

What Could “Thermostat” Do for Us? Can We Obtain Any?

A Hypothetical Substance Could Cut Global Warming By 30%

By Geoff Graham 6/22/2022

Questions? Comments? Anything left out? Anything you disagree with? I’d love to hear your thoughts. Email me at gjraham4health@protonmail.com.

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Abstract

Humanity emits enormous amounts of CO₂ into the atmosphere by heating or cooling buildings and other items. A method to save and transport heat or coldness from where they are generated to where they are needed could greatly decrease carbon dioxide emissions. Because substances differ greatly in the amount of heat or coldness needed to change their temperature by a single degree Celsius, it might be possible to discover a new substance (“thermostat”) which can store large amounts of heat or coldness without a large change in temperature. Possible uses of thermostat are discussed, including harvesting of water from air. Ways to heat thermostat, including concentrated sunlight, are discussed. Potential sources of coldness for thermostat include the deep ocean, tall mountains and—most importantly—the upper atmosphere. A promising place to search for thermostat is at undersea hydrothermal vents where there is a rich biota, and where the ability of an organism to delay a rise in body temperature for a few seconds could favor its survival. However, many common experimental

organisms might contain proteins or other materials that can briefly delay a rise in temperature; to my knowledge, such proteins or other materials have never been searched for. Methods to isolate variants of those organisms having more such thermostatins are suggested. The final step would be to collaborate with a physical chemist to maximize thermostatins' "specific heat" and durability.

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The “thermostatins” idea

We heat our buildings in winter and cool them in summer, expending energy in both cases and emitting considerable amounts of carbon dioxide into the atmosphere. In some heated buildings, even when it is very cold outside, we operate electrically powered refrigerators and freezers. In some cooled (air-conditioned) buildings we operate ovens. If there were some method to collect and store heat or coldness from places where they were abundant and transfer them to places where they were needed, we could save energy and reduce carbon dioxide emissions.

Is the idea feasible? At least to some extent, it must be feasible because humanity already stores both heat and coldness for later use. Before refrigeration was invented, people stored winter ice in “ice houses” or other insulated structures—a practice that was widespread around the globe and which appears to go back [millennia](#) [1]. Although ice houses have mostly been replaced by modern refrigeration, “seasonal energy transfer” technology stores the cold of winter in deep aquifers or underground rock masses which are accessed via a cluster of small-diameter, heat-exchanger-equipped [boreholes](#) [2]. Moreover, heating or cooling a house using a geothermal heat pump that moves heat to and from earth near the house is energetically favorable, although the costs of installing a

geothermal heat pump are usually [prohibitive](#) [3]. Several methods of storing heat are currently in [use](#) [4].

Specific heat. Why don't we use heat storage and coldness storage more often? One reason is that the materials we have available are limited in the amount of heat or coldness that they can store per unit of mass. If we want to increase the usefulness of heat or coldness storage, we will have to discover materials that store more heat or more coldness per gram; in other words, we will have to find materials with higher "specific heats" than the materials we currently have.

Materials differ in the amount of energy required to heat them. It takes one calorie to heat one gram of liquid water a single degree Celsius, but only 0.107 calorie to heat one gram of iron one degree and only 0.0294 calorie to heat one gram of bismuth one degree. Interestingly, although one calorie is required to heat one gram of liquid water by one degree Celsius, only 0.49 calorie is required to heat one gram of ice by a single degree. The number of calories required to raise the temperature of one gram of a given material by one degree Celsius is called that material's "specific heat." In the above examples, water has a specific heat of 1.00 calorie/(gram-°C), while ice has a specific heat of 0.49 calorie/(gram-°C).

Phase changes. Changes in the phase of a compound can also absorb large amounts of heat. Although it takes 100 calories to heat one gram of liquid water from 0 °C to 100 °C, takes more than 5 times that amount of energy (540 calories) to turn one gram of water at 100 °C to one gram of steam at 100 °C. It also takes 80 calories to turn one gram of ice at 0 °C to one gram of water at 0 °C.

Suppose that we were to discover a material with a very high specific heat: let's imagine that this material requires 5000 calories per gram to rise 10 degrees Celsius in temperature. We will give this material the fanciful name "thermostatín" ("thermos" Greek for "hot, warm" and "stat" Latin for "remain, rest; stand, stand still, stand firm").

Why thermostatín could be useful

What could thermostatín do for us?

