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What the Fusion Breakthrough Means for Our Energy Future

Nuclear fusion offers the benefits without today's nuclear challenges. Success would be a game-changer.

By Ernest J Moniz

This month a scientific milestone was achieved when, for the first time in a laboratory, a fusion reaction produced more energy than it took to ignite it. This important result was produced at the Department of Energy's Lawrence Livermore National Laboratory and its National Ignition Facility. It is far from a commercial prototype — for example, its giant lasers are very inefficient — but the result demonstrated the ignition of fusion fuel that is the central requirement for eventually producing clean electricity commercially.

Although fusion reactions power the sun and other stars, enabled by their enormous mass and gravitational pressure, controlled fusion on earth has been elusive for many decades. The NIF result is exciting because when the journey from science demonstration to a commercially viable power plant is completed, the electricity grid will be revolutionized.

Why? Because as much as wind and solar energy, supplemented by batteries and long-distance transmission, are and will continue to be important for providing carbon-free electricity, a large-scale, compact and clean power source available whenever needed, independent of weather, opens up expansive opportunities for an emissions-free reliable grid system. This will be core to a greenhouse gas emissions-free energy economy. Nuclear fission, the basis of today's nuclear power, has exciting new technologies close to being deployed, but is challenged by the need to manage radioactive waste and by concerns that some countries can exploit nuclear fission systems to seek nuclear weapons know-how. Nuclear fusion offers the benefits without those challenges, and widespread deployment would be a game-changer.

Two technology approaches aim to navigate the path from lab to grid: compression of fusion fuel, usually forms of hydrogen, as practiced at the NIF; and confinement of a hot plasma of fusion fuel — the nuclei plus electrons that make up light atoms — through a combination of magnets and accelerators. The latter is more prevalent and is progressing toward success, especially at privately funded companies.

Investors have provided nearly $5 billion of private capital to several companies pursuing multiple fusion technologies, supplementing the considerable government funding going into both compression and confinement large-scale projects. Most are betting that the confinement approach will be first to a commercially viable power plant. (I am on the board of a company developing such technology.)

Nuclear fusion research has been underway for over 60 years, so why has it taken so long to demonstrate that net energy can be provided from this process? The compression and confinement pathways both need to reach other-worldly conditions — literally — that meet and exceed those in stars. The NIF experiment compressed the hydrogen fuel to roughly 100 times the density of lead and to a temperature of about 100 million degrees Celsius, far greater than the temperature at the sun's center.

Achieving these conditions is very challenging. The persistence of the fusion community over many decades is a testament to its ingenuity and to the importance of the prize. Fusion is on a trajectory to achieve scientific demonstration before the end of this decade. The hope is that the next step — engineering one or more pilot power plants and beginning deployment — could take place before the end of the next decade. This is an aggressive schedule commensurate with the scale of the climate challenge, and yet would still add up to an 80-year journey. The public and private sectors need to work together to sustain it.

Game-changing energy technologies routinely have a long gestation period. The comparison with solar photovoltaics technology offers a guide. While there is no official "start date" for solar photovoltaics, I have a personal one: I visited Bell Labs in 1961 as a high school student and saw the prototype Telstar satellite, which would go into orbit the following year. It was covered with photovoltaics that Bell Labs had researched and developed, without the pressure of meeting the stringent cost targets that would be needed for commercial power applications. This puts the extraordinary technical challenges of fusion in context and reinforces a critical reality: the innovation challenge in clean energy has been by its nature has taken decades.

To meet widely accepted climate objectives, we must double the clock speed of the clean energy innovation process. The bipartisan commitment to energy innovation, from discovery stage to initial deployment, manifested itself in the remarkable legislative record of the last year — the Bipartisan Infrastructure Law, the CHIPS and Science Act, and the Inflation Reduction Act. This is encouraging, but it must be sustained even in the face of uncertain short-term macroeconomic conditions. Equally important, federal and state governments need to incentivize private investments in clean energy research, development, demonstration, and deployment by lowering the barriers to bankability. Only by firing on all cylinders in a synchronized way — for fusion and for the broader clean energy portfolio — can we deploy energy, climate, and security solutions faster, including for tomorrow's breakthroughs such as fusion.

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