Q&A: The multiple benefits of a world without air conditioning

September 15 2020, by Molly Seltzer

Eric Teitelbaum (center), speaks to visitors inside the Cold Tube pavilion in Singapore. Credit: Lea Ruefenacht

When most people think of cooling, they automatically imagine air conditioning, or cooling the air in a room. But there is a much more efficient way to cool people, using the body's radiation.

To demonstrate the effect of radiant cooling, Forrest Meggers, assistant

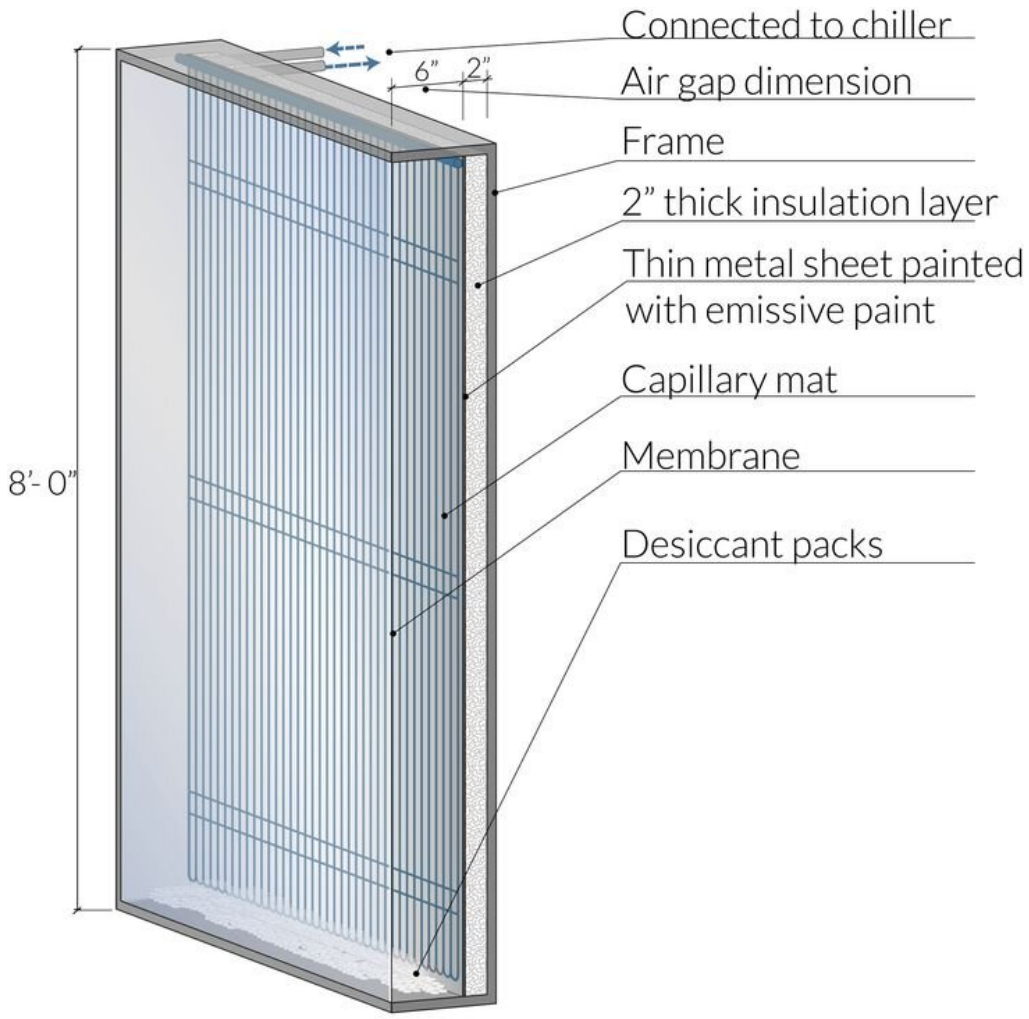
professor of architecture and the Andlinger Center for Energy and the Environment, and a team of researchers built the Cold Tube in Singapore last year. It was an outdoor pavilion lined with novel insulated radiant panels that held cold water pipes inside. The human body is constantly exchanging radiation with objects around it and that radiation flows from hot to cool surfaces. The participants who walked through the exhibit shed their radiation toward the panels and reported feeling cool, despite the air itself having temperature and humidity levels that would ordinarily feel sweltering. The new research showed that people could feel comfortable in hot and humid outdoor environments using only radiant cooling, which could use far less energy than cooling large volumes of air.

