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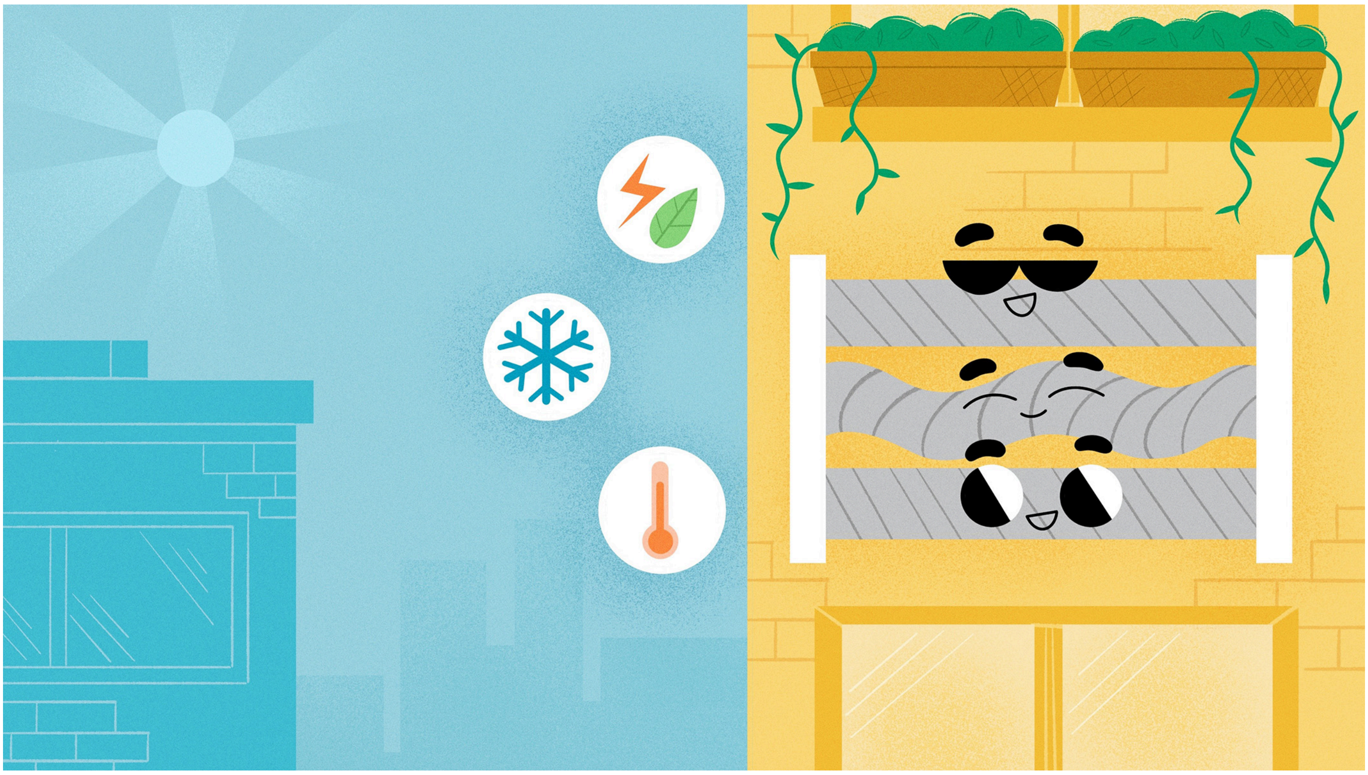

ELASTOCALORICS: COOLING BUILDINGS WITH METALS THAT STRETCH

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Elastocaloric technology is a new way to heat and cool spaces by using stretchy metals, called shape-memory alloys, instead of harmful refrigerant gases. When these metals are squeezed or stretched, they heat up; and when they relax, they cool down. This process is called the elastocaloric effect and it is more energy efficient than traditional cooling systems, making it a cleaner, greener alternative. Elastocaloric systems could cool homes, schools, and workplaces, and they could refrigerate food and medicine in areas with limited electricity. Researchers are also testing this technology for cooling and heating of electric vehicles, where it could help conserve battery life, and for heating buildings in colder climates. Despite its promise, elastocaloric technology faces challenges, such as improving the durability of materials and making the shape-memory alloys more affordable. With continued research,

this technology could someday help to reduce greenhouse gas emissions, lower energy costs, and bring life-saving cooling to more people all over the world.

