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Taking the heat off: breakthrough cooling technology tackles climate challenge

EU-funded researchers are developing a smarter system of sustainable cooling, replacing toxic refrigerants with safer, more efficient and recyclable metals.

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As a young engineering student contemplating the direction of his doctoral research, Jaka Tušek knew he wanted to push the boundaries of science. “I wanted to work on breakthroughs, tackle something new that hasn’t been done before.”

Today, the Slovenian researcher is on the cusp of the first major breakthrough in cooling technologies in the last 100 years. His work is solving one of the fundamental challenges of our time: keeping cool in a warming world without polluting it further.

Time for change

The vapour-compression technology commonly used by fridges, air conditioners and other cooling technology is more than a century old, and is relatively inefficient and bad for the environment.

While the most damaging refrigerants have been banned since 1989, those that replaced them – hydrofluorocarbons – turned out to have a greenhouse effect hundreds of thousands of times greater than CO2.

“If one kilogram of such a refrigerant evaporates into the atmosphere, it has roughly the same greenhouse effect as driving a car for about 30 000 kilometres,” said Tušek.

Because of this, hydrofluorocarbons are also being phased out. But natural alternatives such as ammonia and isobutane come with their own set of issues, from toxicity and explosiveness to poor efficiency in hot climates.

A solid solution

Building on the discoveries of an EU-funded research project named SUPERCOOL, which ran at Slovenia's University of Ljubljana from 2019 to 2023, Tušek's team is developing a system with a fundamentally different approach. It is replacing toxic refrigerants with metal tubes.

While such solid-state cooling technologies are still in their early stages, the thinking is that they will be able to provide safer cooling devices that work quietly and more efficiently, without polluting the environment.

The researchers at the University of Ljubljana are now working to bring this new technology to the market. They are preparing a patent and developing a plan for industry adoption as part of E-CO-HEAT, another research initiative funded by the EU, which runs until early 2026.

Making heating and cooling technologies more efficient and sustainable is at the heart of the EU's Heating and Cooling Strategy, which is a vital segment of the European Green Deal.

Cooling currently accounts for 10% of the world's electricity demand, according to the International Energy Agency (IEA). Worse, the need for cooling technologies is growing exponentially, due to rising temperatures and growing demand in developing countries.

"Nobody wants to work in 50-degree heat and 90% humidity," said Tušek.

There are around 2 billion air conditioning units in the world today, a figure that the IEA expects to almost triple by 2050.

"This growth, combined with the fact that they are relatively inefficient and harmful to the environment, could lead to an environmental disaster," he said.

The quest for efficiency

Cooling depends on the basic chemistry of phase changes, when matter changes from one state (solid, liquid, or gas) to another.

With traditional refrigerants, the transformation from liquid to gas and back again is what powers the cooling cycle. But some materials, such as a nickel-titanium alloy known as nitinol, can go through a phase transformation while remaining solid.

"Simply put, when you put mechanical stress on them, they heat up, when you relieve it, they cool down," said Žiga Ahčin, a researcher on the project. The technology is called elastocaloric cooling, caloric in this case referring to heat.

Unlike traditional refrigerants, these materials are not harmful to people or the environment. In fact, nitinol wires are biocompatible and commonly used in medicine. In theory, the system could also be far more efficient, though it still has some way to go.

"Our prototype is currently at 15% of maximum possible efficiency, while vapour compression has 20-30% efficiency," said Tušek.

"But we've been developing this technology for less than 10 years, while vapour compression technology has been on the market for over a hundred, so I think we still have some wiggle room."

A world first

In theory, elastocaloric cooling could reach up to 70% efficiency, but there is one major snag. Nitinol wires degrade quickly when stretched repeatedly to induce a phase change, a phenomenon known as fatigue.

“Let’s say the device works for 10 000 load cycles. That’s two to three days, and you’re done,” said Ahčin. That did not look promising.

But then, he explained, Tušek had the idea of compressing the materials instead of stretching them, reducing the physical stress on the wires.

The resulting prototype was a world first, reaching new levels of heating and cooling performance without degrading the materials it depended on.

“We proved that the lifespan of such materials can be practically unlimited,” said Tušek. “At the same time, our prototype was the first in the world with a range of over 30 degrees Celsius, which is key for practical cooling and heating applications.”

From the lab to the world

The University of Ljubljana researchers have partnered up with universities from Germany and Italy, as well as a tech company from Ireland, to develop an advanced air conditioner based on the technology. This collaboration, named SMACool, has also received EU funding.

“We’re progressing faster when we work in this interdisciplinary way,” said Tušek, noting that each university is contributing a different area of expertise. He is optimistic that the technology could reach the market in the next 5 to 10 years.

“It’s cool to think that this technology could someday be everywhere,” said Ahčin. “And my kids could say their dad developed it.”

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More info

- SUPERCOOL
- SUPERCOOL project website
- E-CO-HEAT
- SMACool
- EU Heating and Cooling Strategy