- **Buildings.** Using thermostatín, we might cool buildings in summer using chill from the previous winter, and warm buildings in winter with heat from summer. One caveat is that we would have to insulate the thermostatín while it was being stored, which would not be a trivial task.
- **Clothing.** Instead of heating or cooling the insides of buildings, we could heat or cool the clothing that people wear within those buildings—like a

sleeper who stays warm using an electric blanket instead of heating the whole house.

Heated clothing is already for sale but depends on portable batteries. These batteries are limited to a few hours performance and are bulky enough to be noticed. Thermostat might provide more convenient heat.

Artificially cooled clothes are also for sale. Most are cooled using reservoirs of coldness, rather than electric current. They are clammy and often wet with condensation from the air. Cold thermostat, combined with moisture-absorbing silica gel and small air fans might make such clothing more comfortable.

All heated and cooled clothing could be improved by an easy method to control the temperatures of different regions of the clothing. Lack of such a method impedes the adoption of heated or cooled clothing.

- **Electricity transmission.** As global warming increases, electricity transmission lines will get hotter. This will increase their resistance to electric current, which will convert even more of their electric current to heat and so on. It might be possible to use a thermostat jacket, which would be cooled during the night, to keep transmission lines cool during the day. The nighttime cooling might be passive or might involve thermoelectric cooling (the Peltier effect) if surplus power were available at night.
- **Concentrated solar energy.** Solar tower-heliostat systems use many adjustable mirrors (heliostats) to reflect sunlight onto a chamber of molten liquid at the top of a tower. The molten liquid is then used to power a generator. This technology has fallen on hard times; one reason is that solar tower-heliostat installations must be built in arid regions where there are few clouds, but they need abundant water to use as a coolant. If the heated substance were thermostat, hot blocks of thermostat might be loaded onto a train and transported to places where their heat was needed and there would be no need for water.
- **Compressed air energy storage.** Thermostat might boost the performance of compressed air energy storage systems. In principle, an easy way to store renewable energy is to compress air and to save that compressed air for later use when it can drive an electric generator. Unfortunately for this idea, compressing air to high pressures heats that air to very high temperatures. The temperatures can be high enough to damage the compression/storage equipment, but even when this does not

happen the excess heat will inevitably dissipate. Much of the stored energy is thereby lost. Moreover, when the compressed air is released, it becomes very cold and may even liquefy. To combat this, additional heat must be added to the air, which usually requires the burning of natural gas. As an alternative to this, the heat resulting from the compression of air might instead be absorbed by a thermostat blanket around the compression chamber. If the thermostat had a very high specific heat, its rise in temperature might be modest and thus heat dissipation into the environment might also be slowed.

- **Harvesting water vapor.** Coldness might help harvest water from the air. According to the US Geological Survey, the volume of water in the atmosphere at any one time is about 3,100 cubic miles or 12,900 cubic [kilometers](#) [5]. A cubic mile of water is 1.101×10^{12} gallons. The USA's state of California's standard for indoor residential water use is 55 gallons per day. One cubic mile of water is 2.00×10^{10} person-days of water. This amount of water would supply California's 39.35 million people for 508 days, or slightly less than 1 year, 5 months. Hence, the air holds useful amounts of water vapor.

How much water could we harvest from air in a single 24-hour day? The total volume of the Houston (Reliant) Astrodome is 42 million cubic [feet](#) [6] or 1,189,308 cubic meters. At 66 °F and a relative humidity of 70%, a cubic meter of air contains about 14.5 grams of water. Thus, the air in the Houston Astrodome typically contains about 17,245 kg of water. Very vigorous air conditioning of a commercial space might replace the air 50 times per [hour](#) [7], although this would be a monumental undertaking for a structure as large as the Houston Astrodome. If the air in the Houston Astrodome were changed 50 times per hour for 24 hours and all of the water were recovered from the air, 20,694,000 kg of water would be recovered. An Olympic swimming pool contains 2.5 million kg of water. This would yield about 8.27 Olympic swimming pools per day of fresh water.

Because the condensation of one gram of water releases 540 calories of heat, the condensation of 20,694,000 kg of vapor will release 1.12×10^{13} calories of heat. If our thermostat were very effective and absorbed 100 calories per gram per degree Celsius over a range of 50 degrees Celsius (say from 10 °C to 60 °C) absorbing the heat from so much condensing water would require 2.23 million metric tons of thermostat.

Hence, the cooling power of thermostatin could easily be the limiting factor in the harvesting of water vapor, and thermostatin with the highest possible specific heat would be most useful.

