More about why cold fusion will lower the cost of energy

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Jed Rothwell
LENR-CANR.org

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Abstract

Cold fusion will lower the cost of energy because:

The fuel costs far less than any other. [1]

Generators will be optimized for low cost.

It can be decentralized with no distribution grid.

With a decentralized system, consumers will purchase their own home generator instead of using electric power company equipment. Subtracting the cost of power company equipment and fuel, and adding in the cost of the home generator, cold fusion should reduce the cost of energy by a factor of 21.

Ultimately, the cost of generators is likely to fall by a factor of ~200, from $2,000/kW to $10/kW, which is the cost difference between a power company generator and a mass produced automobile engine. I wrote a paper about this in 2016. [1] This is an expanded look at the subject.

Introduction

Let us start with some assumptions. With enough R&D, cold fusion will become –

- Controllable
- With high enough power density for reasonably compact heat engines.
- With reasonably good Carnot efficiency.

That much seems certain. The following is likely:

- Cells will be fully controlled.

[1] D-D fusion with heavy water costing $1,000/kg is roughly 2,100 times cheaper than gasoline. H-H fusion with ordinary water is millions of times cheaper. Most of the cost of heavy water is for the energy it takes to separate it from ordinary water, so with cold fusion it would cost much less than $1,000.

- Cells will be inexpensive. Unless palladium is needed, the materials are inexpensive. They do not require high precision manufacturing. They should be no more expensive per watt of capacity than batteries.
- Cells will be safe. Tritium will either be absent or fully contained the way it is contained in wristwatches and hallway exit signs today. Cold fusion cells will be fully sealed, even more than today's batteries, to avoid contamination, and because there is no need to open them to replenish the hydrogen or deuterium. Enough hydrogen will be added during manufacturing to last for the life of the device.
- The COP (coefficient of production) will be high, or infinite. It is already infinite with some gas loading methods.

The COP is the ratio of input power to output power. [2] This is a big problem with experimental devices today. Electrochemical cells sometimes need much more input power than they produce as excess heat. On the other hand, some gas loaded systems produce excess heat with no input power. The COP is infinite. I assume input power will be reduced to a minimum or eliminated.

Cold fusion energy density is millions of times greater than any chemical reaction because it is nuclear fusion. This was confirmed by measuring the ratio of helium to heat, 24 MeV per helium atom, the same as one of the D-D fusion paths. [2] Each gram of deuterium releases 345,000 megajoules. [3]

Needless to say, cold fusion cells are far from commercialization today. They cannot be controlled. They are very difficult to replicate. Most produce only a fraction of a watt, although a few have produced 50 to 100 W. How will we make them into a practical source of energy? As I see it, here is what must happen. First, it must become generally known that cold fusion is real and that it will probably replace other sources of energy. Once that happens, large industrial corporations will invest huge sums in R&D. Perhaps this will cost $10 million per day for 5 years, ~$18 billion total. This will include money spent on peripheral technologies needed to implement cold fusion, such as improved thermoelectric devices. Corporations have spent about $19 billion on self-driving automobiles so far, so this is not an unreasonable sum.

Will this R&D succeed? Probably. In modern history we have made astounding progress in science and technology. Consider other inventions such as internal combustion engines, transistors, masers, and lasers. The initial laboratory prototypes took years to produce, and they were unreliable. The first maser prototype took three years to make. [4] Today we manufacture millions of them, and all are extremely reliable.

Can cold fusion produce high temperatures and steady power? Can it produce power density high enough for practical use? Yes, we know it can, because it has already done so in a few

[2] The term COP is borrowed from heat pump technology, where it means the ratio of input electric power to the heat transferred by the compressor. A heat pump does not create energy, whereas cold fusion does, so arguably this term is inaccurate.

experiments. One produced 100 W continuously for 30 days. [5] If something can happen once in a laboratory, we can learn to make it happen millions of times a day in the real world.

Finally, will corporations spend $18 billion on cold fusion? Yes, they will, because if they do not, their competition will put them out of business. That is the same reason automobile companies are spending billions to develop self-driving cars.

The other reason companies will spend $18 billion is that revenues to first movers will be roughly $10 trillion over 30 years. Here is the basis for this estimate. I expect that when the market matures, we will spend $340 billion per year on cold fusion generators, water heaters and other equipment. This value is discussed below. That $340 billion will go to the industrial companies that make the equipment. Most will go to the first movers, because once you take the lead in something like this, you keep it for a long time, the way Ford and GM dominated the automobile business for decades, and IBM dominated computers. $340 billion for thirty years is $10.2 trillion.