Coincidentally Yueh-Lin (Lynn) Loo, director of the Andlinger Center for Energy and the Environment, has been based in Singapore for the last five months, not far from where Meggers' team tested the Cold Tube. "These alternative designs can disrupt how we think about simultaneously cooling spaces and promoting air circulation," said Loo, who is also the Theodora D. '78 and William H. Walton III '74 Professor in Engineering and professor of chemical and biological engineering. "I think the Cold Tube and similar technologies are exactly the types of innovations that can help make living in the tropics more enjoyable."

The Princeton researchers, collaborating with scholars at the University of British Columbia, University of Berkeley, ETH Zurich in Singapore, and the University of Pennsylvania, published the Cold Tube results in the August 18 issue of the *Proceedings of the National Academy of Sciences* (*PNAS*).

In this Q&A, Meggers and first author of the paper, Dr. Eric Teitelbaum, who completed the research as a graduate student under Meggers and is now a senior engineer at AIL Research, comment on the potential for their technology to save money and energy, as well to help

keep people safe in a pandemic like the current COVID-19 crisis by allowing for more air flow in a building without installing new infrastructure or requiring extra energy to cool the greater air volume.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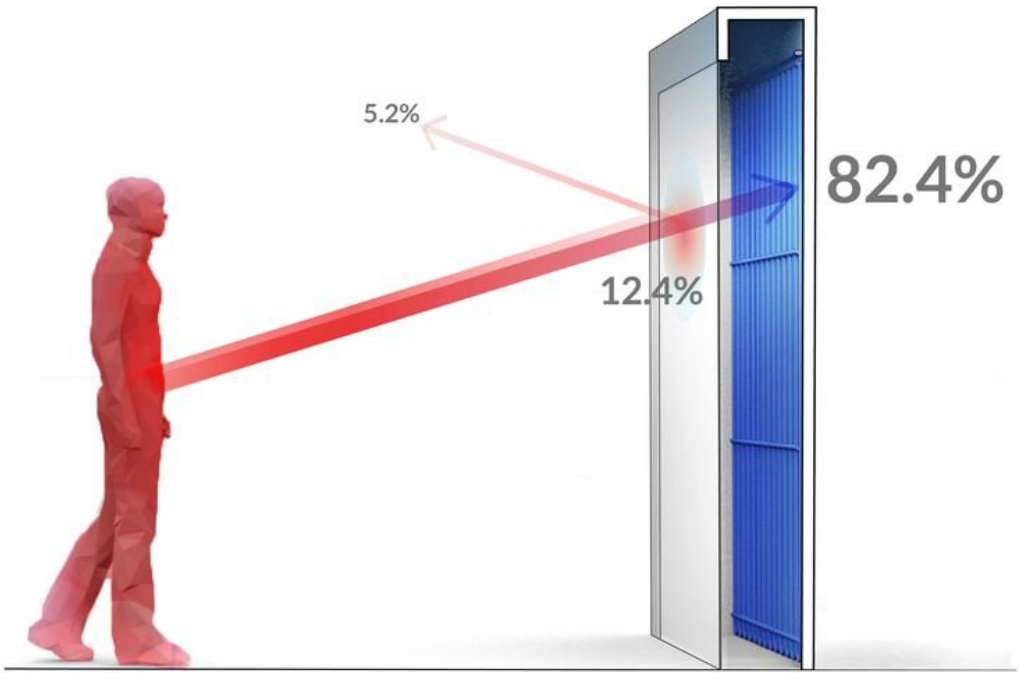
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Schematic of a Cold Tube radiant cooling panel (Upper) and radiant heat transfer through the infrared-transparent membrane (Lower). Credit: Princeton University

What is the biggest misconception about air conditioning?

