MATERIALS

Building climate-resilient cities

Innovative materials will keep growing urban populations safe from heat, floods, and other natural disasters

PRACHI PATEL, special to C&EN

More than half the world's population lives in urban areas, and that share will grow to two-thirds by 2050, according to the United Nations. To be safe and sustainable in the face of extreme weather and other climate hazards, cities will have to adapt. Materials technologies, both low tech and cutting edge, will play an important role.

Cities must brace against a range of threats, including heat waves baking Southeast Asia, tropical storms and rising seas menacing coastal megacities, wildfires raging in Australia, and rivers bursting with torrential rainfall in the US Midwest.

Intense heat, in particular, can melt asphalt roads and buckle railways—and it kills thousands annually. "Heat is the number 1 lethal natural disaster every year," says Kurt Shickman, executive director of the Global Cool Cities Alliance, based in Washington, DC. "And the poorest feel the worst of the effect."

Scientists and entrepreneurs are developing technologies to design the climate-resilient cities the world will need. By planning ahead, cities can save hundreds of lives and billions of dollars in infrastructure. "Mother Nature bats last," says Jason Cervenec, who is education and outreach director at the Byrd Polar and Climate Research Center at the Ohio State University and who led the task force on a climate adaptation plan for his city of Columbus, Ohio. "The accurate way to look at it is 'What's the cost of not doing this?' "

Cool roofs

Mediterranean homes are white stucco for a good reason: coating roofs with calcium carbonate whitewash or white or aluminum paint is an inexpensive way to keep buildings cool and comfortable without the need for air-conditioning. Thin, reflective plastic membranes also work on flat or low-sloped roofs.

Reflective roofs can be as much as 30 °C cooler than dark ones, and they have the potential to chill entire cities by a few degrees by cooling the air above them. But not everyone wants a white roof. Innovative, clear coatings maintain aesthetics while adding reflectivity.

The start-up Cypris Materials of Berkeley, California, is making a paintable, transparent coating based on self-assembling polymers. These materials form nanostructures that reflect a wide spectrum of sunlight. And Columbia University spin-off MetaRE's porous polymer paints that scatter and reflect heat are being tested in low-income households in Mexico as part of the Million Cool Roofs Challenge.

Insulating facades

Well-insulated buildings use less energy to keep residents comfortable in extreme weather, making insulation low-hanging fruit for climate change adaptation and mitigation.

Traditional materials like polystyrene and sprayable polyurethane foams, as well as more ecofriendly cellulose and fiberglass, work well. University of Maryland researchers have invented another sustainable option for midrise apartment buildings: "nanowood," made strong and superinsulating by removing wood's lignin and compressing it.

Windows are hard to insulate. They leak 30% of heated and cooled air. But new options could help. Michigan-based Mackinac Technology, for instance, makes multilayer plastic coatings that reflect infrared heat and trap air to insulate buildings. Meanwhile, University of Colorado researchers have made see-through insulating aerogels from beer-production waste and created heat-reflecting polymethylpentene films embedded with glass microspheres. Smart electrochromic windows that become dark or hazy with the flip of a switch are a more high-tech solution and are typically made of metal oxide layers sandwiching a lithium-ion solution.