The $10.2 trillion will come out of the pockets of energy companies. GE will divert a fraction of ExxonMobil's revenue to itself, the way automobile companies transferred revenue from railroads to themselves in the 1920s, when many people began driving cars instead of taking trains.

End users worldwide now pay $7.3 trillion for fossil fuel and electricity (Figure 1). $340 billion is 21 times less. Such a drastic cost reduction is irresistible. People will stop buying gasoline and electricity. Energy companies will go bankrupt.

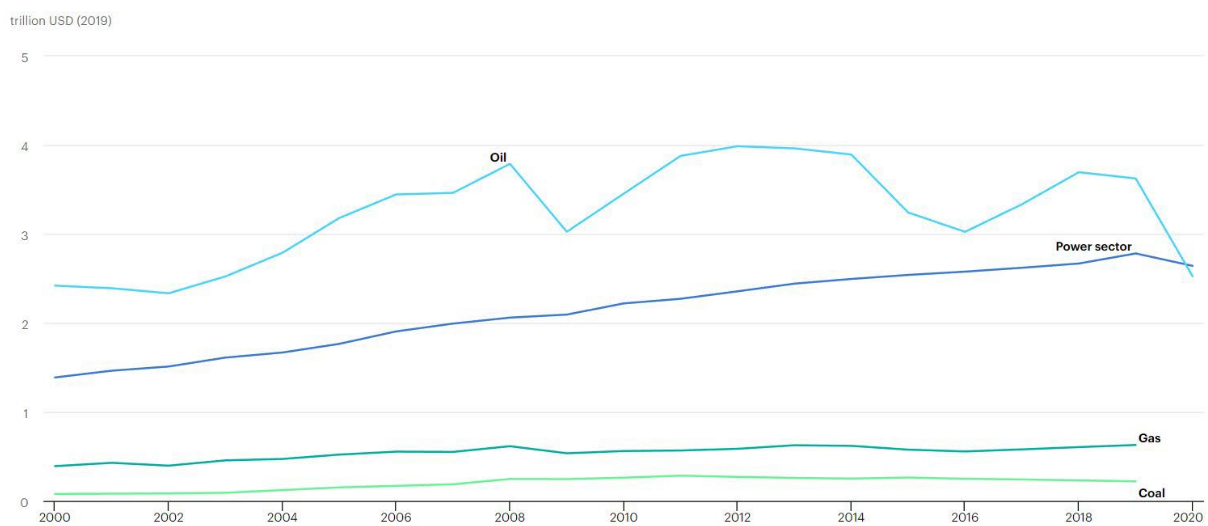


Figure 1. Global end-use spending on energy, 2000-2020, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-end-use-spending-on-energy-2000-2020. The cost of coal and natural gas used in the Power sector is included in that sector. The Gas and Coal shown below that are used in other sectors. 2019 totals are: Oil $3.7 trillion, Power sector $2.8 trillion, Gas $0.6 trillion, Coal $0.2 trillion, grand total $7.3 trillion.

After 20 years, patents will expire, competition will increase, and cold fusion will become a commodity. Profits will be lower. Still, over 30 years the first movers will make trillions of dollars in revenue.

“Becoming a commodity” means competition drives down the cost until it approaches the cost of production. We can estimate the cost of production from the materials, the degree of precision manufacturing, and so on. No doubt the first cold fusion generators will sell at a large premium. But the cost of production will be low. A cold fusion cell should cost roughly as much as a large battery. The heat engines will cost about as much as today’s models. From this, we can predict cold fusion generators will eventually be much cheaper than power company generators. Here is the basis for the estimated cost. Figure 2 shows an electric power bill. In many cities the bill now shows two main items: supply, and delivery.

1. SUPPLY. This is the cost of the generator and the fuel. It is around two-thirds of the total bill, where the generator and fuel are each about one third.
2. DELIVERY. The cost of delivering the power over the grid. This is usually around one third of bill.

The balance is somewhat different in this sample bill, with 40% going to the grid Delivery portion.

PSE&G Electric

Usage	Meter 123456
Actual reading Sep 24	31150
Actual reading Aug 25	30478
Total kWh	**672**

Charges			Rate - RS
Delivery			
Service charge			$2.41
Distribution charges			
kWh charges		600 kWh @ $0.045683333	27.41
	Next	72 kWh @ $0.049722222	3.58
Sub-Total Delivery			**$33.40**
Supply*			
BGS Energy			
Charges		600 kWh @ $0.072983333	43.79
	Next	72 kWh @ $0.082083333	5.91
Sub-Total Supply			**$49.70**
Total electric charges			**$83.10**

**The total supply amount ($49.70, or an average of $0.073958 per kWh) is your Price to Compare for this month should you consider another electric supplier for these services. Your Price to Compare varies each month depending upon your usage pattern.*

THIS BILL PRINTED ON RECYCLED PAPER

Figure 2. A sample electric bill from New Jersey. Supply is 60% of the cost, which is probably about 30% for the generators and 30% for fuel. Delivery is 40%. Bills are split into Supply and Delivery because in New Jersey and other states, customers can choose which company will supply electricity, but there is only one distribution grid. As noted on this bill, customers can select another company for Supply.

