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Nuclear Fission or Fusion on Meeting Electricity Demand of Future Energy Source Economy and Policy

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ABSTRACT

The announcement of the United States Department of Energy (DOE) on Tuesday, December 13, 2022 was a monumental milestone in nuclear Fusion research, where a "net energy gain driven by Inertia Fusion Confinement (ICF)" eventually, after almost 40 years of scientific efforts achieved for the first time in history by scientists from the Lawrence Livermore National Laboratory (LLNL) in California through its National Ignition Factify (NIF) program. For a long time since aftermath of "Manhattan Project", scientists knew and had some clear concept of bringing sun energy to earth by means of "Fusion" process either via Magnetic Fusion Confinement (MFC)or ICF after their success of exploding their nuclear fission bomb through Nevada Test Site (NTS) via "Fission" process. Announcement of such an achievement by simply put it is one of the most impressive scientific feats of the 21st century as "Jennifer Granholm, secretary of U.S. Department of Energy said at a press conference. Such success puts production of electricity from nuclear energy of fusion puts it in different perspectives and it shows that researchers have been working on this for decades alongside of MCF and their efforts behind nuclear fission of Generation - IV (GEN-IV) reactors technology and manufacturing. In this short review paper, we describe all these issues of the differences between Fission and Fusion and each aspect of them being source of generating electricity to meet national and global demand for the source of it from nuclear point of view and not going to detail of renewable source of energy at this point.

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Introduction

On Tuesday, December 13, 2022 scientists at Lawrence Livermore National Laboratory National Ignition Facility (NIF) announced what is being touted as the world's first nuclear fusion "ignition", the crossing of the threshold at which the amount of energy going into a reaction is lower than the amount of energy generated. Nuclear fusion that is known as Inertial Confinement Fusion (ICF) replicates the process inside stars, where multiple atoms join to form a larger one [1]. Unlike nuclear fission, which requires expensive materials like uranium and releases heat and radiation-the stuff people dislike about current nuclear power—fusion uses cheap and abundant hydrogen isotopes namely Deuterium (D) and Tritium (T) by fusing and confining them to produce little or no radiation, depending on which isotopes are used. Similarly, the same fusion scientific approach has been taken into consideration by way of Magnetic Confinement Fusion (MCF), respectively as well [2].

In the week of announcement by U.S. Department of Energy (DOE) and its secretary Jennifer Granholm (Fifure-1), there appear three things worth knowing about the announcement of ICF breakthrough in nuclear fusion technology, which is in alignment with MCF as well.

1. This could one day offer a huge new source of energy, which is a better option than fission nuclear power energy.
2. It will not come just in time to change the dynamics of current greenhouse effect climate crisis and meet the increased demand for electricity and on-going today's technology that is driven by this demand.
3. Do not expect advocates of conventional nuclear power, i.e., fission rather than fusion, which is main focus of this article short review, to cheer this news and they are more likely miffed or angry with such news.

The Tuesday December 13, 2022 announcement that was being touted by Lawrence Livermore National Laboratory (LLNL) National Ignition Facility (NIF) (Figure-2), indicated the breakthrough driven by ICF, where the amount of energy going into a reaction is lower than the amount of energy generated.

Figure 1: U.S. Energy Secretary Jennifer Granholm (Center)

Figure-2 is an illustration of National Ignition Facility Target Area of LLNL in Livermore California, where operators inspect a final optics assembly during a routine maintenance period.

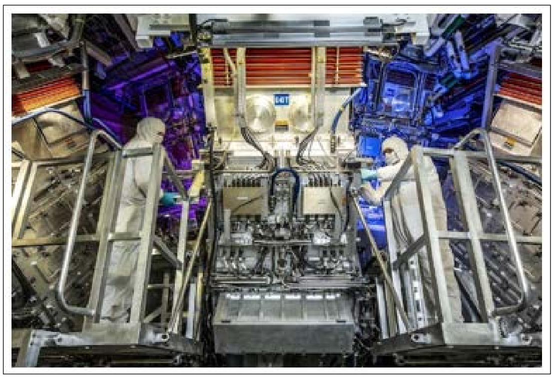

Figure 2: National Ignition Facility at Lawrence National Laboratory

The fact that laboratories have now managed net energy production this way is huge, although the usual caveats apply: This, by all means, does not indicate you can now charge your phone or electrical vehicle with fusion energy, nor can fusion replace renewable source of energy such as wind, solar or for that matter any non-renewable source for energy production, or indeed its cousin nuclear fission, in our short-term efforts to stave off climate change [3].

