Affordable and Sustainable Cooling Using Metal-Organic Frameworks

The world's demand for comfort cooling is growing at a staggering pace. Warming climate, rapid urbanization, and rising incomes are driving the demand for air conditioning. Space cooling will become the single largest user of electricity in buildings, accounting for 16% of the global electricity demand by 2050 *(1)*. The majority of this growth will come from emerging economies with hot, humid climates and growing populations, such as Brazil, India, and Indonesia.

The growing demand for cooling is already putting an enormous strain on the environment, grid infrastructure, and global climate. Cooling accounts for 12% of CO_2 emissions from buildings, consumes more than 2,000 TWh of electricity per year, and produces heat island effects that can raise the temperature by more than 1°C in some cities *(1)*. Meeting the world's demand for cooling while minimizing its negative impacts will be one of the defining challenges of our time. This challenge can be addressed by increasing the efficiency of air conditioners with new materials and chemical processes.

A typical air conditioner performs two functions at once: cooling and dehumidifying. Air conditioners must work harder in hot and humid conditions; an air conditioner operating in a tropical climate can use up to 60% of its cooling power to dehumidify the air. A material that removes moisture from the atmosphere could make it easier and more energy efficient to cool the air. Enter metal-organic frameworks (MOFs): sponge-like, highly porous materials that have more surface area per gram than any other material and can be regenerated with low-grade waste heat. MOFs are an emerging class of materials that promise new commercial opportunities due to their special capabilities.

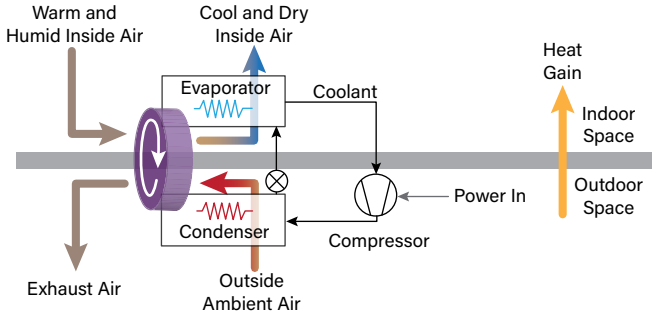
Transaera, Inc., a Somerville, MA-based small business, is developing a new class of air conditioning systems that can achieve unprecedented energy efficiency using MOF materials.

Large water uptake, low regeneration temperature, and low heat of adsorption (almost half as much as commonly used zeolites) make MOFs ideal candidates for cooling applications, especially in humid environments. An air conditioner with a MOF-based dehumidifier accessory can quickly remove moisture from incoming air using less energy than a traditional air conditioning unit.

The unique structure of the material facilitates moisture capture. Once the water vapor enters the pores of the MOF, it becomes dense but does not form into liquid. This phenomenon is enabled by the narrow structure of the pore walls. By keeping the water in the gas phase, trapped within the MOF, the energy required to expel the captured moisture and dry the adsorbent is less than the energy that would be required by common commercial desiccant materials. In Transaera's design, the moisture-saturated MOF is dried and regenerated using only the heat from the air conditioner itself, a source of energy that is currently wasted. The net effect is an increase in the energy efficiency of the air conditioner by as much as 35%.

Because the MOF is able to quickly adsorb and desorb moisture, a small amount of material can remove a large amount of moisture. This allows a smaller evaporator, condenser, and compressor to be used to achieve the same amount of cooling, which ultimately reduces the cost of the system. National Science Foundation (NSF) funding is helping Transaera address the production scaleup of candidate MOFs and the development of composite structures with embedded MOFs. These composites will enable a much higher rate of moisture and heat transfer than traditional packed-bed configurations, which will help to decrease operating costs.

Based on the promising results of these efforts, Transaera was named one of eight finalists in the Global Cooling Prize, an international innovation competition to develop an affordable and sustainable residential air conditioner. "What makes this competition especially exciting is the market transformation opportunity," says Sir Richard Branson, Founder and CEO of the Virgin Group. "It could be one of the biggest technology-based steps we can take to arrest climate change." CEP



◀ A MOF-based cartridge (purple) can be added to an existing air conditioner. The cartridge adsorbs moisture and dries the air before the evaporator cools it. Once saturated with water, the cartridge rotates into the hot air stream to dry and prepare for the next adsorption cycle.

1. International Energy Agency, "The Future of Cooling," www.iea.org/reports/the-future-of-cooling (May 2018).

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