Cold fusion does not need fuel, or the grid, which leaves only the cost of the generator. How much will a cold fusion generator cost? To estimate that, let us look at a 58 MW LM6000 gas turbine generator from GE (Figure 3). It costs about $50 million, around $960/kW of capacity. The "overnight cost" comes to $1,376 per kilowatt. This is a masterpiece of 21st century technology. It is remarkably efficient. It has to be, because otherwise the fuel would end up costing much more over the life of the generator. This generator is optimized for efficiency.

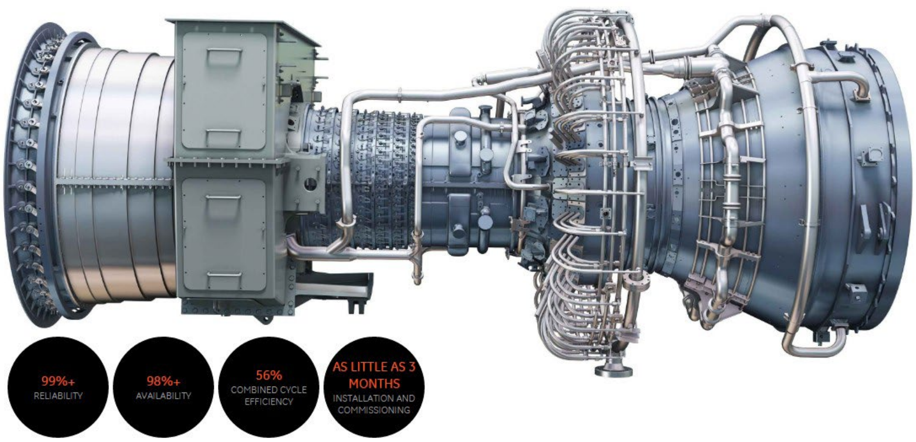
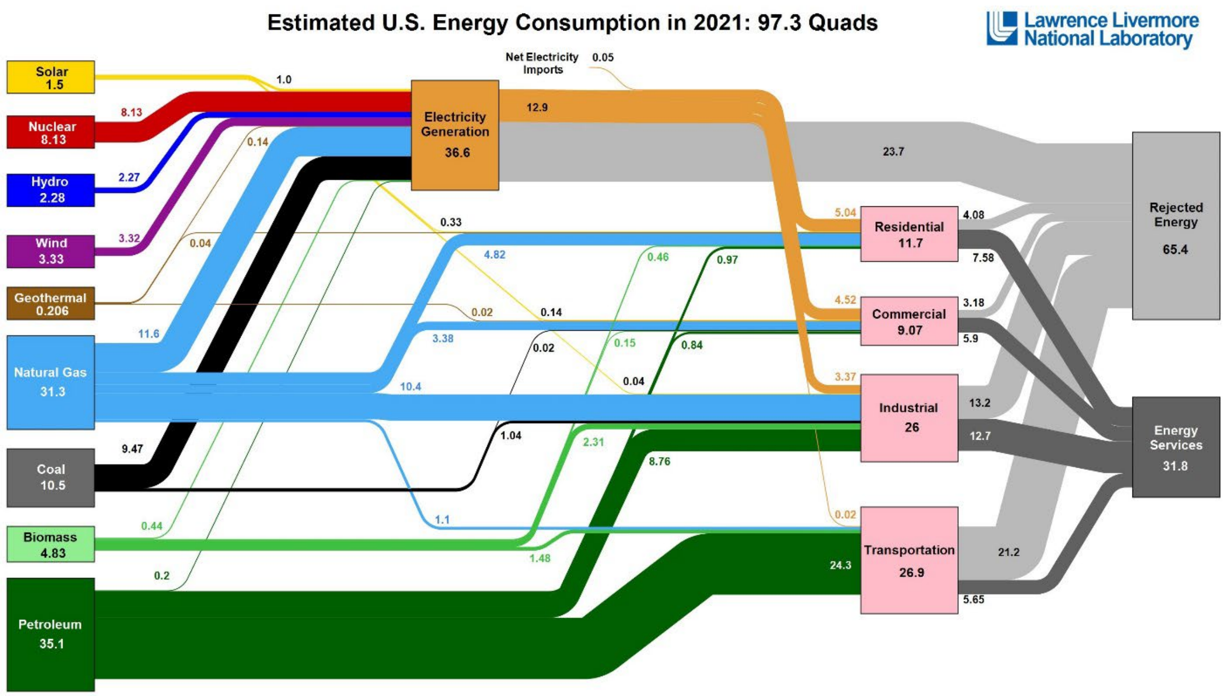


