Fusion power milestone… and prognosis for fusion power?
The view from Vince Gutschick's perspective

Today, December 13, 2022, the US Secretary of Energy Jennifer Granholm announced a "breakthrough" in the quest for practical power from nuclear fusion. The 192 lasers at the National Ignition Facility (NIF) at Livermore National Laboratory delivered a pulse of 2.05 million joules of energy (2.05 MJ) to a small gold pellet holding a mix of two isotopes of hydrogen, deuterium and tritium. The temperature of the mix reached an estimated 150 million kelvin (as I recall reading recently), higher that that in the core of the Sun. The fusion energy released as heat was measured at 3.15 MJ, about 50% higher than the laser energy.

Yes, it's a first, but let's look at the full train of energy consumed in creating those 3.15 MJ. I include a sketch at the end, to accompany the bullet points here:

- The NIF lasers are 1980s models, about 1% efficient in creating light energy from electrical energy. The lasers needed almost 300 MJ of electrical energy for that pulse! OK, we might revisit this calculation with the concept of more efficient (20%) modern lasers (though these may not be suited for the pulses needed). However, the tritium problem is insuperable.
- The electrical energy was supplied from common thermal power plants. These are about 45% efficient in converting thermal energy in fossil fuels to electrical energy. To create 300 MJ out you need 300/0.45 = 670 or so MJ of fossil fuel energy.
- The energy released in fusion was not captured as practical power. If it could have been captured to use in a thermal power plant, it could have been converted to electrical energy again at about 45% efficiency, or 1.42 MJ. (OK, some raw thermal energy can be used for process heating in what's called cogeneration, but this become a minor quibble in this long process).
- Energy was needed to create the deuterium and tritium fuels. Deuterium is readily separated from ordinary water, in which it occurs at an average abundance of 0.031%. Tritium is a very different matter. There are no natural sources of tritium. It's radioactive, with a half-life of 12.7 years. All tritium in use, as in nuclear warheads, is produced in nuclear fission reactors. Short story: it's been shown that the fission energy needed to produce tritium is about 10 times greater that the fusion energy released. So, let's say we might need something on the order of 30 MJ to make the tritium for today's results.

Add up the energy inputs and you get 670 + 30 = 700 MJ in, for a paltry 1.42 MJ out. That about 0.2% yield. Questions, then:

- Does this really point to practical fusion energy, ever, or in "x" decades?
    - IMHO, I see the fusion energy program on a path that can't possibly create practical energy sources in less than, say, 50 or 100 years. Why do I choose those numbers? Part of it is personal. When I was in $5^{th}$ grade in 1955 I created a report on fusion energy, including its promises, the methods being pursued, and its progress. That was 67 years ago. With the energy figures above, we're still way far from the goal.
- Why is fusion so hard? Well, even stars have a hard time doing it… and that's a saving grace for us!
    - Stars, of course, do not use tritium. They do fuse deuterium, as a second step in the process of fusing hydrogen to helium the main process in most stars. Please see my webpage, [https://www.lcaoutreach.org/habitability-of-planets-2/](https://www.lcaoutreach.org/habitability-of-planets-2/). There you can

search for a massive amount of information, say, with terms like “deuterium” or “weak force.”

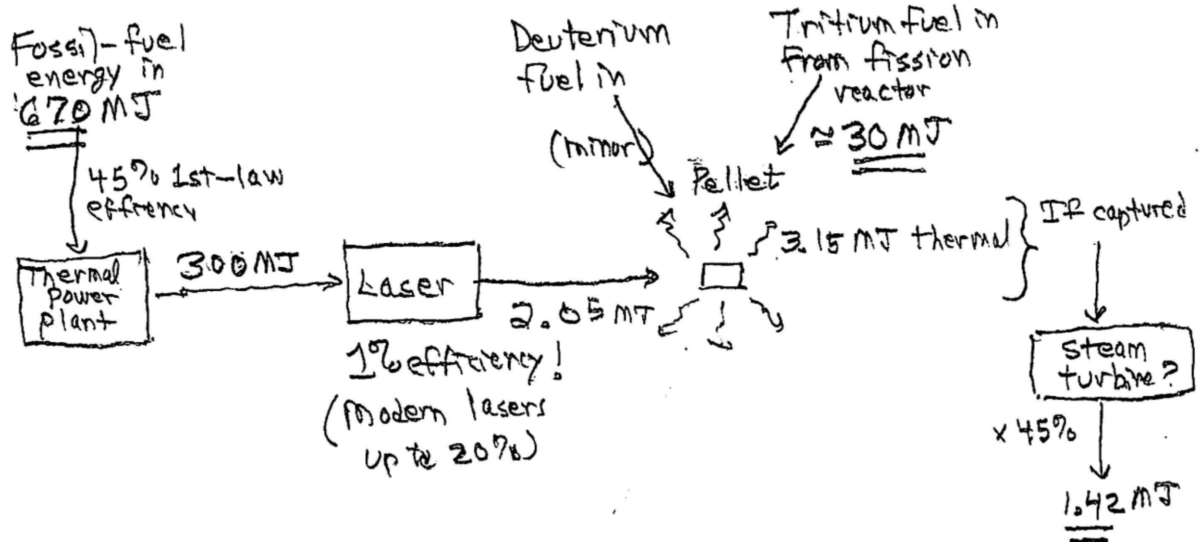
- The first step, fusing two atoms (well, ionized H, the protons) to deuterium needs:
  - (1) The intervention of the weak nuclear force to change a quark into another quark. This really, really slows down the rate of reaction. That’s a good thing! If H-H (or p-p) fusion were fast, stars would not really exist – they’d burn up in extremely short times and would never form as they do now. We are only here as living organisms because of their very slow burn.
  - (2) Even greater temperatures of the plasms, or ionized gas of hydrogen. Just the deuterium-deuterium fusion to helium requires temperatures about 10x higher than deuterium-tritium fusion. Creating these temperatures is immensely beyond current technology. For one thing, the radiative losses from a plasma 10x hotter than current plasmas is greater by a factor of 10 to the fourth power, by the Stefan-Boltzmann law. That’s a factor of 100 million.

So, fusion will not carry us forward in our existential crisis of climate change. We should have taken fossil fuels with their $CO_2$ releases out of our power systems long ago; we had warnings from at least 70 years ago. The real saving graces are from large-scale renewable energy sources – solar photovoltaics, wind power, and hydropower (toss in geothermal, which is technically not renewable; we mine the heat of deep rock that isn’t replenished for many tens of thousands of years or more).

My scientific career has been in physics and chemistry that then merged into biology – plant physiology and ecology, ecosystem dynamics, remote sensing, radiative transfer on small to large scales, etc. My PhD is in chemistry (really, chemical physics) from Caltech. I know of what I speak; that’s what I wish to impart.

Why the news hype, from US DOE, Livermore lab, and, on the largest scale, the International Thermonuclear Experimental Reactor or ITER, the $50 billion project in France? To be rather cynical, the NIF project was really for testing nuclear weapon warhead materials and it needed a peacetime cover story (and a tremendously long-shot hope for peaceful fusion energy). The ITER project is a great place to learn about plasma physics, but it’s aimed sideways as far as practical fusion power is concerned.

Go green for energy. Be amused by nuclear fusion research but count it out of our toolkit for preventing more catastrophic climate change in the critical next 10-20 years.




~700 MJ in

~ 1.42 MJ out as real power

→ 0.2% yield!