Fusion Energy: Fiasco or Finesse?

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Science and technology have never been under greater pressure to come up with some new source of cheap, clean energy than they are today. Not surprisingly, then, we have a renewed interest in Einstein's hypothesis, subsequently verified, that physical mass could be converted to energy – hence nuclear energy.

The extreme nature of this process has become common knowledge. A large power station can use as little as a gram of matter per day. Also common knowledge is the fact that there are two quite different approaches to tapping this energy source: fission and fusion – fission being the splitting of large atomic nuclei and fusion the merging of two light nuclei.

Fission has been producing reliable energy for many decades and has, when in competent hands, a relatively good track record of safety – relative, that is, to comparable industrial activities. Would I live next to a fission plant? Well, not if I could help it, even though recent evidence suggests that low levels of radioactivity may be good for the health. But then I'm a self-indulgent, middle-class westerner with plenty of choices and a penchant for green open spaces.

Half a century should have been long enough for the fission industry to establish credentials as cheap and clean. Has it? Costings of existing plant are uncertain because almost none of the waste has been permanently secured – a serious problem when we have no idea that 'secure' will mean a century, let alone a millennium, into the future. Complicating this is the need to re-process present wastes to produce fuel when stocks of uranium run low. Other costs, such as the diversion of fuel into weapons, are incalculable – particularly if nuclear energy is to become widely available. Rapid expansion of the industry also faces serious problems of skills and materials shortages.

One possible hope for expansion of the fission industry is the current development of small-scale, sealed reactors. These are planned as maintenance-free, trucking container sized units that can be sealed, delivered, buried then reclaimed thirty odd years later for refuelling. The small size decreases unit cost efficiency but this may be more than offset by mass production. With a little ingenuity and cost these could be made tamper-proof, or at least tamper-aware so that timely protective action can be taken. Another possibility is use of the thorium fuel cycle.

What then of fission's Cinderella sister – fusion? The only seriously funded contender here is plasma fusion – an attempt to recreate the conditions of extreme temperatures and pressures found inside the sun in a magnetic bottle (or fiasco). For the last forty or fifty years researchers have been saying that success is forty or fifty years away. Plug those numbers into a risk formula and it will tell you there's Buckley's chance. A closer examination suggests that the situation might not be so bad. Over that period of time the goal-posts have shifted. In the 50s the goal of creating a stable plasma with a high enough temperature to observe some fusion events was an ambitious one and almost beyond speculation. To a speculation-weary mind, the next step to commercial power would have seemed relatively straight-forward.

That initial goal has been largely achieved – but not simply or cheaply. If the problems that have been encountered along the way had been anticipated the effort might never have been undertaken. In the mean time the problem of ramping up to commercial power levels has escalated, or come into sharper focus, and the goal of cheap reliable power is still highly questionable.

Should the efforts be continued? I think definitely, yes. Even discounting the possibility of cheap power, the knowledge that has been accumulated about a new form of matter has been meaningful, interesting and useful, which is more than can be said for the expensive international race for ever larger particle accelerators.

Are there other contenders for fusion technology? Here the issue becomes even more complex and controversial. Simply put, the goal of nuclear fusion is to get the nuclei of two hydrogen atoms to combine to form a helium nucleus which has a slightly lower mass than two hydrogen nuclei – the excess mass being released as energy. This reaction doesn't proceed readily. There is a barrier to cross – a barrier that is both physical and psychological, and perhaps even ideological.

When Einstein showed that the energy of matter could only take certain specific values (was quantised) he opened a window into the world of the atom and below. By the mid 1920s mathematical equations had been constructed that could accurately predict the values of these energy levels and their stability.

These equations describe waves and vibrations but give no direct pointer to what, if anything, is actually waving or vibrating. The most obvious candidate comes from Einstein's theory of relativity. It says about matter that it bends or distorts space and that it is directly interchangeable with energy. A small speculative jump gives us matter as bent space with the associated energy just that needed to do the bending. Quantum Mechanics (QM) suggests vibrations, so we end up with a sub-atomic particles such as our hydrogen nuclei being vibrations of space. QM also indicates that transitions happen when the vibrations are synchronised or resonant. The barrier to fusion can now be seen as a lack of resonance – the particles are 'out of synch'.