Figure 3. General Electric LM6000-PF gas turbine generator (GE Power Generation)

Figure 4 shows a Chevrolet automobile engine, 145 kW. It is abominably inefficient (Figure 5). However, it costs only $1,460, with Free Shipping. That comes to $10 per kilowatt. That is 130 times cheaper than the GE generator. It is 600 times cheaper than some other power company generators. It is cheaper because it is mass produced and because it is optimized for low cost. Since cold fusion energy costs nothing, we will optimize the equipment for low cost. It will eventually be about 200 times cheaper than today's power company generator.

Figure 4. Chevrolet Goodwrench 350ci engine (www.jegs.com)



Source: LLNL March, 2022. Data is based on DOE/EIA MER (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National laboratory and the Department of energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports conception of renewable resources (i.e., Hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal the sum of components due to independent rounding. LLNL-MI-410527

Figure 5. Estimated U.S. Energy Consumption in 2021, Lawrence Livermore National Lab. (https://flowcharts.llnl.gov/sites/flowcharts/files/2022-04/Energy_2021_United-States_0.png) Most petroleum is used in automobile engines in the transportation sector. 21% converts to Energy Services and 79% is wasted. Other sectors convert 35% to 66% to Energy Services.

Granted, an automobile engine is not a generator. You have to add an alternator to make it into a generator, but this does not cost much. You also need a cold fusion cell. As noted, this should cost roughly as much as a battery. There are other differences between a mass produced heat engine and the GE generator, such as the duty cycle, and the longevity of equipment. I discussed these in the previous paper. [1]

Cold fusion energy is free, but so is wind and sunlight. Why should cold fusion be cheaper than wind or solar? The equipment will be optimized for low cost, but so are wind and solar. However, these sources have problems that will never allow them to be as cheap as cold fusion, including:

- Low power density.
- Intermittency.
- Limited availability (you need a lot of sunlight or wind).

- Wind needs a distribution grid, because it only works with gigantic machines, most of them far from major cities.
- Solar needs a grid because power density is low.

Solar power density is so low that in many parts of the U.S. such as the Midwest, even if you cover a large roof with panels (Figure 6, left), they produce only about 612 kWh per month. The average US house consumes 911 kWh per month, so you need supplemental electricity from the grid. You have to pay for the grid even when you have solar.

Figure 6 (right) shows a 20 kW deluxe standby generator (Generac, Guardian model). It will produce up to 14,600 kWh a month. It is much smaller than the solar array. It is also far smaller than your share of power company equipment, because that includes the generator, high-voltage power lines, the poles, wires, the round transformers in your neighborhood, plus the coal mines, the railroads that bring the coal, natural gas pipelines, and so on. You do not see all those things, so you do not realize how big they are, or how expensive.

Figure 6. Left: solar panels on roof. Right: a 21 kW standby generator (Generac, Guardian model)

The Generac generator is 122 cm × 63.5 cm × 74 cm, or 109 L. A 20 kW cold fusion home generator heat engine will be about this big. This generator has an internal combustion piston engine. A first generation cold fusion version would probably be a steam piston engine with a boiler powered by cold fusion.

Rough estimate of cost of a 20 kW cold fusion generator

The 21 kW natural gas fired standby generator in Figure 6 costs $6,400 retail at Lowe's. A standby generator is more expensive than an ordinary gasoline generator because it includes control electronics and equipment to switch off the power company electricity and turn on the generator in the event of a power failure. An ordinary 21 kW gasoline generator costs about $4,200. Costs per kilowatt range from $113/kW to $305/kW (Table 1). The "overnight" cost of power company generators per kilowatt of capacity ranges from $676/kW for natural gas generators up to $6,599 for advanced coal plants (Table 2). (EIA definition: "The term 'overnight' refers to the cost of the project as if no interest were incurred during its construction.")

Some generator equipment is expensive to purchase, but inexpensive to operate. This is especially true of solar photovoltaic, because the fuel cost is zero. The cheapest natural gas generator is a combustion turbine – industrial frame, but combined cycle units are more efficient, so they are cheaper over the life of the equipment. The unsubsidized, levelized cost of a megawatt hour of electricity from various generators is shown in Table 3.

