Nuclear Fusion “Breakthrough”?

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In its announcement about the National Ignition Facility (NIF) achieving ignition, the U.S. Department of Energy foresaw two benefits: it would “provide unprecedented capability to support…[the] Stockpile Stewardship Program” and it “will provide invaluable insights into the prospects of clean fusion energy, which would be a game-changer for efforts to achieve…a net-zero carbon economy”. The media, mistakenly although perhaps expectedly, has largely focused on the latter. That announcement was hailed by many as a step into a fossil fuel energy future. U.S. senate majority leader Charles Schumer, for example, announced that we were “on the precipice of a future no longer reliant on fossil fuels but instead powered by new clean fusion energy”.

Over the last decade or so, there have been many similar announcements featuring breathless language about breakthroughs, milestones, and advances. These statements have come with unfailing regularity from NIF (for e.g., in 2013) and the larger set of laboratories and commercial firms pursuing the idea of nuclear fusion. Apart from the United States, similar announcements have come from Germany, China and in the United Kingdom. France’s turn to make similar announcements is expected to come once the International Thermonuclear Experimental Reactor (ITER) starts operating. ITER is currently being built in Cadarache, France, at an estimated cost of somewhere between $25 billion to as high as $65 billion, much higher than the original estimate of $5.6 billion.

These incredibly high costs also explain why such announcements are made in the first place: without the excitement created by these hyped-up statements, it would be impossible to get funded for the decades it takes to plan and build any of these. Conceptual design work on ITER began in 1988. Of course, that timescale pales in comparison to the time period to the first major announcement about fusion generated electricity. That took place in 1955 when Homi Bhabha, the architect of India’s nuclear programme, told the first International Conference on Peaceful Uses of Atomic Energy in Geneva, “I venture to predict that a method will be found for liberating fusion energy in a controlled manner within the next two decades. When that happens the energy problems of the world will have been solved for ever”. That would not be the last prediction about the imminence of fusion power that would be wrong.

The false promise of “clean fusion energy” and “net-zero carbon economy”

Although most of the media hype did add an obligatory disclaimer about energy from fusion not being around the corner, almost none explained was that generating electrical power from nuclear fusion is unlikely to *ever* be economically viable. Three basic challenges confront the idea of using the same kind of process used in NIF to generate electricity.

First, there is the "physics challenge": to produce more energy than is used by the facility as a whole. NIF is far from meeting this challenge. In the recent experiment, the lasers pumped in 2.05 megajoules of energy and about 3.15 megajoules came out. But to generate that 2.05 megajoules, the 192 lasers at NIF consumed around 400 megajoules. Add to this, all the energy that goes into running the other equipment and the facility as a whole, and the energy used to construct the facility and the equipment, and it becomes obvious that the energy generated was a miniscule fraction of the energy input.

Then, there is the "engineering challenge" of converting this experimental set up that produces energy for a microscopic fraction of second into a continuous source of electricity that operates 24 hours/day and 365 days/year. To do that, these fusion reactions should occur several times each second, each second of the day, each day of the year. As of now, the lasers can fire only once a day, at a single target. To move from that state to what is required will need an improvement by a factor of over 500,000 (assuming around six shots per second).

But it is not just firing the laser. Each of these explosions produces a large amount of debris, which would have to be cleared. And then a new pellet has to be placed with utmost precision at the very spot where the lasers can focus their beams. All of this has to be carried out within a fraction of a second.

There are also challenges with the fuel used, a mixture of deuterium and tritium, two isotopes of hydrogen. Tritium, which decays radioactively with a half-life of only around 12 years, is very scarce, which is why each gram of tritium costs over $30,000. Further, generating tritium in situ is an exceedingly difficult task, which means that tritium would have to be constantly replaced.

The third is the economic challenge of having this incredibly complicated process compete with other simpler and far cheaper ways of generating electricity. Let me just give one example of the nature of the expense (in addition to the high costs of tritium): Because of the extreme precision needed, the pellet used in the NIF experiment reportedly cost over $100,000 to manufacture. Hundreds of thousands of these would be required each day to run a plant.

How does the cost of manufacturing translate into the cost of electricity? That pellet generated 3.15 megajoules, which it is only 0.875 kilowatt-hours, that too of heat, which would produce perhaps 0.3 kilowatt-hours of electricity if it was used to boil water and drive a turbine. At $100,000 per pellet, this amounts to over $300 million/MWh, that is about 10 million times more expensive than solar power today – and this is just the cost of manufacturing the pellets.

The high cost of manufacture is because of the extreme quality requirements. And if the quality falls, fusion doesn't occur. In May of this year, Bloomberg News published an article quoting Lawrence Livermore Director Kim Budil saying that the lab has run five similar experiments since last year's announcement, but ignition had not been achieved again. One of the reasons, according to Budil, was that the quality of the carefully made capsules wasn't quite as high as the one used in December. So fusion will require expensive pellets. This is just one of the economic challenges. There are many more. We can safely conclude that the odds of nuclear fusion generating electricity economically and reliably are miniscule.

In the meanwhile, nuclear fusion experiments like the National Ignition Facility will further the risk posed by the nuclear arsenal of the United States, and, indirectly, the arsenals of the eight other countries known to possess nuclear weapons. It is a way to continue investment into modernizing nuclear weapons, albeit without explosive tests, and dressing it up as a means to produce "clean" energy. The managers of NIF and the larger laboratory in which it is housed are careful to highlight different promises based on the circumstance they are speaking at. When anthropologist Hugh Gusterson asked a senior official about the purpose of the laser program, the official replied, "It depends who I'm talking to…One moment it's an energy program, the next it's a weapons program. It just depends on the audience".

The tremendous media attention paid to NIF and ignition amounts to a distraction, and a dangerous one at that.

As the history of nuclear fusion since the 1950s shows, this complicated technology is not going to produce cheap and reliable electricity to light bulbs or power computers anytime in the foreseeable future. But nuclear fusion falls even more short when we consider climate change, and the need to cut carbon emissions drastically and rapidly. The Intergovernmental Panel on Climate Change has warned that to stop irreversible damage from climate change, the world will have to achieve zero net emissions by 2050. Given this relatively short timeline to turn around our economies and ways of living, spending billions of dollars on this sure-to-fail attempt to develop fusion power only amounts to diverting money and resources away from proven and safer renewable energy sources and associated technologies. Investment in research and development into fusion is bad news for the climate.