Cold fusion may have revolutionary potential

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Unlimited amounts of pollution free energy

Cold fusion is a form of nuclear energy produced in metals saturated with hydrogen or heavy hydrogen (deuterium). It has been replicated in hundreds of major laboratories, and these replications have been published in mainstream, peer-reviewed journals. This literature shows that cold fusion can generate heat at temperatures and power density equivalent to a fission reactor core. It has sometimes produced high power, 20 to 100 watts, in reactions that produced roughly 100,000 times more energy than any chemical fuel. The reaction has seldom been scaled above the 100-watt level because it is difficult to control. If researchers learn to control cold fusion, it is likely to become a practical source of energy. There is enough hydrogen fuel to last for billions of years. The cost of the metals and hydrogen is orders of magnitude lower than the cost of oil, coal or uranium. Cold fusion produces only trace amounts of radioactive material, mainly tritium, which can easily be contained. Thus, it is likely to provide safe, inexpensive energy on a far larger scale than any other source, giving every person on earth as much heat and electricity as first-world residents now enjoy.

Cold fusion does not produce carbon dioxide or any other chemical product, so it would eliminate the source of global warming. Combined with other technology, it can be used for many other beneficial purposes, such as:

- Small generators that eliminate the need for an electric power distribution system, making them cheaper per kilowatt hour and more reliable.
- Cold fusion can enhance indoor farms (food factories). Holland has pioneered these to become the second largest agricultural exporter in the world. [1] Food factories greatly reduce the land area needed for agriculture; they reduce water consumption by 90%; they eliminate the need for pesticides; and they will eventually reduce the cost of food, especially when operated with cold fusion heat and electricity. They could easily provide enough food for every person on earth.
- A massive desalination project can reverse desertification, reducing the Sahara and Gobi deserts back to the size they were before human agriculture began.
- Cold fusion powered automobiles, airplanes, drones (UAV) and other vehicles would have unlimited range. Automobiles would go 48 million miles with one gallon of heavy water (20 million kilometers per liter).

- Small, advanced robots powered by cold fusion might operate autonomously for years without refueling, to do tasks such as cleaning up litter, locating and cleaning up radioactive hotspots from the Fukushima reactor accident, or locating and rooting out invasive plant species.
- Cold fusion would enhance energy intensive, automated, advanced recycling techniques. One such technique is to mix waste materials with molten steel in a sealed container. Most of the waste is converted into useful raw material. None of it escapes into the environment. This has been developed but it is uneconomical, partly because of the high cost of energy. It could be used to safely recycle toxic chemical waste from "superfund" sites. Eventually, it could eliminate most landfills.
- Cold fusion would bring about many other advances we cannot anticipate, just as computers and the Internet have done.

Cold fusion might as easily be used for nefarious purposes, such as new kinds of weapons. Governments might spy on citizens with surveillance drones that can travel any distance and patrol for months. Terrorists might use them to assassinate people. Cold fusion might be used to wreak environmental havoc. When cold fusion was first announced, some critics said that it is such a potent source of energy that giving it to mankind would be "like giving a baby a machine gun." [2] However, both ancient and modern technology can be used to destroy the environment. People are destroying large areas of the Amazon with fire. Ancient people expanded the Sahara desert with primitive agricultural techniques. We can protect the environment with appropriate laws and regulations. They will apply to cold fusion just as they do to conventional energy sources.

Any major technology that is used irresponsibly can cause havoc. There are always people happy to destroy things for money. If you devise a way to earn an easy $100 per acre by incinerating a rain forest, or killing off a thousand tons of ocean krill, you can bet someone will do it unless laws are passed forbidding the practice. Every major technology has both advantages and grave disadvantages. Automobiles give us mobility but they also kill 1.2 million people a year worldwide and they are the main source of air pollution. [3] Cold fusion will probably have fewer deleterious effects than most technologies. It is likely to be safer than other energy sources, especially combustion and fission.

