US announces Fusion energy breakthrough

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In news– Scientists in the United States have, for the first time, achieved a net gain in energy from a nuclear fusion reaction.

What is fusion nuclear energy?

- Nuclear fusion is the **process by which two light atomic nuclei combine to form a single heavier one while releasing massive amounts of energy.**
- **Fusion reactions take place in a state of matter called plasma** — a hot, charged gas made of positive ions and free-moving electrons with unique properties distinct from solids, liquids or gases.
- The sun, along with all other stars, is powered by this reaction.
- To fuse in our sun, nuclei need to collide with each other at extremely high temperatures, around ten million degrees Celsius.
- The high temperature provides them with enough energy to overcome their mutual electrical repulsion.
- Once the nuclei come within a very close range of each other, the attractive nuclear force between them will outweigh the electrical repulsion and allow them to fuse.
- For this to happen, the nuclei must be confined within a small space to increase the chances of collision.
- In the sun, the extreme pressure produced by its immense gravity creates the conditions for fusion.
- **Fusion is a different, but more powerful, way of harnessing the immense energy trapped in the nucleus of an atom.** This is the process that **makes the Sun and all other stars shine and radiate energy.**

- **Attempts to master the fusion process have been going on at least since the 1950s**, but it is incredibly difficult and is still at an experimental stage.

Fusion still far from reality-

- Significant though the achievement is, it does little to bring the goal of producing electricity from fusion reactions any closer to reality.
- By all estimates, use of the fusion process for generating electricity at a commercial scale is still two to three decades away. The technology used in the US experiment might take even longer to get deployed.
- **There are at least two different ways in which fusion reactions are being experimented with.** These differ mainly in the way the input energy is supplied to create the extreme heat to enable fusion, but that also results in differences in design and capabilities.
- At the Lawrence Livermore facility, scientists use high-energy laser beams to achieve those temperatures, also called **'inertial fusion'.**
- At some other places, including the international collaborative project in southern France called ITER in which India is a partner, very **strong magnetic fields are used for the same purpose.**
- According to current timelines, the ITER project is expected to demonstrate the viability of a commercially scalable nuclear fusion reactor between 2035 and 2040.
- **ITER, when operational, would become the biggest machine anywhere in the world,** more complex than the Large Hadron Collider at CERN, or the LIGO project to detect gravitational waves. **Right now, the ITER reactor is in the machine assembly phase.**
- **India joined the ITER project in 2005.** The Institute for Plasma Research in Ahmedabad, a laboratory under the Department of Atomic Energy, is the lead institution from the Indian side participating in the project.

- **As a member country, India is building several components of the ITER reactor,** while also carrying out a number of experiments and R&D activities related to the project.
- **ITER is an international nuclear fusion research and engineering megaproject aimed at creating energy by replicating, on Earth, the fusion processes of the Sun.**

Fusion VS Fission technology-

- **The nuclear energy currently in use across the world comes from the fission process**, in which the nucleus of a heavier element is split into those of lighter elements in a controlled manner.
- A large amount of energy is released in both these processes, but substantially more in fusion than fission.
- For example, the fusion of two nuclei of a heavier isotope of hydrogen, called tritium, produces at least four times as much energy as the fission of a uranium atom which is the normal process of generating electricity in a nuclear reactor.
- Besides greater energy yield, fusion is also a carbon-free source of energy, and has negligible radiation risks.
- But fusion reactions happen only at very high temperatures, 10 times the temperature that exists at the core of the Sun, and creating such an extreme environment in a laboratory requires huge amounts of energy.
- So far, the energy released in such experimental fusion reactions have been lower than what is consumed to create the enabling high temperatures.
- At best, some of these reactions have produced 'near break-even' energies