Table 1. Generator cost per kilowatt of capacity for home generators (Lowe's retail)

Generator size	Cost per kilowatt
5300 W	$113
3500 W	$151
800 W	$230
21,000 W deluxe standby	$305

Table 2. Power company generator cost per kilowatt of capacity ("overnight" cost). (Energy Information Agency) [6]

Generator type	Cost per kilowatt
Natural gas. Combustion turbine—industrial frame	$713
Wind (Great Plains)	$1,265
Solar photovoltaic—tracking	$1,313
Natural gas. Combined-cycle with 90% CCS	$2,481
Coal. Ultra-Supercritical coal (USC) (cheapest)	$3,676
Coal. USC with 90% CCS (most expensive)	$5,876

Table 3. Unsubsidized, levelized cost of a megawatt hour of electricity from various generators. (Lazard) [7]

Generator type	Lowest cost	Highest cost
Solar photovoltaic, Thin Film Utility Scale	$28	$37
Wind, Onshore	$26	$50
Natural gas, Combined cycle	$45	$74
Coal	$65	$152
Natural gas, Peaking	$151	$196

Assuming the cold fusion cell itself is not expensive, with today's equipment a home generator would be 5 or 10 times cheaper than a power company generator.

Mass production will bring down the cost. We should manufacture 170 million devices per year, about twice as many as the number of automobiles we make. This would meet worldwide demand for energy, except for the transportation sector. [3] Most devices would be generators, but

[3] Cold fusion would greatly reduce primary energy consumption and costs in the transportation sector. Details are not covered in this paper because transportation has a very different profile from other energy applications.

some would be things like water heaters and pumps. The average size would be 20 kW. This is how much an average First World house needs, estimated by online programs to configure 'whole home' standby power generators. Some would be smaller for portable power, while others would be much larger, to power factories and the like.

20 kW generators now cost $4,200, but manufactured in large numbers I expect the price will fall to around $2,000 including the cold fusion cell. (This is still well above the cost per kilowatt of an automobile engine, alternator and battery.) Suppose we make 170 million per year. Suppose they last fifteen years, which is about how long internal combustion engines or refrigerator compressor motors last. The cost would be $340 billion, which is 9% of what we now pay for automobiles, or 5% of what we now pay for energy. [4]

Worldwide capacity would be 51,000 GW of electricity. Since cold fusion generators will be about 33% efficient, worldwide primary energy capacity would be 153,000 GWt (gigawatts thermal). [5] That is 7 times more generating capacity and 9 times more primary energy capacity than we have today. That does not mean we would consume 7 times more electricity. It means we would have that much on tap, to use if we want. People do not run small generators or space heaters at full capacity 24 hours a day. The point of making far more capacity than we now have, or than we would actually use at any given moment, is to give everyone access to all the energy they want without the expense of a distribution grid.

$340 billion per year is what it would cost at first, but costs would gradually fall. Think about the development of personal computers in the 1980s. They began with the microprocessor chip. That is the heart of a computer, but it also needs RAM, a keyboard, a screen, a hard disk, and a printer. When personal computers were introduced, these things were expensive. They were manufactured in small numbers for the minicomputer market. There was no such thing as a small hard disk for the home market.

Personal computers began selling in the thousands, and then millions. Engineers worked frantically to make small, cheap hard disks and printers. Prices fell rapidly. When the cost of core technology falls – the microprocessor in this case – it creates an opportunity to invent low cost peripherals. There would be no point to developing a $300 printer in 1975. You could not sell more than a few hundred. But, when the market for printers explodes and millions are sold, it is worth developing a new type of cheap, small printer.

The first implementation of a 20 kW cold fusion generator would use a conventional mechanical heat engine. It would be better to develop thermoelectric devices, because they have no moving parts, and they last longer, around 30 years. These are far more expensive per

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[4] Global automobile sales 2022, $3.8 trillion. (https://www.ibisworld.com/global/market-size/global-car-automobile-sales/ and Stastica).

[5] 170 million generators × 15 years = 2.550 billion generators. 2.550 billion generators × 20 kW = 51,000 GWe capacity; ~153,000 GWt. World generator capacity is now 7,172 GW. World primary energy is 557.10 exajoules/year according to BP. 153,000 GWt run full time, 8760 hours per year = 1.3 trillion GWh per year, or 4,825.01 exajoules. Again, no one would run generators and other equipment at full capacity every hour of the year. https://www.americangeosciences.org/critical-issues/faq/how-much-energy-does-person-use-year

kilowatt today, but with R&D they can probably be made cheaper, the way photovoltaic cells were.

