

## Breakthrough in Nuclear Fusion Energy

### Why in news?

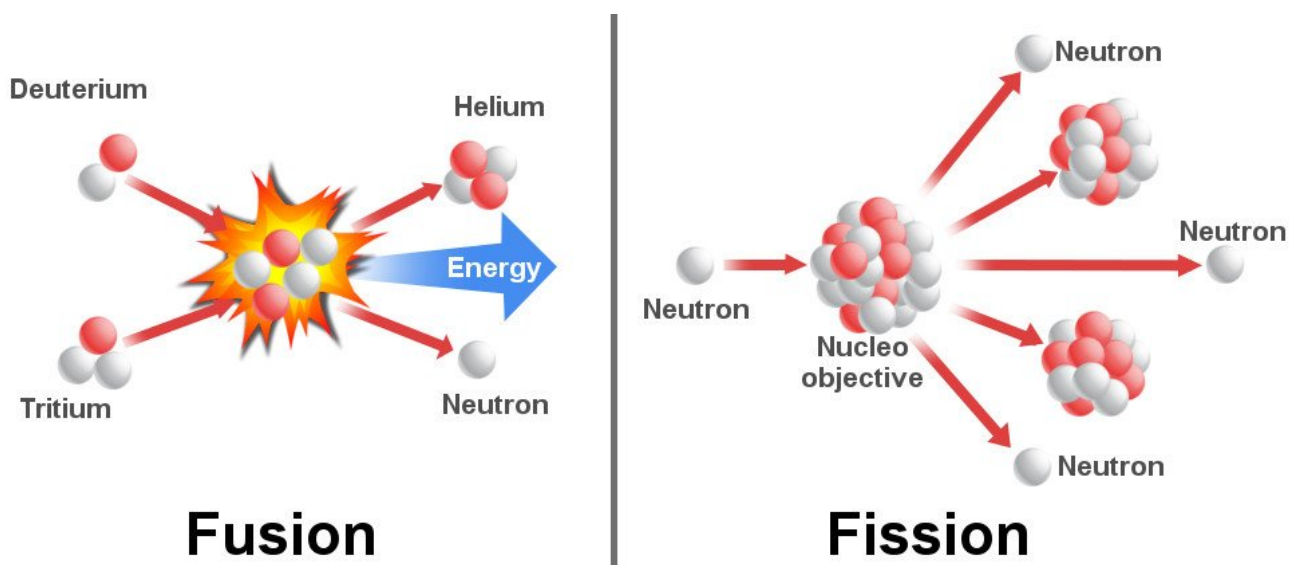
Researchers at the Lawrence Livermore National Laboratory in California for the first time produced more energy in a fusion reaction than was used to ignite it, something called net energy gain.

### What is nuclear fusion?

- Nuclear fusion reactions power the sun and other stars.
- Nuclear fusion reaction happens when two light nuclei (hydrogen) merge to form a single heavier nucleus (helium), releasing enormous amounts of energy and heat.
- To combine two identical elements is actually very hard because they have the same positive charge and naturally repel each other.
- A lot of energy is needed to overcome this resistance.
- In the Sun, this happens due to extremely high temperatures of around 10 million degrees Celsius, and significant pressure of more than 100 billion times that of the Earth's atmosphere.

### Differences between nuclear fission and fusion

- Fusion is the joining of atomic nuclei and fission is the splitting of atomic nuclei.
- Fusion produces far more energy than that created by fission.
- Fusion, unlike fission, does not create harmful radioactive by-products that need to be stored for thousands of years.



### Why is fusion energy so significant?

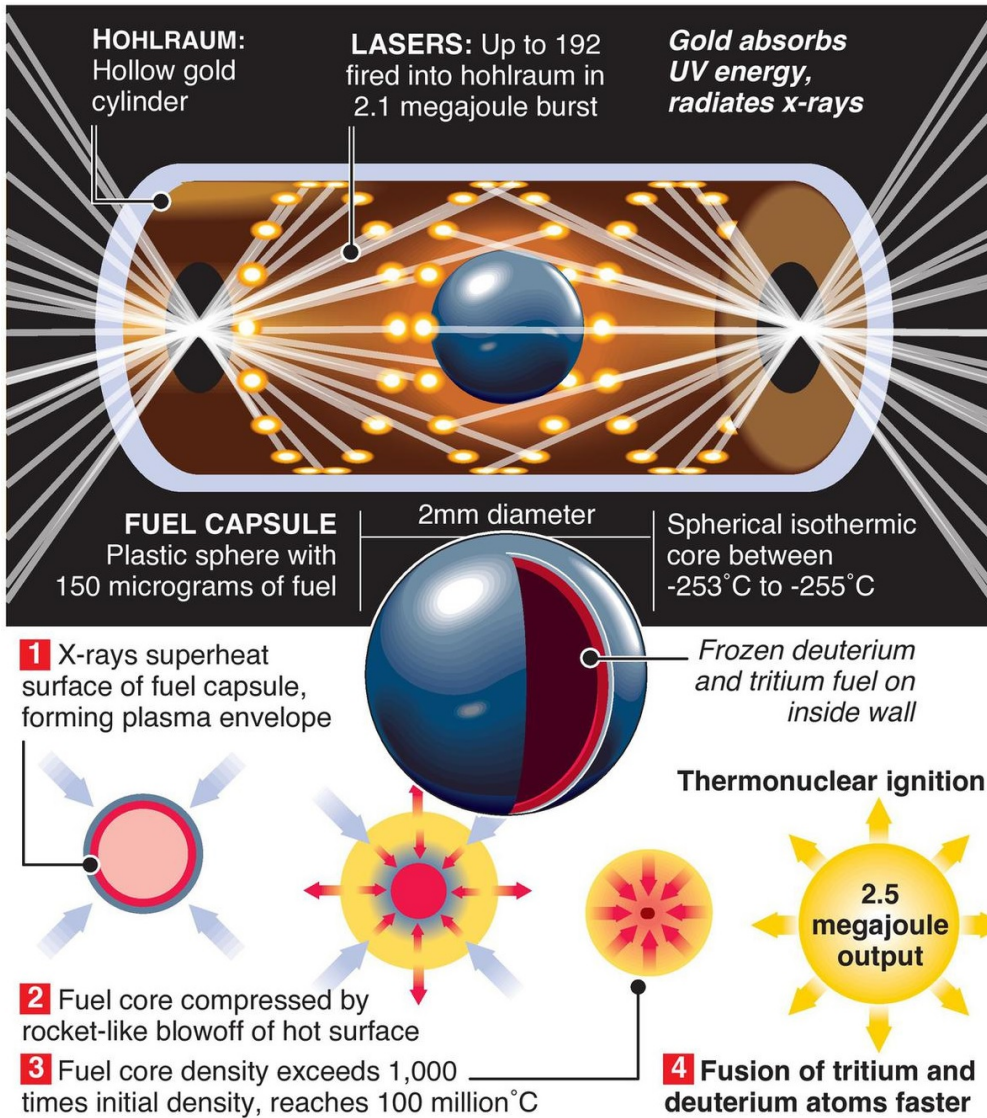
- **Less radioactive** - The waste produced by nuclear fusion is less radioactive and