- **Cooling agricultural crops.** Thermostatin might also be used to cool crops. Spray irrigation has two benefits for crops: it hydrates crops and cools them. Spray irrigation can cool the leafy canopies of crops by as much as 10 degrees Celsius [\[8\]](#) [\[9\]](#) [\[10\]](#) [\[11\]](#) [\[12\]](#) [\[13\]](#) [\[14\]](#) [\[15\]](#). This prevents wilting of the crops and largely protects crops from infection by the fungus *Aspergillus flavus* and subsequent contamination by aflatoxin [\[16\]](#), a very potent natural toxin. For this idea to succeed, the thermostatin would have either to be used to cool sprayed irrigation water or to cool air in an arrangement where air exchange with the environment was limited.
- **Supporting the “cold chain.”** Much of the food that we eat is preserved and transported via a complex arrangement called the “cold chain.” The cold chain keeps perishable foods chilled until they can be consumed, and hence preserves their organoleptic and nutritional properties. Maintaining the cold chain causes 1% or so of global carbon dioxide emissions [\[17\]](#), and this percentage seems likely to rise as the world warms and as more consumers around the world demand higher quality food. Currently, only about 10% of food consumed around the world is protected by inclusion in a cold chain [\[18\]](#). Cold thermostatin might stabilize the temperatures of cold chains and, if the thermostatin were chilled in some process that did not require combustion, could lower carbon dioxide emissions by the cold chain.
- **Engine efficiency.** Heat engines such as internal combustion engines and steam engines generate their power by exploiting the temperature difference between two reservoirs of material: a hot reservoir and a cool reservoir. The amount of power that can be extracted increases as the temperature difference between the reservoirs increases. Cold thermostatin might increase the efficiency of heat engines by lowering the temperature of the cool reservoir.
- **Cooling electronic devices.** For electronic devices to operate properly, their electronic components must be kept cool. This cooling is usually done with the use of heat radiators that transfer heat to the ambient air. However, there is a limit to how much heat can be removed this way. Cool thermostatin might remove additional heat from electronic devices,

although condensation of water vapor onto the cool surfaces is a problem that would have to be solved.

Sources of heat and cold for thermostatin

If thermostatin existed and were used, sources of either heat or coldness would have to be found that could change its temperature. In principle, it might be possible to save heat from summer to winter and vice-versa. Moreover, in some parts of the world, it might be feasible to move thermostatin from winter regions to summer regions and vice-versa. However, in both cases, preventing heat exchange between the thermostatin and its environment would require adequate insulation—something that may not be possible.

The insulation problem. Without adequate insulation, very cold thermostatin would chill the container it was in, causing water to condense and perhaps freeze. Because water's heat of condensation is very high (540 calories per gram) the thermostatin would quickly lose its frigidity and the condensed moisture might damage that container and the surroundings. Without adequate insulation, heat escaping from hot thermostatin might damage warehouses, railroad boxcars, etc., and perhaps start fires.

For the above reasons, the sooner that thermostatin could be used after its heating or cooling, the more efficient it would be.

Fossil fuels as heat sources. Sources of heat for thermostatin would include several combustible sources such as coal, natural gas, and petroleum; however, one of the main advantages of using thermostatin is that it could allow us to avoid such sources of carbon dioxide emission.

Solar, nuclear, geothermal. Other sources of heat might include concentrated solar radiation (as discussed above), nuclear reactors, and geothermal power plants. The ability to store heat might be particularly advantageous to solar and geothermal power plants if the plants were located too far away from the markets they served to send their power by electric transmission line. Geothermal plants, for example, might be located on the sea floor. The hot thermostatin could then be transported to where it was needed. This would be especially efficient in cases where transport was by rail.

The deep ocean. The deep ocean might also be a source of coldness for thermostatin since the average temperature of the ocean below 200 meters depth is only 4 °C (39 °F) [\[19\]](#). For people with access to the ocean, cooling thermostatin in deep water might be easy. However, dumping of heat into the deep ocean might dangerously reduce the water's ability to hold dissolved gases such as oxygen and

carbon dioxide or might cause unwanted upwelling of deep waters. Hence, the cold water would probably have to be pumped upward from the deep ocean, as is done in Ocean Thermal Energy Conversion (OTEC), which pumps cold water to the surface from 1000 meters (3300 feet) depth [20].

