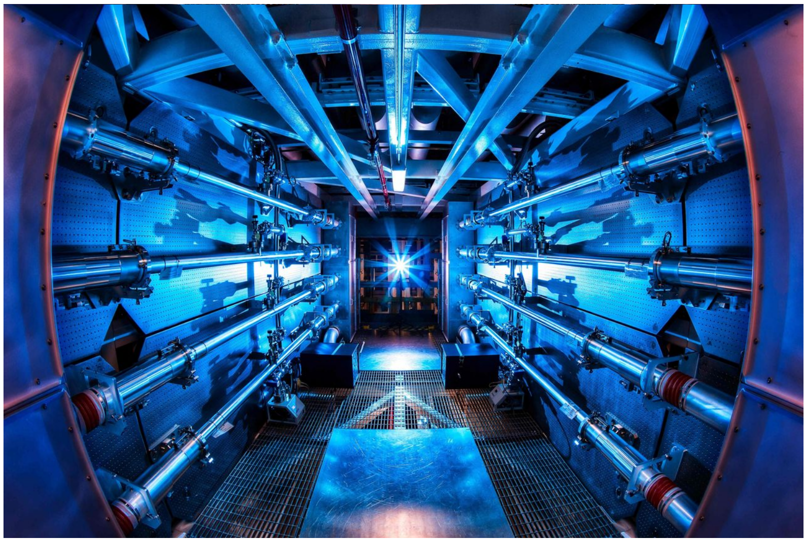
U.S.THE NUMBERS

When Will Nuclear Fusion Energy Be Ready for Prime Time? Watch These Three Numbers

There are two more hurdles before it starts delivering clean, affordable energy



Experiments involving nuclear fusion offer the potential for virtually limitless, clean energy.
PHOTO: LAWRENCE LIVERMORE NATIONAL LABORATORY/AFP/GETTY IMAGES

By Josh Zumbrun Follow
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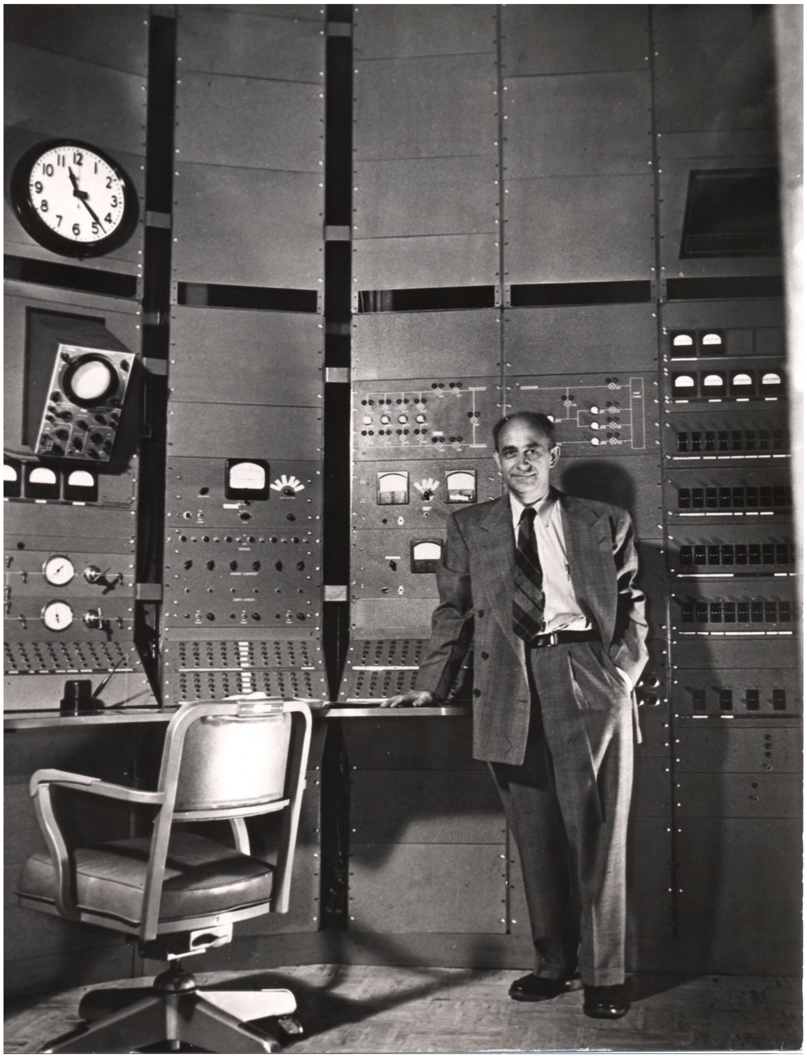
The U.S. Energy Department this past week announced a breakthrough in research on nuclear fusion, after a controlled reaction at the Lawrence Livermore National Laboratory produced more energy than it consumed.

Fusion offers the potential for virtually limitless, clean energy. How long before this breakthrough can deliver on that promise? To get an idea, it's helpful to know three simple numbers in the science and economics of fusion representing key "break-even points."

The first point is called the scientific break-even—this is when a fusion reaction produces more energy than was used to create the reaction in the first place. The Dec. 5 experiment at the Livermore lab broke this threshold for the first time. It's a big deal, but it's only the first of the three milestones.



The recent fusion breakthrough is reminiscent of Enrico Fermi's pioneering work leading to fission reactors.

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The second is the engineering break-even, when the entire fusion reactor produces more energy than it consumes. To be a useful source of power, you need facilities that on net produce, rather than consume, energy. The recent reaction wasn't close.

