Comments on nuclear fusion

Preamble:

last updated Nov 25, 2021

The main reason climate change activists should know something about “commercial” nuclear fusion is because nuclear advocates may well bring the idea up as the next magical mystery ride after the idea of small modular reactors begins to lose its lustre, as is already happening.

Controlled nuclear fusion is one of the many dazzling goodies in the Nuclear Dream Factory. The “Nuclear Dream Factory” is where the nuclear industry goes to fetch “new” ideas (which are in fact not new at all!!) in order to distract political leaders and the public, preventing them from focusing their attention on the truly dreadful aspects of nuclear energy — earth-shattering nuclear weapons and the never-ending legacy of radioactive waste. Like SMRs, nuclear fusion is another Dirty Dangerous Distraction — a mesmerizing illusion of a nuclear utopia that simply has no substance in the near term and cannot live up to its grandiose promises.

See https://www.youtube.com/watch?v=LJ4W1g-6JiY. [Thanks to Brennain Lloyd for calling this illuminating short video to my attention.] The presentation, from a fusion enthusiast, explains how deceptive the promoters of fusion can be, bending the simple concept of “net energy” completely out of shape in order to keep the money flowing in their direction.

That is not to deny that controlled nuclear fusion might be possible in the somewhat distant future, but it is debatable whether it is a desirable way to go even then. At present it is highly unlikely to make a bit of difference other than to gobble up much of the money allocated to reduce greenhouse gases without doing a thing to solve the problem.

Windmills and solar collectors can be put up anywhere in the world at the drop of a hat; not so with fusion reactors or even SMRs. Let’s not be like Nero, fiddling while Rome burns. Do what can be done quickly and cheaply first of all.

Nuclear Fusion

My experience with the promise of fusion energy is that it has always been just five years away, or at most 10 years away, from realization. This has been so, decade after decade, ever since I first became aware of fusion energy in the 1950s. And today, we are told it is still just 5 or ten years away.

Perhaps England’s 19th century poet laureate Alfred Lord Tennyson had fusion in mind when he wrote, “Yet all experience in an arch wherethrough gleams that untravelled world whose margin fades forever and forever as we move.”

The main requirements in achieving a self-sustaining fusion reaction on Earth are:

(1) Creating a “plasma” (whereby atomic nuclei are stripped of their orbiting electrons).

(2) Reaching and maintaining a temperature of about 150 million degrees C.

(3) Containing the hot plasma inside an electromagnetic “bottle” without contacting and/or melting other materials. (Difficult to prevent turbulence.)

(4) Massive electromagnets are needed for containment of the plasma, requiring extraordinary amounts of energy input.

(5) igniting a fusion reaction and keeping it going for more than 101 seconds (the world longevity record, set in China on June 4 2021).

Advantages of fusion:

(1) The fuel is the most abundant element in the universe: hydrogen (and its heavier isotopes deuterium and tritium)

(2) Nuclear fusion is a very long-lived process that powers the sun and the stars, illuminating the entire universe.

(3) Because atoms are not fissioned, there is no high-level radioactive waste (irradiated nuclear fuel).

(4) Catastrophic reactor accidents (releasing large quantities of fission products and actinides) are not possible.

(5) Fusion is a virtually inexhaustible source of energy, provided we can get it working with a net energy output.

Disadvantages of fusion:

(1) Fusion is not available - there’s no self-sustaining fusion reaction as yet, and no net gain in energy output over energy input so far. (It’s not even close!)

(2) Fusion neutrons are about 14 MeV (million electron-volts) compared with fission neutrons that are approximately 4 MeV — the fusion neutrons are very powerful, and very penetrating.

(3) Reactor structures become intensely radioactive (through neutron activation); in particular, a great deal of tritium is produced/released. (Materials become long-lived radioactive waste.)

(4) Neutron embrittlement of structural materials is severe — there is much greater damage than in the case of fission reactors. (Weakened components may have to be replaced often.)

(5) Excess neutrons can be used (if desired) to produce plutonium for nuclear weapons using a depleted uranium “blanket” to absorb neutrons after they have been slowed down.

The problem of neutron embrittlement may require replacing the structural materials in a fusion reactor much more often than is required for a fission reactor, seriously compromising the cost/benefit ratio, which is already rather fragile to begin with. Irradiated materials become long-lived radioactive wastes. The full extent of this problem is as yet unknown.

Technical Background:

Nuclear energy is energy that comes directly from the nucleus of an atom. There are two ways that nuclear energy can be released in a sustainable way: nuclear fission and nuclear fusion.

Radioactivity is another form of nuclear energy that, unlike fission or fusion, cannot be controlled — there is no method for stopping it or speeding it up or slowing it down. A radioactive atom has an unstable nucleus that will disintegrate spontaneously in a sudden and violent and unpredictable manner. However, the “half-life” is the time is takes for half of the atoms of a given type to disintegrate; radioactive disintegration is probabilistically predictable, but not individually predictable. The “subatomic shrapnel” given off by radioactive disintegrations will damage nearby living cells and can provoke a host of immediate or delayed medical problems, depending on the dose.

That’s why we have a radioactive waste problem. Fission and fusion can, in principle, be controlled, radioactivity cannot.

(1) Nuclear fission

In nuclear fission, a very heavy atom (like uranium or plutonium) splits apart, releasing enormous energy as the nucleus undergoes a sudden catastrophic disassembly. The splitting, or “fission”, of the nucleus can sometimes happen spontaneously, but it is more often provoked by bombarding the nucleus with subatomic projectiles called neutrons. The unstable nucleus literally splits apart into two rather large chunks, or fragments, while giving off a small number of additional neutrons, all of them travelling very fast.