As we know from history of Fusion and physics of H-Bomb as very destructive weapon of century, as deGrasse Tyson said, “We’re long overdue to have converted something so destructive that finally it could be used for a peaceful purpose in the service of civilization”.

Nuclear Source Driving Energy Production

Currently, nuclear power plants use fission, which breaks atoms apart to make energy. Even though it is not burning fossil fuel, meltdowns like Chernobyl and Fukushima are evidence that our nuclear fission can still harm humans and our environment. However, there is a huge movement behind companies that are involved with manufacturing of nuclear reactors of new generation of these reactors that is known as Generation IV (GEN-IV) and these generations tout out as very safe and modularized to make them small as far as footprint of their existence is concerned.

But now, fusion’s moment appears to finally be here.

“This is a landmark achievement for the researchers and staff at the National Ignition Facility who have dedicated their careers to seeing fusion ignition become a reality, and this milestone will undoubtedly spark even more discovery”, Granholm said, adding that the breakthrough “will go down in the history books.”

Obviously Nuclear is the future for sustainable Carbon free energy, as illustrated in Figure-3, which is presentation of fission reactor power plant facility.

Figure 3: Fissionable Nuclear Power Plant Facility

Civilization’s need for energy will always increase due to growth of population globally and as well as modern technology is driven by demand for electricity also. Nuclear energy is the only minimal resource way of providing the world transportation system’s energy requirement with a zero Carbon emission solution for electric and Hydrogen powered vehicles [3].

The future of energy management is a direct function of manufacturing in particular solving the business challenges of E-Vehicle (EV) charging for auto dealerships of near future and individual owners of such EVs. In case of dealerships that are selling these types’ vehicles within next few years are on rise, due to demand for carbon free energy and population engines. See Figure-4

Future Energy’s EV dealership solution delivers a complete, turn-key strategy to enhance sales conversion, after-sales opportunities, inventory management, power-use management, financial assistance and more.

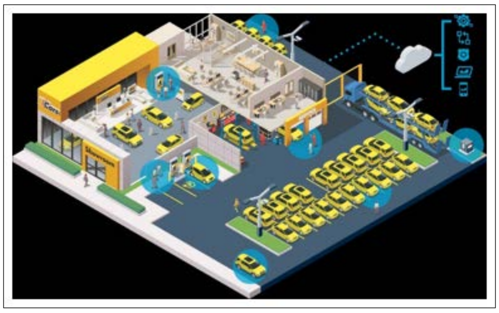

Figure 4: E-Vehicle Dealership of Near Future

Electric Vehicles (EVs) are here to stay and more are coming, given the fact that Tesla is not the player in the game of manufacturing EVs anymore and more player are opening the footprint into market of EVs and in fact states like California pushing 100% these vehicles into market by 2026 and presently Biden Administration campaigning this matter into market.

A recent report from Lucintel on the EV market forecasts a compound annual growth rate of 29% from 2021 to 2026. A number of factors account for this rise, including President Biden’s proposed $174 billion investment in the U.S. EV market, the increasing availability of public and private funding for EV adoption, and a broad cultural shift toward reducing greenhouse gas emissions.

Consumer Reports fielded a nationally-representative survey of Americans to understand attitudes toward fuel economy among Americans who intend to purchase a vehicle in the next two years and to better understand American drivers' familiarity with an attitude toward electric vehicles, including what they see as incentives and barriers to owning them. The results are based on interviews conducted from July 29, 2020 through August 12, 2020.

The results from Consumer Reports' latest nationally representative survey on electric cars—conducted in July and August of 2020 with 3,392 American adults with valid driver's licenses— shows that public perception of EVs is inching toward the mainstream [4].

The relationship (if any) between energy consumption and Gross Domestic Product (GDP) has been the center of many studies. The goal has been to find out, how does or does not, the use of energy affects the growth in economic activities. The impact of availability and use of energy (supply and chain) on inflation, the factor that affects the supply and demand for energy, and the impact of the use of energy on the environment are among other topics that we have discussed in the reference Zohuri, et al. [3].

It is impossible to overstate the importance of energy. Just thinking about where humanity would be without it may be enough to demonstrate this point. Like in the past, energy will play a vital role in shaping future industries, cities, nations, and the world. That is why we believe that energy is a critical factor in shaping future paradigms in any target entity or world. To have a better understanding of the role that energy plays in the world today and in the future, in this article, we briefly look at the definition of energy and its different forms, and review some data related to energy consumption in the world and the United States.

Furthermore, as a source of clean energy, we believe the future of nuclear power technology, despite the challenges it faces, is an important option for this country and the rest of the world to meet future energy needs without emitting CO (carbon monoxide) and CO_2 (carbon dioxide), or other GHGs (greenhouse gases), and other atmospheric pollutants and it is more efficient among its other comparable sources of renewable energies, such as solar, wind, etc., [5].