To deploy fusion also requires attaining a third milestone, known as the economic, or commercial, break-even, when a fusion power facility is cost-effective to operate compared with other power sources.

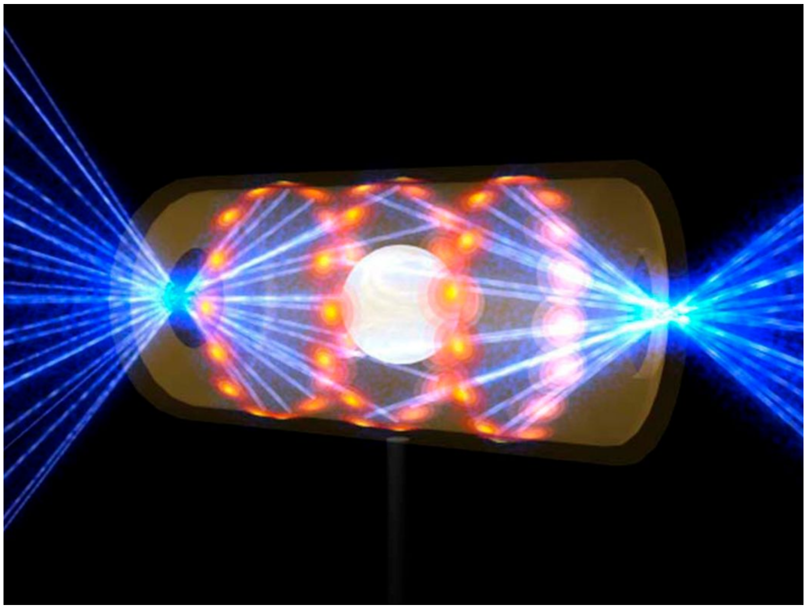
So where do we stand after the recent news?

Today's nuclear-power plants employ fission: splitting a large atom, unleashing energy (and generating long-lived radioactive waste). Fusion occurs when two small atoms are heated enough to fuse, producing energy.

Fusion is the process that powers stars, including the sun. Experiments such as the Livermore lab's seek to re-create this phenomenon on Earth. It involved firing the world's most powerful laser system at a tiny, nearly perfectly round, supersmooth diamond capsule, crushing the hydrogen atoms inside.

A simple ratio commonly known as Q provides an easy and intuitive way to understand if scientists are making progress: It's energy released divided by energy used. A Q below one means the reaction consumed more energy than it produced. A Q above one means more energy was produced than consumed.

In this latest experiment, scientists put in 2.05 megajoules of energy and got 3.15 megajoules out. Q was 3.15 divided by 2.05, or about 1.5.



Fusion tests seek to re-create the process powering stars.
PHOTO: LAWRENCE LIVERMORE NATIONAL LABORATORY/ASSOCIATED PRESS

Tony Roulstone, a nuclear-energy engineer at the University of Cambridge, called this milestone the "now we know it works" one, equivalent to when the physicist Enrico Fermi first created a nuclear chain reaction in 1942, ultimately leading to the hundreds of fission reactors around the world that today produce 10% of the world's electricity.

If a reaction produces more heat than it consumes, couldn't you just run the experiment on repeat and create infinite energy? The practical challenges are enormous, said Mr. Roulstone. The laser would have to be fired many times a second, with those perfect little diamond capsules accurately inserted and positioned dozens of times a second, he said.

The bigger obstacle is the second Q value, the engineering break-even. The scientists behind the recent breakthrough have been careful to clarify that the specific reaction produced more energy than it consumed, but the entire reactor didn't.

Mark Herrmann, the Livermore lab's program director for weapon physics and design, told reporters that to generate 3.15 megajoules of energy, the lab consumed about 300 megajoules of energy to fire its laser.

You don't need to be a physicist to realize that this is far from a viable source of power. The Q value for the entire reactor is about 0.01—roughly 1% of break-even.

"The laser wasn't designed to be efficient," said Mr. Herrmann. "The laser was designed to give us as much juice as possible to make these incredible conditions happen in the laboratory."

This means scientists need to improve the technology by a factor of 100, said Jonathan Menard, chief research officer at Princeton Plasma Physics Laboratory.

The thing to watch in forthcoming fusion experiments is whether this engineering Q value starts to march toward 1, or remains tiny.

There's reason for hope. Over time, lasers have grown more efficient, using less electricity to generate the same optical power. (This is known by the delightfully low-tech term "wall-plug efficiency.")

Also, the Livermore scientists said that the diamond capsule in their experiment had imperfections and that construction of the National Ignition Facility, where the experiment took place, began over 20 years ago. "The technology is '80s and '90s technology," said Tammy Ma, lead for the laboratory's inertial fusion energy institutional initiative.

“If you gain a factor of 10 on the fusion and 10 on the efficiency, that gives you a factor of 100 roughly,” said Dr. Menard. “That would be in the ballpark of break-even. Both of those are theoretically possible.” With government support that could take one to two decades, he said. “We should try for one and push really hard for that,” he added.

Then comes the final challenge: economic, or commercial, break-even. Once you have fusion reactors that produce more energy than they consume, will they actually be worth building, or would other sources of energy be cheaper?

That will depend on what happens to the prices of other power sources such as fossil fuels. Even if fusion is more expensive than some alternatives, Dr. Menard said he thinks it would likely have a useful role. Even with better battery systems, for example, solar and wind power will likely remain most useful when the sun is shining and the wind is blowing. Fusion plants could be powered up at other times to fill the gap.

“It’s going to take a lot more technological advancement to make it a practical energy source,” he said. But it’s still inspiring, he said: “I hope people will get excited to work on this superfun challenge—making a star on Earth.”

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