THE WORLD NEEDS A NEW WAY TO KEEP PEOPLE COOL

If you live in a place with hot summers, you know how refreshing it feels to step into a cool, air-conditioned building after being outside. But air conditioning is more than just a luxury—it can be a lifesaver. High temperatures can be dangerous, especially for children, older adults, and people with certain health conditions. Having access to cool indoor spaces can prevent heat-related illnesses and even save lives during extreme heatwaves.

As global temperatures rise, the need for cooling is growing quickly. By 2050, the energy used for air conditioning and refrigeration is expected to more than triple [1]. Most cooling systems today rely on electricity, much of which comes from burning fossil fuels. The more energy we use, the more greenhouse gases are released into the atmosphere, making climate change even worse. There is another problem: **refrigerant** gases used in cooling systems, like freon or hydrofluorocarbons. These chemicals cool the air but can leak into the environment, trapping heat and contributing to global warming. Some refrigerants are thousands of times more harmful to the climate than carbon dioxide.

REFRIGERANT

A solid or liquid material used in air conditioners and refrigerators to cool the air. Some refrigerants, mainly the fluids, can harm the environment if they leak.

In places where electricity is limited or expensive, many people cannot rely on air conditioning to stay cool. This means that millions of people, especially in developing countries, may not have a safe way to cope with extreme heat. We need a new kind of cooling system—one that uses less energy, avoids harmful chemicals, and works even in areas where electricity is scarce.

EMERGING TECHNOLOGY: ELASTOCALORIC HEAT PUMPS

Most cooling systems today rely on a process called **vapor-compression cooling**, which uses refrigerant gases. These gases are compressed to release heat and then expanded to absorb heat, cooling the surrounding air. While effective, this process uses a lot of electricity to power the compressor—in addition to relying on dangerous refrigerant gases.

VAPOR-COMPRESSION COOLING

A process that cools air by compressing and expanding refrigerant fluids. This method is used in most air conditioners and refrigerators today.

Elastocalorics could offer a new, better way to cool and heat spaces by mimicking how muscles work. When you stretch a muscle, it heats up slightly because the molecules inside it rearrange

ELASTOCALORICS

A cooling technology that uses shape-memory alloys that heat up or cool down when squeezed or relaxed, providing an energy-efficient way to control temperatures.

and rub against each other, generating heat. When you relax the muscle, it cools down as the tension is released and absorbs heat from its surroundings. Elastocaloric heat pumps use materials that behave similarly—releasing heat when stretched or compressed and absorbing heat when relaxed.

SHAPE-MEMORY ALLOYS

Metal mixtures, often nickel and titanium, that return to their original shape after being stretched or squeezed. Their ability to handle repeated stretching and relaxing makes them essential for elastocaloric cooling.

Instead of harmful refrigerant gases, elastocaloric systems use **shape-memory alloys** made of metals like nickel and titanium. These metals can come in various forms, like flexible strips or coils, tubes, or other advanced structures. When shape-memory alloy structures are stretched or squeezed by a machine, they heat up. The heat generated can be transferred to a fluid like water or air, which carries it away and releases it outside the building. When the pressure is released, the metal relaxes and returns to its original shape, cooling down and absorbing heat from the surrounding air or water in the process. This absorbed heat is carried away by the fluid in the next cycle, ensuring that the room or building stays cool. This cooling cycle repeats over and over, and the shape-memory alloys can handle millions of cycles without breaking down.

TECH TO THE RESCUE

One big advantage of elastocaloric heat pumps is their efficiency. By directly converting mechanical (stretching/compressing and relaxing) energy into cooling, they skip the energy-intensive steps of compressing and expanding refrigerant gases used in traditional systems. This means elastocaloric heat pumps use less electricity, making them an environmentally friendly and cost-effective alternative [2]. Elastocaloric heat pumps could be especially useful in areas where electricity is limited or expensive [3].