Globally, renewables made up 29 percent of electricity generation in 2020, much of it from hydro-power (16.8 percent). A record amount of over 256 GW of renewable power capacity was added globally during 2020 and continues to be the focal point for climate and energy solutions [5].

Demand for electricity is direct function of population growth globally and is also driven by the present century's extraordinary speed of technological developments, in particular among countries with very high (GDP) [5].

Bottom line, The U.S. Energy Information Administration (EIA) estimated that the energy consumption of the U.S. manufacturing sector increased by 3.7% from 2010 to 2014. The increase seems insignificant, but uncontrolled and further increases can pose additional challenges to energy management in manufacturing.

The manufacturing sector accounts for 33% of all the energy consumed in the U.S. – and that's excluding transportation. Energy managers are constantly testing innovative technologies, new business processes, and enlightened energy management strategies. The future of energy management is on the rise, and lies in new technologies and energy efficiencies that are now impacting industries. [6].

Integrating data shows that, industry leaders are embracing data as the future of energy efficiency. Sharon Nolen, manager of Eastman Chemical Company's Worldwide Energy Program, shares her data-driven energy program that helped the company improve its energy efficiency by 9% since 2008 and save $30 million in one year alone [7].

It has 5 components each extensively using data to monitor and analyze business processes for more informed decision-making:

- Employee energy awareness
- Data on energy efficiency measurement
- Governmental assistance that allows firms to share energy-saving ideas
- A centralized approach for uniform implementation throughout all departments in the company
- Budget for energy projects

In fact, the future of energy management in manufacturing can be driven by these types of data and will reduce energy costs as part of prediction. See Figure-5

Figure 5: Energy Management Infrastructure

Fission and Fusion: What is the Difference?

According to the U.S. Department of Energy (DOE) website, all of the energy we produce comes from basic chemical and physical processes. That is mostly been accomplished throughout history by burning carbon-based material like wood, coal and gas—or by harnessing power from the source of renewable energy, such as sun, wind, and water.

Fission and fusion are two physical processes that produce massive amounts of energy from atoms. See Figure-6 that is illustrating very holistic configuration of these two processes

They yield millions of times more energy than other sources through nuclear reactions.

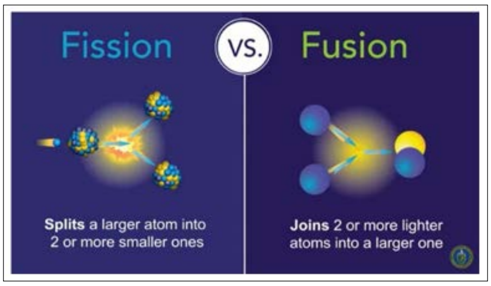

Figure 6: Fission Vs. Fusion Illustration

Fission by Definition
Fission occurs when a neutron slams into a larger atom, forcing it to excite and split into two smaller atoms—also known as fission products. Additional neutrons are also released that can initiate a chain reaction. When each atom splits, a tremendous amount of energy is released.

Uranium and plutonium are most commonly used for fission reactions in nuclear power reactors because they are easy to initiate and control.

The energy released by fission in these reactors' heats water into steam. The steam is used to spin a turbine to produce carbon-free electricity.

Fusion by Definition
Fusion occurs when two atoms slam together to form a heavier atom, like when two hydrogen atoms fuse to form one helium atom.

This is the same process that powers the sun and creates huge amounts of energy—several times greater than fission. It also doesn't produce highly radioactive fission products.

Fusion reactions are being studied by scientists, but are difficult to sustain for long periods of time because of the tremendous amount of pressure and temperature needed to join the nuclei together and this is the major challenge in obtaining energy from fusion.

Figure 7: Shows the Initial Fuel Utilized by either Fission or Fusion Process

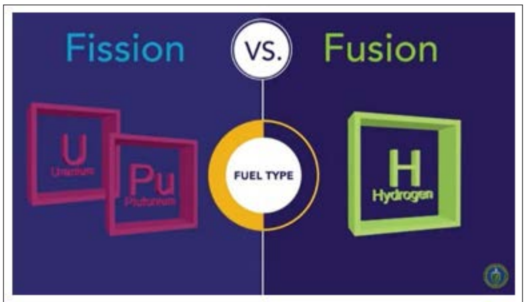

Figure 7: Initial Fuel Used in Fission and Fusion Process

Table 1: below lists the various differences between nuclear Fission and Fusion reactions

Table 1: Nuclear Fission Versus Nuclear Fusion [8].