The additional neutrons are needed to multiply the number of subsequent fissions and magnify the energy output from the micro to the macro level and beyond. But those additional neutrons also damage structural material through embrittlement, and make them radioactive through “neutron activation”. When a non-radioactive nucleus absorbs a stray neutron it is often destabilized, becoming a radioactive nucleus (radionuclide). The extra neutrons also transform unfissioned uranium atoms into atoms of neptunium, plutonium, americium, curium etc., the so-called “transuranic” elements, making the connection between peaceful nuclear power and the proliferation of nuclear weapons.

The broken fragments of the originally intact nucleus repel each other very strongly as soon as they are liberated from the binding force that normally shackles them together inside the nucleus. A tremendous “kick” (kinetic energy) is imparted to these positively charged fission fragments by the force of electromagnetic repulsion. The momentum is transferred to surrounding atoms and molecules by repeated collisions, causing enormous quantities of heat to be generated in the surrounding material as the fast-moving fragments of fission are rapidly slowed down. Each fragment becomes the nucleus of a newly created radioactive atom called a fission product. The fission products, numbering in the hundreds of different varieties, remain trapped in the fuel -- they constitute the bulk of the high level radioactive waste from present-day nuclear reactors. Most of them were never found in nature prior to the discovery of fission in 1939.

Once created, these radioactive waste materials cannot be neutralized or rendered harmless. Some disintegrate in the blink of an eye, others last for hundreds of thousands or even millions of years as radioactive poisons. Each of these human-made radioactive elements has its own “half-life” — the time required for half of the atoms to disintegrate by radioactive decay.

(2) Nuclear fusion

In nuclear fusion, very light atoms (like hydrogen, deuterium or tritium) are fused together to make heavier atoms. The main difficulty in achieving fusion is getting two positively charged objects — the nuclei of the two hydrogen atoms — to come close enough together to merge into a single entity, a new nucleus. The force of electromagnetic repulsion is strong, and it gets stronger and stronger the closer the two objects come together, approaching infinity as the distance between them approaches zero. But when they get close enough, another force takes over — one that is millions of times more powerful than the electromagnetic force. It is called “the strong nuclear force”, and it is what binds the constituents of a complex nucleus together, easily overwhelming the electromagnetic force of repulsion that would blast the positively charged constituents of the nucleus apart if they were not held together by the much stronger "nuclear force". There are actually two nuclear forces (the “strong nuclear force” and the “weak nuclear force”) and they are confirmed by modern science to be the strongest forces in the universe.

The only mechanism we know that can force two positively charged nuclei together, despite their mutual repulsion, is by greatly increasing the kinetic energy of the nuclei by raising the temperature to an extremely high degree. In much hotter objects, the atoms and molecules move much faster, colliding with each other with ever-greater momentum. If the temperature is hot enough — about 150 million degrees C — two nuclei on a collision course are moving so extremely fast that the force of electromagnetic repulsion is unable to deflect them quickly enough from their trajectory. They can then come close enough to each other so that the nuclear force can take over, easily overpowering the repulsion and binding them so tightly together that the two nuclei fuse together to form a larger nucleus. For example, when two hydrogen atoms are forced to “fuse”, they form an atom of helium. At the moment of fusion, enormous energy is released. The energy density (energy per unit mass) released from fusion is much greater than it is from fission.

In the center of the sun, fusion occurs at a lower temperature of about 15 million degrees C. That's because the fusion process is greatly assisted by the concentrated gravitational force pressing inwards towards the center. On Earth, without that extra boost from gravity, the temperature required for fusion to occur must be about ten times higher.

Gordon Edwards.

P.S. Because a nuclear fission chain reaction can be triggered by a single neutron, there was no doubt that atomic bombs (A-Bombs, based on fission) would work, using either highly enriched uranium (> 90 percent U-235) as in the Hiroshima bomb, or plutonium as in the Nagasaki bomb.

But because nuclear fusion has no trigger except extremely high temperatures, the much more powerful H-Bombs or "Hydrogen Bombs" (thermonuclear weapons, where most of the energy release is from the fusion of hydrogen isotopes) requires a small A-Bomb as a trigger in order to raise the temperature to the tens of millions of degrees C needed to ignite the fusion reaction. That's why a small plutonium A-Bomb must be used as a triggering mechanism in every H-Bomb. When the plutonium "pit" is removed, the H-Bomb is rendered harmless.

See the discussion by Robert Alvarez: www.ccnr.org/Con-Fusion_2014_02_15.pdf

Although the bulk of the energy released from a thermonuclear explosion is from the fusion of hydrogen nuclei, that energy is mainly in the form of extremely energetic neutrons, which have such great penetrating power that they do not contribute to the blast as much as they might, so the military uses cast-off uranium (depleted uranium, mainly uranium-238) left over from the enrichment of natural uranium (whereby the fissile uranium-235 is concentrated and the non-fissile uranium-238 is discarded). Although U-238 cannot sustain a nuclear chain reaction, the nuclei of U-238 atoms can be – and are – split by the enormously powerful fusion neutrons.

It is not widely appreciated, even in the nuclear community, that by far the largest contributor to the actual "blast" of a thermonuclear weapon is due to the fissioning of depleted uranium atoms (in particular, the fissioning of uranium-238 atoms.) The very first thermonuclear weapon tested by the US military was the Ivy Mike bomb, using uranium-238 in the third stage of the fission-fusion-fission weapon, yielding a blast (due mainly to the fissioning of uranium-238) approximately 700 times more powerful than the blast of the Hiroshima bomb (due to the fissioning of weapons-grade uranium, more than 90 percent uranium-235).

GE.