Estimated savings per household

I expect all home cold fusion generators will be cogenerators, also known as combined heat and power generators. The waste heat from a cogenerator is used for space-heating in winter, eliminating the need for a home furnace. A small generator is inefficient, requiring 60 kWt to generate the 20 kWe needed for the average house, with 40 kW of waste heat. The average house space heating furnace produces 18 kW (60,000 BTU), so there would be more than enough waste heat. A cogenerator is simple. It resembles the cabin heater in an automobile. This heats the cabin with waste heat from the engine by directing fresh air through a heat exchanger connected to the engine radiator. This is why you get no heat until the engine warms up. A home cogenerator would bring some waste heat into the house in winter, or vent all heat outside in summer.

Cogenerator waste heat might also be used to heat water.

For several years, cold fusion cogenerators will probably sell at a premium, perhaps much more than a middle class family can afford. They might cost $50,000. They would resemble modern electric cars such as the Tesla, which began as luxury items and are now falling to a price that middle class people can afford. When electric cars become commodities, they should be cheaper than gasoline models, because they are simpler with fewer parts, and they are easier to assemble. Cold fusion cogenerators may eventually be cheaper than the furnaces they replace, but not at first.

Here is an estimate of the price at which it would be economical to replace a conventional gas-fired furnace with a cold fusion cogenerator. The cost of today's energy sources and equipment in the U.S. are as follows:

EQUIPMENT FOR HEATING, VENTILATION AND COOLING (HVAC)

A gas fired home furnace costs $2,200 for a small house, and up to $4,000 for a large house. The average is $3,900 including installation.

The average water heater costs $1,200

The average central air conditioner costs $5,651, but an early model cogenerator would probably not replace it. A cogenerator would power a conventional electric air conditioner, so the cost would not change. Decades from now thermal air conditioners powered directly by cold fusion or by cogenerator waste heat may become cheaper than electric models.

Equipment total: $5,100. Most HVAC equipment lasts about 15 years, so the cost is $340/year

ENERGY

Average residential energy costs are:

$115/month electricity, $1,380/year

Natural gas costs ~$100/month gas, $1,200/year. Much of this is used for space heating.

Electricity and gas total: $2,580/year. (Incidentally, this is close to what we pay at our house in Atlanta, Georgia. Electricity $1,164, natural gas $1,333.)

A cold fusion cogenerator would eliminate the electric bill, and greatly reduce the natural gas bill, because most natural gas is used for space heating.

Today's cost of energy plus equipment: $2,920/year, $43,800 over the 15-year life of the generator.

When the cost of a cogenerator falls substantially below $43,800, most people will buy a cogenerator when their old furnace wears out. The electric power and gas companies will gradually go bankrupt. They cannot afford to lose most of their customers. Their generators and network are not designed for a much smaller customer base. When the power and gas companies go out of business, remaining holdout families will be forced to buy a cogenerator. The transition will be complete.

Low and medium power devices

One of the reasons cold fusion R&D may cost $18 billion is that we need to invent many new things to take advantage of cold fusion. To make full use of personal computers, we needed new kinds of hard disks and printers. To make full use of cold fusion we will need many new inventions, especially better, cheaper heat engines. The companies that invent cold fusion cells will not be the only ones who make money. Whoever comes up with a better heat engine will also make large profits.

I assume that thermoelectric heat engines will be used with small devices, such as wristwatches and cell phones. To illustrate the challenges of developing cold fusion – challenges other than cold fusion itself – here is a problem with small devices.

Any small heat engine is inefficient. Present day thermoelectric devices are particularly inefficient. This makes them too hot for cell phones and laptop computers. They generate too much waste heat. Commercial thermoelectric devices today are only 15% efficient. Laboratory devices are up to 40% efficient. A cell phone draws 3 W when it is online. At 15% it would produce 20 W of waste heat. That is too hot to keep in your pocket. 40% efficiency would produce 7.5 W, which is probably cool enough.

But there is another problem. Like all heat engines, thermoelectric Carnot efficiency is better at higher temperatures. You can only get 15% today, or 40% in the future, when the hot side temperature is 1230 K (928°C). That would be fine for something like a home generator, but how could you put such a hot object in your pocket?

Perhaps something like the following would work. Imagine a gas loaded cold fusion cathode the size of an incandescent lightbulb tungsten filament that is kept at 930°C. It is encased in ceramic which is surrounded by thermoelectric devices. The heat is radiated evenly from the surface of the phone. At 7.5 W it would be a moderate temperature. But, if you drop the phone, or run over it with a car, the ceramic may crack open and expose the incandescent core. I suppose the reaction would stop and it would rapidly cool, but it might be dangerous. For that matter, a conventional cell phone battery can be dangerous. Run over one with a car and it might discharge quickly, and ignite or explode.