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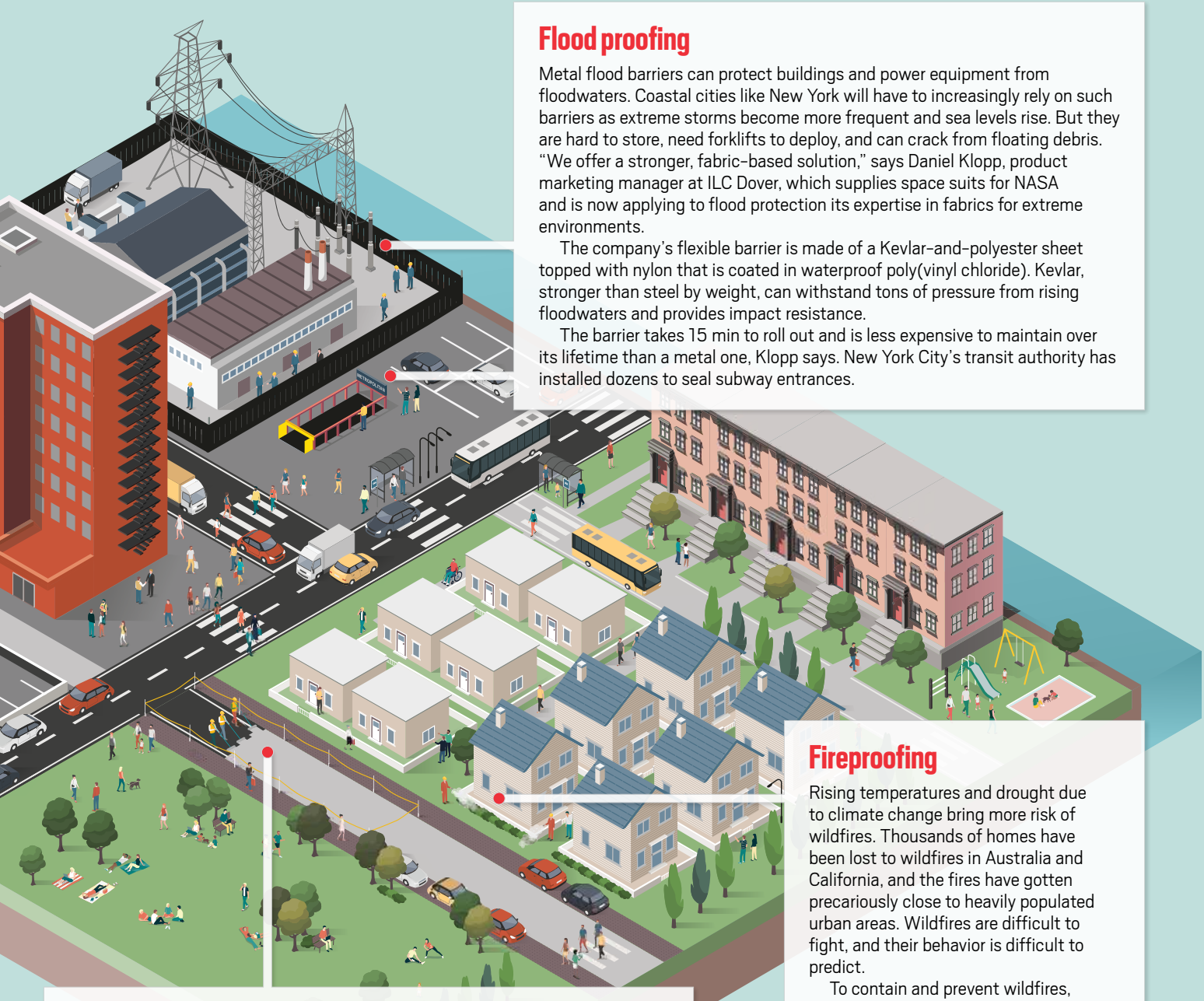

Flood proofing

Metal flood barriers can protect buildings and power equipment from floodwaters. Coastal cities like New York will have to increasingly rely on such barriers as extreme storms become more frequent and sea levels rise. But they are hard to store, need forklifts to deploy, and can crack from floating debris. "We offer a stronger, fabric-based solution," says Daniel Klopp, product marketing manager at ILC Dover, which supplies space suits for NASA and is now applying to flood protection its expertise in fabrics for extreme environments.

The company's flexible barrier is made of a Kevlar-and-polyester sheet topped with nylon that is coated in waterproof poly(vinyl chloride). Kevlar, stronger than steel by weight, can withstand tons of pressure from rising floodwaters and provides impact resistance.

The barrier takes 15 min to roll out and is less expensive to maintain over its lifetime than a metal one, Klopp says. New York City's transit authority has installed dozens to seal subway entrances.

Fireproofing

Rising temperatures and drought due to climate change bring more risk of wildfires. Thousands of homes have been lost to wildfires in Australia and California, and the fires have gotten precariously close to heavily populated urban areas. Wildfires are difficult to fight, and their behavior is difficult to predict.

To contain and prevent wildfires, vegetation and structures in high-risk areas could be sprayed with fire-retardant gels. Substances that responders use today can wash away and evaporate, but a new ecofriendly gel formulated by a Stanford University team is more persistent, staying put and effective for months.

Traditional building materials and landscaping aren't designed with fire in mind. In high-risk areas, homes can be made fire retardant with fiber-cement siding, metal gutters, and fiberglass or metal doors and window frames.

Cool pavements

Roads make up over a third of the surface of many cities. Most are made of asphalt, which is becoming a liability in hot climates. Asphalt soaks up the sun, stores heat, and is known to buckle and liquefy during scorching heat waves, which are becoming more common in some regions thanks to climate change.

Reflective pavements can be more than 10 °C cooler than blacktop. To keep costs low, these materials need to be easy to apply and durable. Light-colored sealants made by companies like GuardTop can be applied just like conventional protective coatings. The start-up ePAVE, meanwhile, makes a mix of cement with a polymer-and-titanium dioxide blend that binds to asphalt and reflects infrared light. The 3 mm thick overlay cures and becomes rock hard in 20 min, so traffic disruption is minimal, and it should last 10 years, CEO Klara Moradkhan says.

Los Angeles; Melbourne, Australia; and Tokyo are piloting reflective roads. Others are testing permeable pavements made of porous asphalt or paving stones for their ability to help roads chill through evaporative cooling.

Prachi Patel is a freelance science journalist.