decays much more quickly.

- **No need for fossil fuels** - Nuclear fusion doesn't need fossil fuels like oil or gas.
- **No GHGs** - It also doesn't generate greenhouse gases (GHGs).
- **Targeting net zero** - Widescale use of nuclear fusion could help countries meet their targets to produce net zero emissions by 2050.
- **Availability** - Since most fusion experiments use hydrogen, which can be extracted cheaply from seawater and lithium, nuclear fusion offers the possibility of "basically unlimited" fuel.
- **Self-limiting process** - Fusion is a self-limiting process in which the machine switches itself off if the reaction cannot be controlled.
- Because of its significance, it has been described as the "**holy grail**" of energy production.

### **How are scientists trying to produce fusion energy?**

- **Magnetic confinement** - Magnetic confinement uses a reactor called tokamak, in which a hydrogen plasma is heated to high temperature and the nuclei are guided by strong magnetic fields.
- **International Thermonuclear Experimental Reactor (ITER)** is a famous example of an experiment trying to achieve fusion using magnetic confinement.
- **Inertial confinement** - In the Livermore lab, a 192-beam laser fire pulses at a small capsule filled with deuterium-tritium atoms inside a cylinder called a hohlraum.
- The latter heats up and releases X-rays, which heat the nuclei to millions of degrees centigrade and compress them to billions of Earth-atmospheres.
- It is called inertial confinement because the nuclei's inertia creates a short window between implosion and explosion in which the strong nuclear force dominates, fusing the nuclei.
- It is relatively easier to attain break-even energy levels through inertial fusion compared to magnetic fusion.



### What has the experiment achieved?

- **Gain** - The ratio of the output energy to the input delivered to the container is the gain.
- A gain of 1 is called '**scientific breakeven**' - an important milestone in the development of fusion energy.
- **Lawson criterion** - In August 2022, the facility reported it had produced a burning plasma that met the Lawson criterion.
- According to Lawson criterion, the heat generated was sufficient to potentially trigger other fusion reactions as well as offset heat loss during the reaction.
- Now, the facility has reportedly achieved a burning plasma that meets the Lawson criterion as well as a gain greater than 1.

### What issues lie ahead?

- **Effectiveness** - Some of the input energy is devoted to compressing the capsule instead of raising the temperature.
- This fraction will increase as the amount of fuel increases, creating another barrier to high gain.
- **Gain** - Future research will need to focus on reaching the next major milestone - a

target gain of  $G > 100$ , which is required to run a power plant efficiently.

- **Rate of firing** - The rate at which any reactor fires its lasers at the hydrogen capsules needs to be orders of magnitude faster.
- **Conversion to usable form** - Even if the inertial fusion process is more efficient, the produced energy still needs to be converted into usable electricity.
- **Cost** - The cost to run and maintain an inertial fusion reactor needs to decrease dramatically.
- **Commercial viability** - It is still not obvious whether inertial fusion can be commercially competitive.
- Fusion is still far from reality.

## Quick facts

### International Thermonuclear Experimental Reactor (ITER)

- ITER is the world's largest experimental fusion reactor facility in **France**.
- It is a large-scale scientific experiment intended to prove the viability of fusion as an energy source.
- It includes the contributions of 35 countries, including **India**, China, South Korea, Japan, Russia and the United States.
- ITER will not produce electricity, but it will resolve critical scientific and technical issues in order to take fusion to the point where industrial applications can be designed.

## References

1. [The Hindu | Understanding the fusion energy breakthrough](#)
2. [The Indian Express | Why fusion could be a clean-energy](#)
3. [BBC | Nuclear fusion breakthrough](#)
4. [IEEE Spectrum | Fusion breakthrough won't lead to practical fusion energy](#)
5. [ITER | International Thermonuclear Experimental Reactor \(ITER\)](#)