Vibration and resonance are ubiquitous in nature. A simple examples are a pendulum or child's swing. A series of small pushes can build up the energy of the swing if they are synchronised to the movement of the swing. Too much 'excitation' and the child is flung off the swing, so we quickly place a swimming pool in position to catch them and note the splash produced from the excess energy of the fall. Alternatively we can imagine two trapeze artists building up their swing until they can reach each other in the centre of the circus tent – but only if their swings are synchronised. A thin elastic band connecting the swings could help synchronise the swings – absorbing energy one moment then letting it out the next – acting as a catalyst. Eventually our trapeze artists will meet in mid air, clasp each other and be united. If they both let go of the swings they will fall together to the safety net below and the energy of the fall will be dissipated in vibrations of the net.

What our two hydrogen nuclei need, then, is something that will nudge or finesse them into synch then remove the excess energy so that it doesn't break the pairing up again – the catalyst. Hot fusion relies on chance for synchronisation. In a hot, dense plasma particles collide often and some will be in synch. Excess energy is removed by the emission of another particle such as a photon of light.

The big question, then, is any other approach possible? There are comparable QM transitions. In a laser (Light Amplification by the Stimulated Emission of Radiation) an excited atom in an intense light beam is coaxed into dropping to a lower energy level by the vibrations of the light to produce a new photon that adds to (amplifies) the beam.

In the 1950s it was predicted that the muon, a particle much like an electron but with over 200 times the mass, could act as a catalyst for fusion. This was soon verified experimentally. The catch was that muons are expensive to produce and, though they are not used up in the reactions, they have a short life span. The reaction does, however, provide a proof of concept because the reaction happens at temperatures much lower than necessary for plasma fusion.

The question then becomes: are there cheaper alternatives to muons? In metal crystals the metal atoms are arranged in regular arrays and some of the electrons are free to move about, which is what allows them to conduct electricity. Groups of elections can synchronise and these clusters can, in QM, be seen as particles in their own right. These particles can potentially have the mass of millions of electrons.

Metals can also absorb hydrogen which forms regular arrays in between the metal atoms. In the 1980s, QM calculations suggested that these might form flat resonant sheets of matter within the crystal. Here adjacent hydrogen nuclei are already synchronised and the large synchronised sheet can potentially act as the catalyst. One metal, in particular, absorbs hydrogen readily: palladium. Now if we look beside the road we have followed we see a battered and bullet-holed sign saying 'Cold Fusion Was Here'. Respectable, orthodox physicists quickly avert their eyes and cross themselves nervously repeating a few grave incantations: 'Nuclear fusion in a test-tube? Impossible! It needs high temperatures. It must produce high energy photons or other particles. We've seen so in plasma fusion. That's how it happens in the sun.'

For a couple of electro-chemist interlopers to suddenly appear centre stage in the Physics tent and put on a poorly rehearsed performance was too much to bear. They were jeered off the stage and pelted with the academic equivalent of rotten eggs. Overnight reviews condemned. Cautious reviewers procrastinated. The act went underground. In retrospect, pushing for large scale energy production – even test-tube scale – was probablty too ambitious. A more conventional approach would be to attempt to set up and observe single fusion events in an appropriate solid lattice and scale from there. Metals may not be the best place to start. There are plenty of regualar structures in nature that exhibit large-scale quantum resonance – even structures in the cells of our bodies. Carbon nanotubes provide a strong, regular structure with interesting electrical properties.

One intriguing possibility for this Lattice Catalysed Fusion is the direct transfer of energy to electrons in the lattice and, hence, the possibility of direct and efficient production of electrical energy. Quick results are unlikely but the potential benefits are too great to be ignored.