Mountaintops. The tops of tall mountains might be a useful source of coldness, especially if the top of the mountain were subject to cold winds. Mount Denali (formerly Mt. McKinley) in Alaska and the highest peak in North America, has long been considered the coldest mountain on Earth, with its lowest recorded temperature being around -73°C [21]. Mount Rainier, in Washington State, also has a cold summit, as do a dozen or so other mountains in the USA [22]. In principle, a pulley system for transporting thermostatin to the mountaintops and back again would lose no energy except to friction, since discharging heat at the cold mountaintops would not increase or decrease the mass of the thermostatin. On the other hand, the mountain peaks would be warmest in the summer when chilled thermostatin was most needed, the summits might be difficult to access from the ground, and the mountains are far from the lowland cities where thermostatin would be most needed.

The upper atmosphere. Within a few miles of each of us is a region of almost inexhaustible frigidity that might chill large amounts of thermostatin. That region is above our heads. At 15,000 feet (4.572 kilometers) above sea level, the average temperature is 5.55°F (-14.7°C) [23]. At 25,000 feet altitude (7.62 kilometers) the average temperature is -30.05°F (-34.5°C). Since, warm objects cool more rapidly in a very cold environment, it might seem that allowing thermostatin to chill at the greatest possible altitude would be most efficient. However, air pressure declines with increasing altitude and the rate of temperature equalization by convection declines with decreasing air pressure (14.7 psi at sea level, 8.3 psi at 15,000 feet, and 5.5 psi at 25,000 feet) [24] [25]. Hence, the optimal altitude for cooling thermostatin would have to be determined either by sophisticated modeling or direct measurements. Thermostatin might be sent aloft supported by a hydrogen balloon; when the thermostatin was sufficiently chilled, the balloon could deflate or perhaps rearrange itself to form a glider that could glide back to the ground.

A possible obstacle to cooling thermostatin high in the sky is that winds at high altitudes are strong. At 10 kilometers ($\sim 33,000$ feet) they may be close to 20 meters per second (45 miles per hour). [26] During the time required for thermostatin to cool at that altitude a balloon might drift a long way. What could power a propeller to fight such a drift? One possibility is lightweight solar panels. A second

possibility is to tap the temperature difference between the thermostat and the surrounding air.

The Ocean Thermal Energy Conversion (OTEC) process can power an efficient electricity generator using two streams of ocean water whose temperature differs by only 20 to 25 °C. The key is to use a liquid such as ammonia that boils at a low temperature. A similar process of heat exchange might be devised to cool thermostat at high altitude while powering a propeller that could work against wind drift. [27]

Airliners. If thermostat could absorb enormous amounts of chill within a low volume and mass, commercial airliners might carry thermostat with them as they flew at normal cruising altitude (31,000-38,000 feet). The thermostat could then offset the carbon footprint of the airliner by air conditioning the airport, supplying refrigeration to parts of the airport, or increasing the efficiency of heat engines in the airport.

How we might obtain thermostat

The biota of hydrothermal vents. One place to look for thermostat, or a model substance that might lead to the invention of thermostat, is at hydrothermal vents. Hydrothermal vents are hot spots at the bottom of the world ocean. They occur near the boundaries of tectonic plates and result when sea water is heated by hot, upwelling magma. Although water near the bottom of the ocean is generally very cold (2 °C), water emerging from hydrothermal vents ranges in temperature from 60 °C to 465 °C, depending on the vent [28]. In some cases, pressure and temperature combine to force the water into a supercritical state [29].

Hydrothermal events deposit minerals from magma and the crust into ocean water. These minerals can support a rich, dense ecosystem [30]. Most organisms that live near a hydrothermal vent are nourished directly or indirectly by chemosynthetic bacteria, which in turn are nourished by dissolved minerals, including hydrogen sulfide that provides them with energy. Hydrothermal vents are spread around the world and differ in the complement of organisms present.

A need to delay heating? It seems likely that the hottest regions of the hottest hydrothermal vents are hot enough to kill the organisms around them. What happens if a sudden flow of water, perhaps caused by a fish or the toppling of precipitated material around the vent pushes a small organism into dangerously hot water? Vent organisms have had thousands or millions of years to adapt to this possible danger. Organisms containing some material that could delay an increase in temperature by even a second or two, giving them time to escape into cooler

water, might be more likely to survive such an event. If such biogenic thermostatin were physically possible, one or more hydrothermal vent organisms might synthesize it.

Testing for delayed temperature rise. Some devices can tell an object's temperature by analyzing the infrared radiation emitted by that object. Such thermal radiation thermometers are primarily used in medicine to assess people's body temperatures [31] [32] [33]. A videorecording thermal radiation thermometer might be used to identify creatures whose heating was delayed when they were pushed by a sudden current into superheated water.