Nuclear Fission	Nuclear Fusion
When a heavy atom splits, a tremendous amount of energy is released	The energy released during nuclear fusion is several times greater than the energy released during nuclear fission.
When the nucleus of an atom splits into lighter nuclei through a nuclear reaction, the process is termed nuclear fission.	Nuclear fusion is a reaction through which two or more light nuclei collide with each other to form a heavier nucleus.
Fission reactions do not occur in nature naturally	Fusion reactions occur in stars and the sun as shown in Figure-8
Comparatively, less energy is needed to split an atom in a fission reaction	High energy is needed to fuse two or more atoms together in a fusion reaction
Atomic bomb works on the principle of nuclear fission. Figure-9	Hydrogen bomb works on the principle of nuclear fusion.

The table above would have given you a clear idea about how the two terms nuclear fission and fusion vary from one another.

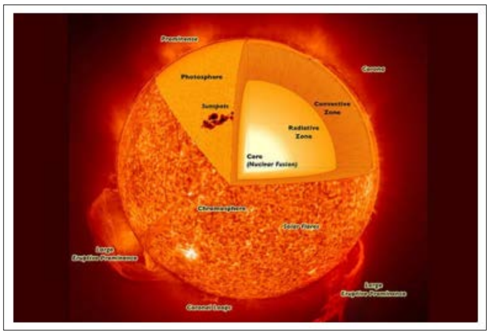

Figure 8: Sun Core Layers

Figure 9: Bikini Island Nuclear Weapon Explosion

Moreover, nuclear fusion and nuclear fission are different types of reactions that release energy due to the presence of high-powered atomic bonds between particles found within a nucleus. In fission, an atom is split into two or more smaller, lighter atoms. Fusion, in contrast, occurs when two or smaller atoms fuse together, creating a larger, heavier atom.

Nuclear Fusion Technology Issues & Solutions
In this section we define the issues and solutions between to technical approach within fusion confinements as follows:

Inertial Fusion Energy
Realizing inertial fusion energy will be transformative for humanity because it would allow us to devise strategies to minimize the human causes of climate change.

Development strategy must indicate, step by step, how commercial power from inertial fusion can be made available in the first part of the next century.

At this time, there appear to be no insurmountable fusion technology barriers to realizing the components of an IFE system, although knowledge gaps and large performance uncertainties remain, including those surrounding the performance of the system as a whole. for example, chamber materials damage and target fabrication and injection or the chamber repetition rate and its cleaning issues can have major impacts on the basic feasibility and attractiveness of IFE and thus on the direction of IFE development [9].

Here we brought some strategies toward Inertia Fusion Energy that can be beneficial to develop the IFE technology maturity, some of which are already implemented. This are included:

- Identify and develop solutions for critical technology issues and systems such as targets and target systems; reaction chambers (first wall/blanket/shield); materials development; tritium production, recovery, and management systems; environment and safety protection systems; and economic analysis.
- Economic analyses of inertial fusion energy power systems.
- A comprehensive system engineering approach should be used to assess the performance of IFE systems. Such analysis should also include the use of a technology readiness levels (TRLs) methodology to help guide the allocation of R&D funds.
- Further efforts are needed to explore how best to minimize the capital cost of IFE power plants even if this means some increase in the cost of electricity. Possible options include the use of a smaller fusion module, even at a higher specific capital cost per megawatt of electricity, and the use of a fusion module for which capital cost is reduced by accepting a higher operating cost.
- There are several technology development areas in which there is overlap and/or synergy between Magnetic Fusion Energy (MFE) and Inertial Fusion Energy (IFE). The overlap and synergies that exist between MFE and IFE technology development areas should be exploited.
- Focus on issues that are common to the most likely IFE choices and, in addition, try to anticipate the serious materials challenges that could affect the choice of an initial IFE prototype.
- Accelerating fusion R&D with AI, through the creation of a platform and cross-community network for innovation and partnership.

Magnetic Fusion Energy

Many researchers believe that the dream of a small sun on Earth will be realized using Magnetic Fusion Energy (MFE) in the near future. Tokamaks are fusion power plants that used this method to harness very hot plasma due to nuclear fusion in material walls. Currently, the International Thermonuclear Experiment Reactor (ITER) project in France is under construction and is predicted to complete in 2050. This long and massive project involved many countries, such as the USA, Japan, China, Korea, India, and the EU. The next generation of fusion reactors is fusion demonstration power plants (DEMO) that would be built after ITER.

Fusion or Fission, Which Nuclear Energy Technology Adheres to Market Economic Principles?

It is generally known that the principles of market economies and the peaceful use of nuclear energy are difficult to agree upon.