Why we know this is a nuclear reaction

We know that cold fusion is a nuclear reaction because it produces far more energy than any chemical reaction, and because it produces helium in the same ratio to the heat as plasma fusion does, and also nuclear products such as tritium, neutrons, gamma rays and transmutations, albeit at much lower ratios than plasma fusion does. [4] Researchers at Amoco described this in the discussion of their results:

> “The calorimetry conclusively shows excess energy was produced within the electrolytic cell over the period of the experiment. This amount, 50 kilojoules, is such that any chemical reaction would have had to been in near molar amounts to have produced the energy. Chemical analysis shows clearly that no such chemical reactions occurred. The tritium results show that some form of nuclear reactions occurred during the experiment. The tritium produced was not nearly enough to account for the excess energy.” [5]

In a series of tests at Toyota, cathodes the size of coins, weighing 2 to 15 grams each, produced 20 to 100 watts of heat for months. In the best case, a cathode weighing 15 grams produced 101 watts for 30 days continuously, and 22 watts average over the entire 158 days of the experiment, adding up to 294 megajoules. [6] Burning 15 grams of the best chemical fuel, gasoline, produces 0.6 megajoules, or 459 times less than this. However, this is not a reasonable comparison, because there is no gasoline or any other chemical fuel in a cold fusion cell. No chemical transformations other than a slight tarnishing of the cathode have been observed in a cell that produced anomalous heat. McKubre estimates that there would be at most 7 kilojoules of chemical fuel in a cell exposed to “an unlimited supply of oxygen.” [7] There is very little oxygen in a cold fusion cell, so this estimate is “in practice, extremely unlikely and certainly overestimates the amount of chemical energy that is realistically available.” Fleischmann made a more realistic estimate of ~0.5 kilojoules in a typical cell. [8] The Toyota cell produced 588,000 times more energy than this.

Note that it is very easy to detect 20 to 100 watts of heat. In many cases, there is no input power, so the cell would be at room temperature if it were not producing cold fusion heat. Think about how it feels to hold your hand above an old fashioned incandescent light bulb producing this much power. This can be measured with absolute confidence using laboratory grade calorimetric equipment, which can usually detect power as low as 0.01 watts.

In the experiment producing 294 megajoules, the hydrogen fuel was not used up; the experiment might have continued far longer. Cold fusion devices can probably produce 10 million times more energy than any chemical fuel of equivalent weight.

Many people have the impression that all nuclear reactions produce dangerous radiation and long-lived radioactive byproducts. That is incorrect. Nuclear power from plutonium-238 is so safe that plutonium thermoelectric devices have been used in heart pacemakers. They are mainly used in satellites and in the Mars Curiosity Rover. Plutonium-238 cannot be widely used because it is rare; it must be separated from dangerous isotopes; and it is expensive, costing about $10 million per kilogram. [9]

Cold fusion produces microscopic amounts of tritium, which is radioactive. Tritium has a short half-life and it produces beta decay which can be stopped with a sheet of paper. It is used today in wristwatches and emergency exit signs.

Cold fusion is not a chain reaction, and it only occurs in an intact metal lattice, so it cannot cause a catastrophic nuclear explosion.

As noted, the highest power achieved with palladium has been about 100 watts, sustained continuously for a month. Much less research has been devoted to other metals such as titanium and nickel. Most tests of nickel have failed to produce heat, or they have produced very low power, at marginal signal to noise ratios. Nickel and titanium are much more abundant and cheaper than palladium, so if they can be made to work they will have many advantages. Nickel appears to work with ordinary hydrogen, rather than deuterium.