Elastocaloric technology is already showing promise for heating and cooling. Researchers are testing elastocaloric heat pumps as replacements for traditional air conditioners (Figure 1C). These systems could cool homes, schools, and workplaces more efficiently while reducing greenhouse gas emissions. Elastocalorics also has potential for refrigeration, especially in areas where electricity is limited. In rural communities or developing countries, elastocaloric heat pumps could provide an affordable way to keep food fresh or medicines cool (Figure 1A). Because they use less energy, elastocaloric systems can run on smaller, renewable energy sources, like solar panels, which are often more practical in these settings.

Elastocaloric technology is also being explored for electric vehicles. Current car heating and cooling systems use a lot of energy and can quickly drain car batteries, reducing the driving range of electric cars. Elastocaloric technology could offer a more efficient solution, helping electric vehicles maintain comfortable temperatures while conserving

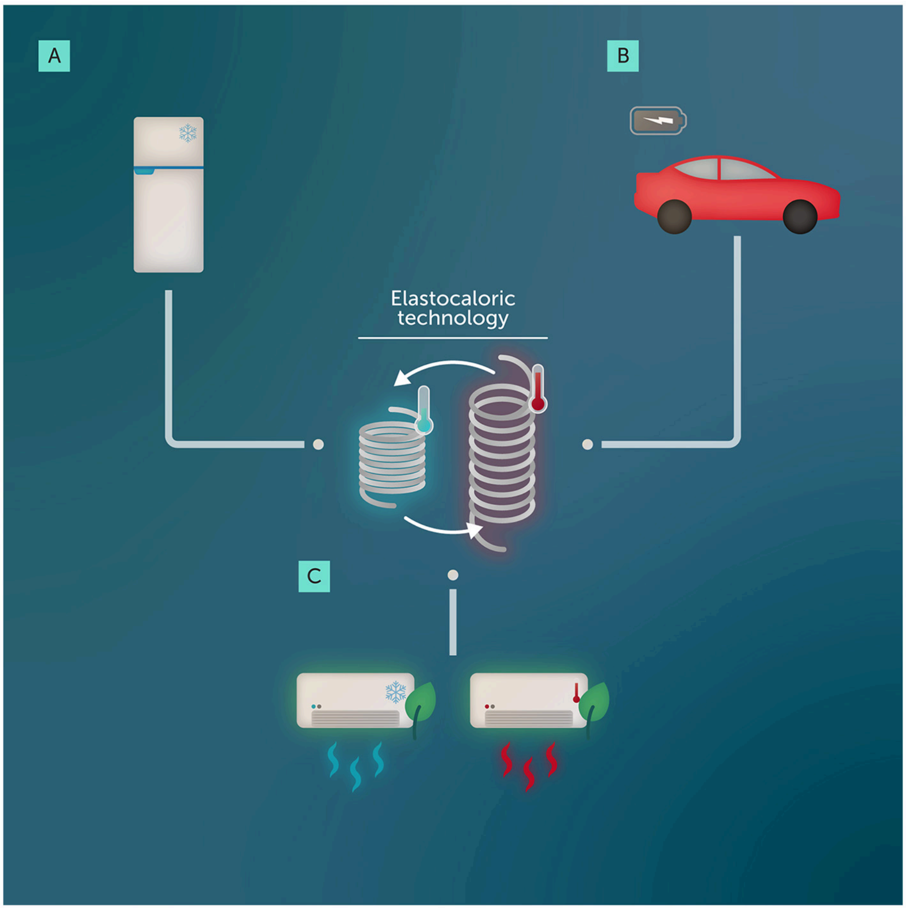

Figure 1

Figure 1

By mimicking the way that muscles contract and relax, elastocalorics could improve how we cool and heat spaces. **(A)** Elastocalorics can be used for refrigeration, to keep foods or medicines cool. **(B)** By reducing the amount of battery energy needed for heating/cooling, elastocalorics could increase the driving range of electric cars. **(C)** Elastocaloric technology can also be used to heat homes and buildings. Since elastocaloric heating and cooling use less energy, they are an environmentally friendly alternative to traditional air conditioning.

energy—making these cars more practical and appealing to drivers (Figure 1B).