The idea that risk and culpability should be intertwined is one of these ideas. Any investor should be permitted to keep the return on their investment (mainly in the form of profits). But they must also bear responsibility for the repercussions of this investment.

One ought to be able to keep the rental money from a property they built if they decide to rent it out. However, they are also in charge of ensuring the security of their citizens. They will make sure the residents live in a safe home if they are deemed responsible in the case of a house collapse. Those who gain must also bear.

That tenet is incompatible with the peaceful use of nuclear energy now practiced. Due to two factors.
First, if a nuclear disaster occurred, the damage might be so severe that the business in charge of running the nuclear power station would not be able to cover the costs (not to mention that the deaths of people cannot be offset with money).

Second, the expenses associated with the ultimate disposal of nuclear waste are predetermined. In addition, charges could materialize in the future (if, for example, the stored barrels are no longer tight and new types of closures have to be found). However, the corporation running the nuclear power plant will not be around in a few hundred years. It is no longer holdable

Nobody is certain that this sum will be adequate.

However, a lot of nations still use nuclear power. Due to the fact that the current cost is cheap. Moreover, nuclear fission doesn't result in carbon dioxide emissions.

Nuclear energy advocates now have fresh motivation thanks to climate change. But it is impossible to ignore the drawbacks.

Nuclear fusion energy is a new type of nuclear power that might be the answer to the problem.

The process of nuclear fusion is the union of two light atomic nuclei into one heavier one while releasing enormous quantities of energy (more here).

Recently, a development in this potential method of energy production was disclosed. The first reaction that generated more energy than it was consumed was created by US scientists that are known as "Breakeven Criteria".

The speed at which fusion power can be used is economically limited. These are caused by the big unit size, high overnight investment cost, and lengthy construction period, which prevent an efficient innovation cycle, as well as the requirement to pass the valley of death at an unprecedented degree of expenditure. If the DEMO reactor can be made smaller, simpler, and more affordable by technology advancements or new design concepts, all of these limitations could be greatly eased. This might accelerate the introduction of fusion power by several decades.

Knowing that the market introduction, or "passing the valley of death," will be the main economic barrier of fusion once DEMO has provided the proof of concept, it makes far more sense to focus design efforts in this direction.

Conclusion: The Future of Nuclear Energy

Despite a turbulent history, the allure of nuclear energy — electricity production on a massive scale with minimal emissions — remains attractive. Its low emission rate is why the United Nations International Panel on Climate Change recommends doubling the world's nuclear capacity by 2050.

Nuclear power is the use of nuclear reactions to produce electricity. Nuclear power can be obtained from nuclear fission, nuclear decay and nuclear fusion reactions. Presently, the vast majority of electricity from nuclear power is produced by nuclear fission of uranium and plutonium in nuclear power plants.

Nuclear decay processes are used in niche applications such as radioisotope thermoelectric generators in some space probes such as Voyager 2. Generating electricity from fusion power remains the focus of international research.

Either we go in path of nuclear fission using Advanced Reactor Concept (ARC) or near future nuclear fusion approach to generate a clean source of energy one way or the other as a source for production of electricity to meet its globally demand of it, the nuclear is the way to go from these authors point of view [10].

It is useful to realize that the fusion reactor of the future, based on the present design, will also be a breeder reactor. Although the central fusion process or energy release in plasma is quite different from the process of nuclear fissioning, there are remarkable parallels between fusion and fission breeders in reactor operation. Lithium in fusion corresponds to uranium-238 (and thorium-232) in fission breeding; tritium in fusion Corresponds to plutonium (and uranium-233) in fission. In both cases, there are radioactive inventories and radioactive wastes. Both types of breeders today are geared to electricity generation. Lithium resources and uranium-plus thorium resources are similar in size, and either type yields an energy output of about 20 kWh/g. In spite of these qualitative similarities, a technically mature fusion reactor could offer considerable quantitative advantages over the fission breeders.

Technical maturation of fusion reactors, however, will still continue far into the 21st century. No more than 2-3 TWyr/yr can be expected from fusion in 2030, although its share will possibly increase thereafter [11].

In conclusion, nuclear fusion projects are highly very complex and require Design to Cost (DTC) evaluation and analysis. These difficulties are frequently linked to the project's structure. A laser power project for fusion reactors must be customized to the local environment, the skills of potential partners, and the availability of the equipment and fuel required for full-scale generation.

Additionally, there can be specific reservations regarding international cooperation, particularly in light of security issues. The variety of the project's goals, the body of knowledge upon which it is built, and the region in which it operates are significantly influenced by the financial and practical resources available.

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