# Addressing food insecurity in arid regions with an open-source evaporative cooling chamber design

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Top left: Fans installed in the roof of a forced-air evaporative cooling chamber in Kenya. Top right: Forced-air evaporative cooling chamber built by the Hunnarshala Foundation in India. Bottom right: A member of the Solar Freeze team installing cooling pads in the interior of the used shipping container that houses a forced-air evaporative cooling chamber in Kenya. Bottom left: CAD rendering of a solar-powered forced-air evaporative cooling chamber with produce crates in the interior visible. Credit: Solar Freeze, Hunnarshala Foundation, MIT D-Lab

Anyone who has ever perspired on a hot summer day understands the principle—and critical value—of evaporative cooling. Our bodies produce droplets of sweat when we overheat, and with a dry breeze or nearby fan those droplets will evaporate, absorbing heat in the process creating a welcome cool feeling.

That same scientific principle, known as evaporative cooling, can be a game-changer for preserving fruits and vegetables grown on smallholder farms, where the wilting dry heat can quickly degrade freshly harvested produce. If those just-picked red peppers and leafy greens are not consumed in short order, or quickly transferred to cold—or at least cool—storage, much of it can go to waste.

Now, MIT Professor Leon Glicksman of the Building Technology Program within the Department of Architecture, and Research Engineer Eric Verploegen of MIT D-Lab have released their open-source design for a forced-air evaporative cooling chamber that can be built in a used shipping container and powered by either grid electricity or built-in solar panels. With a capacity of 168 produce crates, the chamber offers great promise for smallholder farmers in hot, dry climates who need an affordable method for quickly bringing down the temperature of freshly harvested fruit and vegetables to ensure they stay fresh.

"Delicate fruits and vegetables are most vulnerable to spoilage if they are picked during the day," says Verploegen, a longtime proponent of using evaporative cooling to reduce post-harvest waste. "And if refrigerated cold rooms aren't feasible or affordable," he continues, "evaporative cooling can make a big difference for farmers and the communities they feed."

Verploegen has made evaporative cooling the focus of his work since 2016, initially focusing on small-scale evaporative cooling "Zeer" pots, typically with a capacity between 10 and 100 liters and great for household use, as well as larger double-brick-walled chambers known as zero-energy cooling chambers or ZECCs, which can store between six and 16 vegetable crates at a time. These designs rely on passive airflow. The newly released design for the forced-air evaporative cooling chamber is differentiated from these two more modest designs by the active airflow system, as well as by significantly larger capacity.

In 2019, Verploegen turned his attention to the idea of building a larger evaporative cooling room and joined forces with Glicksman to explore using forced, instead of passive, airflow to cool fruit and vegetables. After studying existing cold storage options and conducting user research with farmers in Kenya, they came up with the idea to use active evaporative cooling with a used shipping container as the structure of the chamber. As the COVID-19 pandemic was ramping up in 2020, they procured a used 10-foot shipping container, installed it in the courtyard area outside D-Lab near Village Street, and went to work on a prototype of the forced-air evaporative cooling chamber.

Here's how it works: Industrial fans draw hot, dry air into the chamber, which is passed through a porous wet pad. The resulting cool and humid air is then forced through the crates of fruits and vegetables stored inside the chamber. The air is then directed through the raised floor and to a channel between the insulation and the exterior container wall, where it flows to the exhaust holes near the top of the side walls.

Leon Glicksman, a professor of building technology and mechanical engineering, drew on his previous research in natural ventilation and airflow in buildings to come up with the vertical forced-air design pattern for the chamber. "The key to the design is the close control of the airflow strength, and its direction," he says. "The strength of the airflow passing directly through the crates of fruits and vegetables, and the airflow pathway itself, are what makes this system work so well. The design promotes rapid cooling of a harvest taken directly from the field."

In addition to the novel and effective airflow system, the forced-air evaporative cooling chamber represents so much of what D-Lab is known for in its work in low-resourced and off-grid communities: developing low-cost and low-carbon-footprint technologies with partners. Evaporative cooling is no different. Whether connected to the electrical grid or run from solar panels, the forced-air chamber consumes one-quarter the power of refrigerated cold rooms. And, as the chamber is designed to be built in a used shipping container—ubiquitous the world over—the project is a great example of up-cycling.

## Piloting the design

As with earlier investigations, Verploegen, Glicksman, and their colleagues have worked closely with farmers and community members. For the forced-air system, the team engaged with community partners who are living the need for better cooling and storage conditions for their produce in the climate conditions where evaporative cooling works best. Two partners, one in Kenya and one in India, each built a pilot chamber, testing and informing the process alongside the work being done at MIT.

In Kenya, where smallholder farms produce 63% of total food consumed and more than 50% of smallholder produce is lost post-harvest, they worked with Solar Freeze, a cold storage company located in in Kibwezi, Kenya. Solar Freeze, whose founder Dysmus Kisilu was a 2019 MIT D-Lab Scale-Ups Fellow, built an off-grid forced-air evaporative cooling chamber at a produce market between Nairobi and Mombasa at a cost of

$15,000, powered by solar photovoltaic panels.

"The chamber is offering a safety net against huge post-harvest losses previously experienced by local smallholder farmers," comments Peter Mumo, an entrepreneur and local politician who oversaw the construction of the Solar Freeze chamber in Makuni County, Kenya.

As much as 30% of fruits and vegetables produced in India are wasted each year due to insufficient cold storage capacity, lack of cold storage close to farms, poor transportation infrastructure, and other gaps in the cold chain. Although the climate varies across the subcontinent, the hot desert climate there, such as in Bhuj where the Hunnarshala Foundation is headquartered, is perfect for evaporative cooling.

Hunnarshala signed on to build an on-grid system for $8,100, which they located at an organic farm near Bhuj. "We have really encouraging results," says Mahavir Acharya, executive director of Hunnarshala Foundation. "In peak summer, when the temperature is 42 [Celsius] we are able to get to 26 degrees [Celsius] inside and 95% humidity, which is really good conditions for vegetables to remain fresh for three, four, five, six days. In winter we tested [and saw temperatures reduced from] 35 degrees to 24 degrees [Celsius], and for seven days the quality was quite good."

## Getting the word out

With the concept validated and pilots well established, the next step is spreading the word.

"We're continuing to test and optimize the system, both in Kenya and India, as well as our test chambers here at MIT," says Verploegen. "We will continue piloting with users and deploying with farmers and vendors, gathering data on the thermal performance, the shelf life of fruits and vegetables in the chamber, and how using the technology impacts the users. And, we're also looking to engage with cold storage providers who might want to build this or others in the horticulture value chain such as farmer cooperatives, individual farmers, and local governments."

To reach the widest number of potential users, Verploegen and the team chose not to pursue a patent and instead set up a website to disseminate the open-source design with detailed guidance on how to build a forced-air evaporative cooling chamber. In addition to the extensive printed documentation, well-illustrated with detailed CAD drawings and video, the team has created instructional videos.

As co-principal investigator in the early stages of the project, MIT professor of mechanical engineering Dan Frey contributed to the market research phase of the project and the initial conception of chamber design. "These forced-air evaporative cooling chambers have great potential, and the open-source approach is an excellent choice for this project," says Frey. "The design's release is a significant milestone on the path to positive impacts."

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