Andrea Rossi has reported large sustained reactions with gas loaded nickel nanoscale powder, sometimes in the kilowatt range lasting for weeks. There is usually no input power with this technique, or only intermittent input, so a measurement error is unlikely. Rossi's results have not been independently replicated. However, they have been independently confirmed by other groups who visited Rossi's laboratory and brought their own instruments to measure the heat. This was done in 2011 by researchers from U. Bologna. In 2013, a group of researchers sponsored by ELFORSK visited the laboratory three times and made more extensive measurements, confirming the claims. (ELFORSK is the Swedish electric power company research consortium with an annual budget of $43 million.) In the first test, they observed a gas loaded steel cell that melted from a runaway reaction of high but indeterminate power. It was connected to an ordinary electric outlet which could not possibly supply enough electricity to melt steel. In the third test, they measured sustained anomalous power of 578 watts produced continuously for 116 hours, or 240 megajoules. The cells are 33 cm × 10 cm diameter. The ELFORSK observers opened the cell after the test and found only a small amount of nickel powder, proving this is far more energy than chemical fuel of equivalent weight can produce. [10, 11]

Difficulties with research

Progress in this research has been slow for these reasons:

The problem turned out to be more difficult than anyone anticipated in 1989.

Cold fusion resembles cloning in that it has been widely replicated but replication is still difficult and it requires great skill. Most researchers can make cold fusion work about two-thirds of the time, whereas the success rate with cloning is 0.1% to 5%. [12, 13] The fact that an effect is difficult to reproduce is no indication that it does not exist, or that it will remain difficult.

There is no widely agreed-upon theory, although many individual theorists believe they can explain the reaction. There are no useful models. Researchers must resort to Edisonian trial and error.

There is a great deal of opposition to the research because of academic politics, so there has been little funding. [14] The details are beyond the scope of this article, but the result is that most research is done on a shoestring by retired professors.

Mass media inaccuracy

Many people have the mistaken impression that cold fusion does not exist, or that it has never been replicated. Such misinformation has often been reported in the mass media. Even scientists sometimes believe this, because they have read the *Washington Post* rather than the *Japanese Journal of Applied Physics* or the *Journal of Electroanalytical Chemistry*.

The weight of evidence in mainstream peer-reviewed journals of chemistry and physics is overwhelmingly in favor of cold fusion. The literature proves beyond doubt that the effect is real, and that it has produced high power, and high signal to noise ratios. A tally of experiments published by the Institute of High Energy Physics, Chinese Academy of Sciences, shows 14,700 positive experimental runs in the literature. [15] In the database compiled by Storms and Britz there are 153 peer-reviewed papers describing excess heat results, and many other describing tritium, neutrons, transmutations and other nuclear effects. (In some cases researchers did not look for heat, but only for tritium or other nuclear products.) [16] In 1990, Will tallied positive results from 92 major laboratories. [17] Storms lists replications in more than 180 major laboratories such as Los Alamos, China Lake, the Italian ENEA national nuclear laboratories, BARC, [18] Mitsubishi and several national universities in Japan. [4]

There were some prominent failures in 1989. Three of these failed experiments, from MIT, Cal Tech and Harwell, are often cited as proof that cold fusion does not exist. However, when experts re-examined these results, they found evidence for significant excess heat, so these were probably false negatives. [19, 20] Most of the other early negative experiments failed for reasons that were unclear in 1989 but are now well understood.

In experimental science, a phenomenon that has been widely replicated at a high signal-to-noise ratio must be considered real. There is no other standard of truth. Some theoreticians claim that cold fusion cannot be real because it violates theory. Or, they say that if this is a nuclear reaction, theory says it must produce a deadly flux of neutrons. Many people have observed cold fusion reactions without being killed, so the reaction cannot be producing neutrons at the expected rate. If these theoreticians are correct, and theory does make these predictions, this proves the theory needs to be reworked. It is fundamental to the scientific method that when replicated experiments conflict with a theory, the experiments are right and the theory is wrong.

Mass media reporters do not realize that papers have been published. They are usually surprised to learn this. The lesson from this is that you should read original sources to evaluate a scientific claim. Editors and authors at science magazines may be aware that papers are available, but apparently they have not read them, because they often make technical errors. For example, in 2005 the *Scientific American* editors claimed that:

1. “Helium 4, a suggested cold fusion by-product, was detected at amounts close to background levels.”

