unanimity by any single body of users. The battery and semiconductor industry *is* demanding more lithium than ever before, and the efficient lithium-6 is much more rare than lithium-7. Whether or not a self-breeding lithium reaction could occur isn't a physical questi6l.1, rather an economical one. Tritium currently costs $30,000 a gram to extract, and that figure will take some time to go down without mass production (Wietzsche). When it comes to waste, not every neutron will pair with the surrounding lithium, and whatever atom it joins will become

radioactive. Of course, these materials are limited in scope to what is contained within the device, so as opposed to fission, what exactly the radioactive waste is can be controlled and will have smaller half-lives (Murphy).

No matter which angle is approached, any issue concerning fusion is internal within its community. Any waste that occurs is miniscule in retrospect to the worldwide carbon emissions from fossil fuel sources. The sheer quantity and availability of fuel, coupled with zero emissions, will make fusion the most substantial of mankind's achievements. Space colonization, an electric transportation network, and widespread desalinization will all be achievable (Grossnickle). Driven by the simple realization of attaining energy for everyone, a second renaissance will flourish in the developing world. More people will be brought out of poverty, and mankind will be able to grow and accelerate faster in innovation into a new era of infmmation. Only a few researchers knew of the light bulb and electricity in the 1800's with limited information networks; now it is a connnodity of life. Society has the ability to get excited about this and ready themselves to become oil-free, as fusion cannot be pursued unilaterally from one angle.';Its expansion will soon happen, and all corners of humanity will be met with the development off first-world Earth. The competition has influenced an ever-increasing rate of progress, and

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