I do not know whether a hot ceramic core would work, but I expect someone will come up with a solution.

Cardiac pacemakers and other low power devices

One of the best potential uses of cold fusion would be for a cardiac pacemaker. A cold fusion thermoelectric pacemaker that lasts for 50 years would be a great benefit to patients, because today's battery-powered ones have to be replaced from time to time.

An incandescent core might be acceptable in a cell phone, but you would not put one in a pacemaker battery. No one would implant that in a patient's chest. Fortunately, that will not be necessary. It turns out that for very low power levels, inefficient heat engines are fine. As long as the COP is very high, or infinitely high with no input power, cold fusion will work.

Figure 8 shows a thermoelectric nuclear-powered pacemaker from the 1970s. It was powered by plutonium-238, which produces heat without significant radiation (5 to 15 mrem per hour gamma rays and neutrons). This device produced 0.13 W of heat, which converted to about 50 µW of electricity. Conversion efficiency was 0.04%. That was acceptable. The 0.13 W of waste heat did not cause a problem in the patients' chests.

Figure 7. A plutonium powered pacemaker. The plutonium has been removed; it fit into the slot on the top left. See technical details at: https://www.orau.org/health-physics-museum/collection/miscellaneous/pacemaker.html

Incidentally, some of these pacemakers were still implanted and functioning after 30 years, which shows that a nuclear powered pacemaker is robust and can last a long time.

There is one marvelous possibility on the horizon. Frank Gordon and Harper Whitehouse have developed and experimentally demonstrated a device they call a Lattice Energy Converter (LEC) which produces both a voltage and a current through a load. [8] Several people have independently replicated these results. Whitehouse claims to have a device that is still operating after 7 years. The LEC has two outstanding features:

1. It does not need input power; the COP is infinite. It self-initiates (spontaneously starts up on its own), and self-sustains.
2. It outputs mainly electricity, so it does not need a heat engine.

Power is very low, at the microwatt level, about the same as a wristwatch battery. Some people still wonder whether this is some sort of chemical battery. Gordon and several people who replicated the device point out that it is producing ionizing radiation in conditions where this should not happen without a nuclear process.

Gordon thinks that for general use, power output needs to be increased by nine orders of magnitude to the kilowatt level. That sounds unlikely, but laboratory science often accomplishes such things. The first fission reactor, the Chicago Pile 1, produced 0.5 W. The first power reactor a few years later produced 236 MW (8 orders of magnitude). At ICCF24, Gordon described many promising methods that might increase power by 1 or more order of magnitude, such as raising the operating temperature, or increasing surface area by a factor of 10. If power can be raised to 1 W, this will make it easier to measure the output, and allow a test showing that it lasts far longer than a 1 W battery or any other chemical device. This would also make it easier to look for helium when deuterium gas is used, to see if this is D-D fusion.

A LEC outputting 1 to 3 W would also have important practical uses, such as lighting an LED lamp or charging a cell phone. This would be a great benefit in the Third World.

Energy may become thousands of times cheaper

The notion that energy might be made thousands of times cheaper may seem ridiculous to some people. These people have not read history. The cost of food and many other things has fallen dramatically since the Industrial Revolution began. In particular, intangible things such as travel, lighting, and information are cheaper. Energy is an intangible.

The cost of lighting from 1800 to 2000 fell by a factor of 3,300, while efficiency increased 700 times. [9]

Over the last 50 years, the cost of information, data storage, and computation fell more than any other commodity in human history. From 1962 to 2000 the cost of computer memory fell by 8 orders of magnitude (Figure 9). I personally own more terabytes of disk storage than existed in the entire world in 1964. [6] [10] Disks are cheaper partly because they became much smaller.

[6] I have 13 TB of storage including backups. Sanders [8] estimated there were approximately 15,000 computers in 1964 just before the introduction of the IBM 360. Looking at the specifications for the most common type, the IBM

Cold fusion will also be cheaper partly because the equipment will be smaller. It will not need the high voltage power lines, poles and transformers, or the coal mines and railroads, gas pipelines, and the rest of the unseen infrastructure we must have for today's energy sources.