Correction: In some experiments helium-4 has been close to the background, but in others it has been far above background. In one case the concentration rose above atmospheric concentrations of helium. In another set of experiments, helium was added to the cell before the test to bring it up to atmospheric concentration, and it then rose above that. These tests show that the helium cannot be contamination from the atmosphere.

2. “Expected gamma rays were not produced; experts doubted the explanation that all energy was generated as heat instead.”

Correction: gamma rays have been detected in many experiments although not in amounts commensurate with a conventional plasma fusion reaction. Other nuclear products including tritium, helium, x-rays, charged particles and transmuted elements have also been detected. Tritium has sometimes been measured at high levels, ranging from 50 times background up to millions of times background. [21, 22]

3. “Not all chemical explanations for the excess heat were eliminated.”

Correction: In all replications on record, there is not a single instance in which significant amounts of chemical fuel was present in the solution. Chemical transformations have not been found. As noted above, cold fusion has generated 588,000 times more energy than chemical fuel. To put it another way, cold fusion devices the size of a coin have produced as much heat as you would get if you burned the laboratory instruments, the furniture, and notebooks; or as much as you get from burning 4.2 gallons of gasoline (16 liters).

4. “Excess power was only a few percent more than the power applied, suggesting that measurement errors could account for the purported net energy.”

Correction: Excess power has sometimes ranged up to 3 to 25 times input, when input power is applied. [23] In many cells, no power is applied, so this measurement error cannot occur. These include gas loaded cells, and electrochemical cells when the power is off. After electrolysis is turned off, small reactions sometimes continue for hours. Large reactions have continued for 1 to 15 days, sometimes increasing in power, before gradually subsiding and falling to zero. [24-26]

Advantages

Cold fusion has many advantages over other energy sources, summarized in Table 1.

Table 1. Comparison chart for different energy sources

	Pollution free	Very Safe	In-Exhaustible	Unlimited	Low fuel cost	Low reactor cost	Compact	Locate anywhere	Works 24/7 (4)	Ready Now
Fossil fuel						✔	✔	✔	✔	✔
Hydro-electric	✔	✔	✔		✔	✔	✔			✔
Wind	✔	✔	✔		✔					✔
Solar	✔	✔	✔		✔					✔
Uranium fission	(1)		✔	✔	✔		✔	(3)	✔	✔
Plasma fusion	(2)		✔	✔	✔		✔	(3)	✔	
Cold fusion	✔	✔	✔	✔	✔	✔	✔	✔	✔	

(1) Fission reactors produce no pollution during operation, but uranium mining does, and the disposal of radioactive waste (radwaste) and spent fuel are serious and expensive problems. The accidents at Chernobyl and Fukushima released large amounts of nuclear waste into the environment, forcing people to abandon large areas. In Japan 4% to 8% of the land is now contaminated with radioactive cesium. [27]

(2) According to a Los Alamos study, plasma fusion reactors would produce about the same amount of nuclear waste that conventional, present-day fission reactors do, they would not be commercially competitive with advanced fission reactors, and they would not have significant environmental, safety and health (ES&H) advantages over advanced fission. [28]

(3) Fission reactors are located far from cities because they can fail catastrophically, and plasma fusion reactors would probably produce large amounts of dangerous radwaste, so it would not be prudent to locate them near population centers.

(4) “Works 24/7” means the energy source is available on demand, and it is available at night, unlike solar energy. Solar or wind energy might be converted to hydrogen and stored for times when they are not available, but this would increase cost. Hydroelectric power has to be reduced during droughts. Any energy system must be turned off periodically for maintenance.

Even at the present primitive stage of development, it is clear that cold fusion has the potential to be flexible, scalable, clean, safe, and easy to use, with no emissions. It is millions of times more energy dense than chemical fuel. It is available nonstop, unlike solar or wind. The fuel is available in unlimited amounts; enough to vaporize the whole planet Earth. The nickel hydride version is even better: materials, manufacturing, distribution, maintenance and disposal appear to be inexpensive and safe. If researchers learn to control the reaction, it will become the ideal source of energy.