In addition to cooling, elastocaloric heat pumps could also improve heating systems in colder climates. By reversing the process—absorbing heat from the outside air and releasing it indoors—they could efficiently warm homes and buildings, providing an all-in-one solution for temperature control.

BIG CHALLENGES, BIGGER OPPORTUNITIES

Before elastocaloric technology is widely used to keep us cool, there are some challenges to solve. One big challenge is the durability of the materials. Shape-memory alloys can handle millions of cycles of stretching and relaxing, but researchers are working to improve their lifespan and performance, to make them more cost-effective for large-scale use. Another challenge is designing the machinery that stretches and relaxes the materials efficiently from an energetic point of view: these systems must be precise, durable, and energy efficient to compete with the commonly used vapor compression cooling systems. Engineers are testing different designs, like advanced motors or rotating mechanisms, to create the stretching motion in a continuous cycle. Another issue is the cost of producing the specialized metal alloys needed for elastocaloric systems. These alloys are expensive, so researchers are looking for cheaper ways to manufacture them in large quantities. Making these materials affordable is key to ensuring this technology can be used all over the world.

If researchers can overcome these challenges, elastocaloric technologies could reduce greenhouse gas emissions, lower energy costs, and expand access to cooling and heating, helping people all over the world to keep cool.

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As a junior high school student, I have a keen interest in the field of STEM. I enjoy baking, reading, and learning new topics. I aspire to pursue a career that blends technology and research.

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As a second year middle school student, I am interested in the fields of science and mathematics. I enjoy playing piano, crochet, and reading books.

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ADRIANA GRECO
Adriana Greco is a professor of engineering in Naples, Italy. She studies how to heat and cool things in smart, energy-saving ways. She works at the University of Naples Federico II, where she leads a research team that studies refrigeration and heat transfer. Her team works with scientists around the world, including in China, Spain, Germany, and India. Adriana has spent over 20 years studying new ways to cool things using special materials that do not harm the environment. She helped create the first Italian heat pump that uses an exciting method called the elastocaloric effect—which cools things down by stretching and releasing certain metals. She also leads a big European project to improve this type of cooling. She has written over 140 scientific papers and is part of several international science groups. Her work is so well known that she was named one of the world's top 2% of scientists in 2020 and 2022.

CLAUDIA MASSELLI

Claudia Masselli is a professor at the University of Naples Federico II in Italy. She studies heat transfer and how to design better, more eco-friendly ways to cool things down. Her favorite kind of cooling is called solid-state cooling, which uses special materials instead of harmful gases. She has helped build three real devices that use this kind of cooling—one that uses magnets and two that use stretchy metals. Claudia also works on improving traditional cooling systems and using renewable energy. She has written over 120 scientific papers and won two awards for her research as a young scientist. She helps lead several science journals and reviews papers written by other scientists. She is also part of international science groups that focus on refrigeration and energy systems.

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Mine Orlu is a scientist who studies medicines and how they work for older people. She teaches at University College London (UCL) and helps design medicines that are easier to take as people age. She leads a research group focused on medicines for older adults and helps run a pharmacy master's program. Dr. Orlu also works with teams in the UK and Europe to improve medicine safety and effectiveness for different groups of people. She is passionate about making sure everyone gets the right medicine for their needs. *m.orlu@ucl.ac.uk

WILFRIED WEBER

Wilfried Weber is a scientist who leads the Leibniz Institute for New Materials in Germany. He studies how to create new materials by learning from nature. For example, just like plants grow toward light, he designs materials that can change and adapt to their surroundings. Before this, he was a professor at the University of Freiburg, where he combined biology and materials science to develop new technologies. His work helps create smarter materials that could improve medicine and make construction more sustainable.