If a thermal radiation videorecorder failed to identify organisms that delayed a sudden increase in temperatures, it might be necessary to test individual organisms, in an undersea laboratory. It would be better to do the tests under the same hydrostatic pressure that the organisms were used to, in case the high specific heat of the biogenic thermostatin turned out to be pressure dependent. In one way, the high pressures involved make the project more likely to succeed because the specific heats of materials under high pressure are less well known than are the specific heats of materials under normal pressure, making it more likely that something useful has been overlooked.

Traditional laboratory microbes and small animals. So, should we prepare for an expedition to hydrothermal vents, including getting the necessary permissions and assembling the necessary equipment? Well... Not immediately.

First, it would be better to test some organisms that biologists are more familiar with, and which can be manipulated in an ordinary laboratory. Although there have been many published research papers and untold numbers of science fair projects testing the effects of heat on the survival of experimental organisms, there may be few published papers that report delay in temperature rise of these organisms. (So far, I have found no such papers.) Among the organisms that are well-studied and whose genomes have been sequenced are the bacterial species *Escherichia coli*, *Bacillus subtilis*, and various species of *Pseudomonas*; yeast species such as *Saccharomyces cerevisiae* and *Schizosaccharomyces pombe*; other single-celled eukaryotes such as *Dictyostelium discoideum*, *Chlamydomonas reinhardtii*; simple multicellular eukaryotes such as the fruit fly *Drosophila melanogaster* and the nematode *Caenorhabditis elegans*; and perhaps plant species with pollen grains or seeds that might occasionally be exposed to short bursts of fire.

We would hope to find a genetic variant of one of these species that has a larger-than-normal delay in temperature rise after exposure to a heat pulse. If such a variant also contained a larger than normal amount of some protein or other

substance, that protein or substance might be the cause of the delay and would thus be a candidate for biogenic thermostat.

Creating variants with more thermostat. There are two approaches to creating populations of variants that can be screened, with each having advantages and disadvantages. The first approach is to treat a population of a species of interest with radiation or chemical mutagens, for example, to expose one hundred billion *Escherichia coli* bacteria to enough mutagenic ultraviolet radiation to kill 90% of them. This approach will create a population of mutants that synthesize both abnormal proteins and changed amounts of both normal and abnormal proteins. This method is more likely to succeed if creating biogenic thermostat requires the participation of multiple genes or if changes to one or more proteins can increase the amount or effectiveness of the biogenic thermostat.

The second approach is to create expression libraries containing each gene of the species that is being investigated for biogenic thermostat. (Such expression libraries may already exist for many of the species mentioned above.) The individual cloned genes could then be expressed at a high level in either their species of origin or a common expression host such as *Escherichia coli* or *Saccharomyces cerevisiae*. The method is more likely to succeed if biogenic thermostat needs no sequence changes to its own gene or other DNA sequences to briefly delay a temperature rise in its host.

Enrichment for delayed-heating variants. When a “library” of mutants or gene-carrying single cells has been created, it becomes possible to enrich for individual cells that resist a rapid rise in temperature. One way to do this is to create an apparatus that passes single cells through a needle that is first hot and then cold. The cells would then pass into a collecting reservoir where they could recover. This arrangement is diagrammed in Figure 1 below.