Cold fusion seems so good that some people suspect the researchers are engaged in wishful thinking, and they are making mistakes. If the reaction had only been measured at a fraction of a watt, with nearly as much input power as output power, this would be plausible, but in many instances it has been measured at irrefutably high power for long durations. More to the point, a small number of scientists may make mistakes, but thousands of professional scientists do not blunder repeatedly over many years. If that could happen, the experimental method would not work. People who think cold fusion is too good to be true should remember Michael Faraday's dictum: "Nothing is too wonderful to be true if it be consistent with the laws of nature." Mankind has discovered countless wonderful things that ancient people would have thought miraculous, and also things such as thermonuclear weapons that ancient people would have found unimaginably dreadful.

What we will do with it

I hope that people use this technology to let much of the earth go back to nature, by producing food in factories, and in the distant future by putting highways and industrial plants underground. Winston Churchill discussed nuclear fusion in 1932, and that is what he advocated. He wrote: [29]

> "Nuclear energy is incomparably greater than the molecular energy which we use today. . . . If the hydrogen atoms in a pound of water could be prevailed upon to combine together and form helium, they would suffice to drive a thousand-horsepower engine for a whole year. . . . There is no question among scientists that this gigantic source of energy exists. . . ."

Churchill described the immense power this would give us for good or for evil:

> "The discovery and control of such sources of power would cause changes in human affairs incomparably greater than those produced by the steam-engine four generations ago. Schemes of cosmic magnitude would become feasible. Geography and climate would obey our orders. Fifty thousand tons of water, the amount displaced by the *Berengaria*, would, if exploited as described, suffice to shift Ireland to the middle of the Atlantic. . . ."

He described some things that have already come to pass, such as cell phones and food factories. He showed that nuclear fusion would enhance these technologies:

> "Communications and transport by land, water and air would take unimaginable forms, if, as is in principle possible, we could make an engine of 600 horse-power, weighing 20 lb and carrying fuel for a thousand hours in a tank the size of a fountain-pen. Wireless telephones and television, following naturally upon their present path of development, would enable their owner to connect up with any room similarly installed, and hear and take part in the conversation as well as if he put his head in through the window. The congregation of men in cities would become superfluous. . . . The cities and the countryside would become indistinguishable. Every home would have its garden and its glade. . . ."

He described food factories. As I mentioned, Holland has developed these to become the world's number two agricultural exporter, second only to the U.S., even though it has 1,800 times less land than the U.S., and 35 times greater population density. Cold fusion would enhance food factories, allowing multilevel structures and 24-hour growing cycles. I have estimated that with existing techniques plus cold fusion the U.S. could grow all of its plant crops in an area the size of greater New York City. This would leave the rest of the land for other purposes, or to be returned to nature. Churchill described vast underground food factories:

> "If the gigantic new sources of power become available, food will be produced without recourse to sunlight. Vast cellars in which artificial radiation is generated may replace the cornfields or potato-patches of the world. Parks and gardens will cover our pastures and ploughed fields. . . ."

I described a similar vision of the future:

> "The ultimate purpose of cold fusion, or any technology, is to give people the freedom to do for themselves, take charge of their lives, and make themselves happy or miserable. The immediate goal of cold fusion should be to restore life back to some semblance of what it was before the population boom and the dark satanic mills of industrialization took hold. Of course some people prefer cities and dark satanic nightclubs, but I hope most will choose to live close to nature. Except they will have full access to television, the Internet, grocery stores, hospitals and all other modern conveniences and necessities. I am not suggesting anyone should go "back to nature" and live in primitive conditions, unless they want to. People should live in harmony with nature, not disturbing it more than they need to, but *never again* should anyone have to live at nature's mercy." [30]

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