Meggers: Air conditioning does not equal cooling. It's a highly engrained method of cooling buildings, but it's not the only one. Additionally, your window air conditioners are just cooling existing air in the room; they don't bring new, fresh air into your room. Air conditioning (AC) units have become so normalized and integrated into daily life but, in reality, they are huge machines that require a lot of energy, and should not be treated like turning on a light switch. A seemingly simple window unit requires 10 to 1000 times more energy than a ceiling fan, and leaving the AC on is comparable in energy to leaving the light on in 100 rooms.

What is the benefit of cooling surfaces, such as walls and tables, instead of cooling the air?

Meggers: In the Cold Tube, occupants are cooled entirely by thermal radiation, which means energy was primarily used for cooling the water inside the walls, not cooling the air. With air conditioning, dehumidification and cooling occur simultaneously. The benefit of the Cold Tube technology is that it decouples cooling from the providing of fresh air, meaning people can keep their windows open, while maintaining comfort, and without expending massive amounts of energy to cool and dehumidify the air flow. Air should be only for breathing, not cooling.

How are the findings relevant to keeping people safe from viruses like COVID-19?

Teitelbaum: The way buildings are built today, using exclusively AC for cooling, we can't increase the amount of fresh air we deliver to buildings at will because air flow is coupled with the amount of air conditioning buildings need to provide. If you want more outdoor air flowing into the building, you also need additional capacity to dehumidify and cool that air. Most systems weren't built with the capacity to flow the amount of air that, in many cases, is being recommended to dilute indoor air contaminants and prevent the spread of contagion, like the recent COVID-19 virus. And if they can, it requires massive amounts of energy. But with radiant systems, people can open the windows and still remain comfortable, while letting in extra fresh air to reduce the concentration of virus in the air.

How does this technology help mitigate climate change?

Teitelbaum: This system uses at least 50% less energy than a comparably-sized air conditioner. Letting the air warm up by five degrees while cooling surfaces can lower energy demand by up to 40% and maintain occupant comfort. Allowing even hotter air temperatures would result in higher energy savings.

Could this alternative to air conditioning improve outdoor air quality as well by mitigating the urban heat island effect?

Meggers: Most of my coauthors and I have traveled around Southeast Asia and have seen firsthand how quickly AC units have been deployed at scale. Adding AC window or split units to buildings is done with little contemplation of the effects on surface temperatures, and the climate of

and heat in a city. The units work by rejecting the heat from the air in a room to the outside. Rejecting heat outside the buildings along the façade leads to sidewalks and areas around buildings becoming very hot, and many spaces becoming unusable. Our technology does exactly the opposite; it provides opportunities to regain thermal acceptability in various parts of the city without having to build a huge park. You can install these cooling panels outside and build "cool havens" where people can gather, eat, and play.

How important is this experiment in paving the way toward a world where people are cooled without AC?

Teitelbaum: It will take more than an 8-month experiment to change the way people think about comfort systems and energy efficiency in the built environment. Much of Professor Megger's C.H.A.O.S lab's research has focused on expanding the knowledge bubble of thermal radiation's influence on comfort and efficiency. The Cold Tube experiment created a lot of new knowledge, which is a great academic success. Commercially, while there are companies that manufacture similar technologies, there is still a need to continue to demonstrate and experiment with new concepts to not only further the technology, but also this paradigm shift. The shift away from air conditioning towards more holistic comfort design would help us act as stewards of the planet as well as our own built environments. In many parts of the world, such as Singapore and other tropical areas that are increasingly seeking ways to condition spaces, significantly more energy goes towards dehumidifying the air than just cooling the air. This is one of the places that we believe our comfort paradigm will have the greatest efficiency increases and impact, since dehumidification is not required for people to feel comfortable.

More information: Eric Teitelbaum et al. Membrane-assisted radiant

cooling for expanding thermal comfort zones globally without air conditioning, *Proceedings of the National Academy of Sciences* (2020). DOI: 10.1073/pnas.2001678117

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