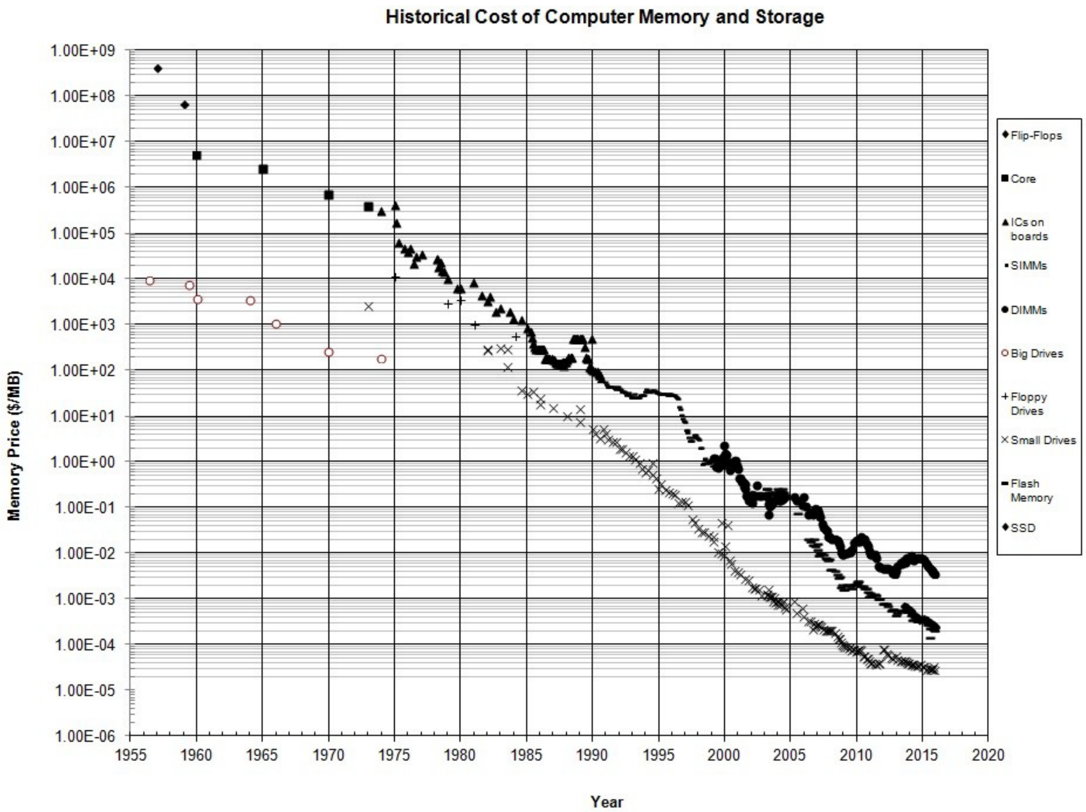

Figure 8. J. C. McCallum, National University of Singapore, Graph of Memory Prices Decreasing with time (1957 – 2015). https://www.researchgate.net/publication/227349575_Seven_Centuries_of_Energy_Services_The_Price_and_Use_of_Light_in_the_United_Kingdom_1300-2000

References

1. Rothwell, J. *Cold Fusion Will Lower the Cost of both Energy and Equipment*. in *ICCF20 International Conference on Condensed Matter Nuclear Science*. 2016. Sendai, Japan.
2. Hagelstein, P.L., et al. *New Physical Effects in Metal Deuterides*. in *Eleventh International Conference on Condensed Matter Nuclear Science*. 2004. Marseille, France.
3. Borowski, S.K., *Comparison of Fusion/Antiproton Propulsion Systems for Interplanetary Travel*. 1996, NASA.
4. Townes, C.H., *How the Laser Happened - Adventures of a scientist*. 1999: Oxford University Press.

Model 1400 and the model 1301 disk storage unit, and adding in the well-known supercomputers at that time, I estimate there were ~1.7 TB of disk storage in the world. If every one of the Model 1400 computers had the maximum number of disk drives it could support (250 MB), there would be 3.75 TB total. Actually, many were equipped with tape drives only.

5. Roulette, T., J. Roulette, and S. Pons. *Results of ICARUS 9 Experiments Run at IMRA Europe*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan.
6. *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies*. 2020, Energy Information Administration, U.S. Department Of Energy https://www.eia.gov/analysis/studies/powerplants/capitalcost/.
7. *Levelized Cost of Energy Comparison—Unsubsidized Analysis* 2021, Lazard https://www.lazard.com/media/451905/lazards-levelized-cost-of-energy-version-150-vf.pdf.
8. Gordon, F. and H.J. Whitehouse, *Lattice Energy Converter.* J. Condensed Matter Nucl. Sci., 2022. **35**: p. 30-48.
9. Fouquet, R. and P.J.G. Pearson, *Seven Centuries of Energy Services: The Price and Use of Light in the United Kingdom (1300-2000).* The Energy Journal, 2006. **27**(1): p. 138-178.
10. Sanders, D., *Computers in Business, an Introduction*. 2 ed. 1972: McGraw-Hill.