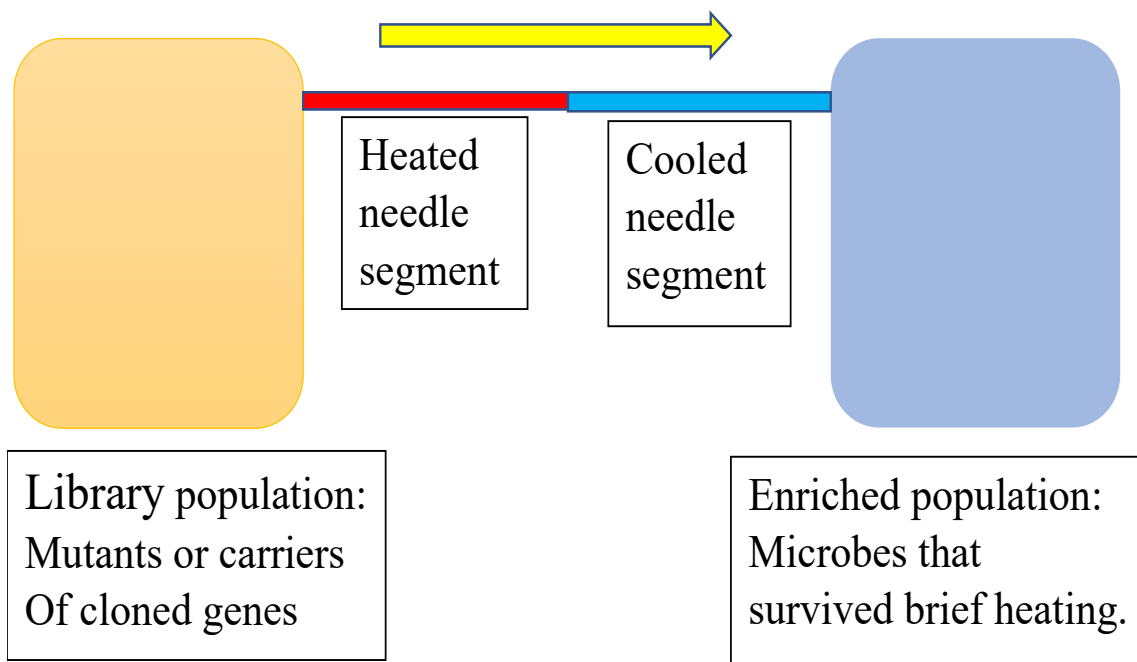


Figure 1. Mutagenized microbes or microbial carriers of cloned genes are pumped from a container (far left) rightward through the heated needle, then through the cooled needle, and finally into a collecting container (far right). The arrangement is intended to enrich for library members that can survive brief heating. Some of these may experience delayed heating and thus might produce a biogenic “thermostatin.”

As someone who has conducted microbial mutant hunts and who has read published accounts of others, I can attest that it is always surprising how many different ways living things can evolve to cope with a problem. Most of the mutants recovered from the above enrichment procedure will be unusually resistant to heat damage rather than unusually slow to rise in temperature. The enrichment procedure might be done several times on the library of mutants or gene-carrying cells, until the surviving cells were highly enriched in heat-resistant variants.

Following this enrichment scheme, the cells from the enriched population would be plated on agar or on a nitrocellulose filter lying upon agar, grown to

colony size and then tested in some way (probably using a thermal emission thermometer) for heating that was delayed for a second or two.

A last-gasp possibility. If we failed to isolate delayed-heating mutants using any of the methods discussed so far, we could make one final effort. We could mutagenize bacteria in the presence of ions that they were normally not exposed to: lithium, boron, bismuth, tin, and so on. We would then repeat the selection for delayed-heating mutants in the hope that the presence of unusual ions would make possible protein conformations that would otherwise not be possible.

The final step: a physical chemist. If we found and isolated biogenic thermostatin, we would still have one remaining step before research gave way to development. The next step would be to collaborate with a good physical chemist. Once a high specific heat material is in hand, it can be dissected in order to determine what physical principles confer its high specific heat. New materials, employing those same physical principles—perhaps in an enhanced way—can then be designed. A variant of thermostatin that kept its properties over a wider temperature range than most biological materials do, and that was more durable than most biological materials are, would be more useful than thermostatin that did not.

Concluding Remarks

No research program, no matter how sophisticated, can produce a substance that is physically impossible. It may well be that a substance with a specific heat of 5000 calories/°C/gram cannot exist. However, we know that passive storage of heat and coldness can have at least some value because they confer benefits on society now and have conferred greater benefits in the past. Hence, a substance with a specific heat of only 5 calories/°C/gram might extend the benefits of passive heating or cooling.

And there is still the hope of getting very lucky. A very high-specific-heat, durable type of thermostatin might confer enormous benefits on civilization in the form of CO₂-free, pollution-free heating and cooling. Even if winning this prize is a long shot, the value of the prize may make the effort worthwhile.

What interests me most is that, as the world warms, we will increasingly need refrigeration. And yet, just a few miles above our heads, is an almost inexhaustible supply of frigid air. If we can exploit its coldness, we may benefit greatly.

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Near the text string: **introducing salinity into the fluid**
30. https://en.wikipedia.org/wiki/Hydrothermal_vent
Near the text string: **a density of organisms**
31. https://en.wikipedia.org/wiki/Infrared_thermometer
32. <https://www.fda.gov/medical-devices/general-hospital-devices-and-supplies/thermal-imaging-systems-infrared-thermographic-systems-thermal-imaging-cameras>
33. <https://www.aimspress.com/article/doi/10.3934/electreng.2022004?viewType=HTML>