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Refrigeration goes off the grid with the Chill Challenge

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THE FROZEN FRONTIER

An innovation competition organised by Engineers Without Borders USA is providing much-needed cooling solutions to off-the-grid communities. **Willow Aliento** reports on the Chill Challenge.

There's nothing like a challenge to encourage innovation, and the Engineers Without Borders USA (EWB-USA) Chill Challenge has definitely fostered some unique ideas for providing refrigeration and cooling in the world's lowest-income communities.

About two billion people globally lack access to reliable refrigeration. This is both a public health problem and has economic implications for food producers as lack of cooling for fresh produce, dairy and other foods increases the amount of waste.

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Launched in August 2019, the Chill Challenge called for a solution that is off-grid, affordable, scalable and delivers either a 150–250L refrigerator that can chill 20L of water per day from 35°C to 3°C, and costs less than US$12/month to own and operate; or development of an icemaker that can produce 100–1,000kg of ice per day at a cost of US$0.03/kg or less.

ASHRAE partnered with EWB-USA for the competition, contributing to the expert panel of technical reviewers and providing outreach. Open Philanthropy provided financial support including grants of between US$30,000 and US$50,000 for up to 10 successful proposals to assist with prototyping and technology development.

WHY IS IT NEEDED?

"Refrigeration plays a critical role in addressing the UN's Global Development Goals in eliminating hunger, poverty and inequality, and ensuring universal access to safe water, education, health care, clean energy, and more," says CEO of EWB-USA, Jackie O'Brien.

"Successful solutions to our refrigeration challenge will be a game-changer for millions of people. We are extremely proud that EWB-USA is at the forefront of catalysing new thinking around refrigeration."

O'Brien says the challenge will hopefully contribute to a broader understanding of the various technologies being tested, too. EWB-USA plans to publish the results of the various team efforts, both successful and unsuccessful.

**Jackie O'Brien,
CEO of EWB-USA**

**EWB-USA volunteers
F. Andrew Dowdy and Larry Bentley**

"In addition, another goal of the challenge is to promote a broader understanding of the fundamental off-grid refrigeration challenge encountered by off-grid communities," says O'Brien.

"Whether or not we identify a solution through the Chill Challenge, this is an area that will need innovative engineering thinking for years to come."

The Chill Challenge has been overseen by senior engineers and EWB-USA volunteers Larry Bentley and F. Andrew Dowdy.

For both it has been an opportunity to put a lifetime of experience to work for the greater good.

Dowdy says his interest in the project stems from work he did on energy access in a previous career.

"However, as I started working with Larry and others at EWB on the nuts and bolts of getting electricity to off-grid communities, we realised that refrigeration would be one of the most difficult challenges, and an application with potentially high rewards.," Dowdy says.

"We designed the challenge to respond to that 'refrigeration gap'."

WHY CHILLED WATER?

The liquid chilling specification is a straightforward test of the refrigeration capacity that matches the Food and Agriculture Organization (FAO) standards for milk chilling, Dowdy says. That is, the fridge would be able to safely chill 20L of milk, if that were the application.

Although production of chilled water as a final product wasn't a requirement, Bentley notes that the capability of chilling it has some vital applications through using water as a heat transfer medium as a viable way of doing fairly rapid cooling.

He recalls seeing a homemade system in a refugee camp in southern Ethiopia where the Somali owner was circulating chilled saltwater brine to freeze sugar, water and food colouring into plastic bags and selling "pop-cycles".

"Since it was close to 40°C I bet they sold well," he says. "All this was running off a diesel generator as there was no grid power for many kilometres."

WHY DOES ICE MATTER?

The second half of the Chill Challenge brief was for an ice plant.

"Ice can serve poor households in insulated boxes as low-cost 'refrigerators' and is also used to chill fresh fish and dairy products, extending their marketability times," Bentley says.

"Typically, dairy farmers have to feed the evening milking to their livestock or dump it since it will be bad by morning market time. Providing them a way to market that product will improve incomes."

It was also important the refrigeration technologies could operate at elevated temperatures as the impacts of climate change escalate.

Conventional refrigerators are designed to hold food at around 3–5°C in a home that is 20–25°C.

"A lot of the target areas for these products are well above 35°C and for some daytime peaks of 45°C aren't unusual," says Bentley. "This basically means the units have to push heat up a steeper hill than typical designs."

DESIGNING FOR THE MANY, NOT THE FEW

Bentley says the brief's requirement for environmental sustainability and low cost required a very different engineering design focus to the one Western business models are trained to produce. It's about creating appropriate technology for the context.

"A newly reproduced WWII 'jeep' would better serve many African nations than the upscale four-wheel drive vehicles that are popular in the richer nations and the wealthy in Africa," Bentley says.

He says that in the Majority World context, "you need to design to reduce cost, not features."

But those features need to have valuable functions and not just be flash. You can have flash but not at any real expense – for example, paint or decals are cheap. Also, you have to design recognising the electricity grid is not available everywhere and if it is present, it will not be up a lot of the time.

"You have to design for simple local parts and maintenance and provide troubleshooting instructions and a parts supply chain," says Bentley. "While the manufacturer may not do all this, the market will often find a way to fill in some of those gaps."

Challenges around repair or equipment supply chains are something many of us would be familiar with.

"You can get an iPhone fixed a lot of places other than an Apple store, even though Apple works hard to make it difficult," says Bentley. "The Western world is now finding medical ventilators are so locked up by the manufacturers that repair is difficult or impossible apart from the manufacturer, and they may have discontinued it or gone out of business or been bought out.

"Google 'right to repair' and see some of the horror stories manufacturers are building into their products."

Bentley believes that ultimately the market will be the judge on maintainability and longevity of any commercially deployed solutions developed by teams in the Chill Challenge.

Although addressing inequality is the mission, marketability and profitability are still objectives, Dowdy says.

"If our teams don't create units that are commercially viable, they will never be deployed at a meaningful scale," he says.

"One of the reasons the Chill Challenge is necessary is there is often a 'market failure' in developing technology for poor populations in the developing world. Many new technologies developed over the last century, [such as] TVs, microwaves and cell phones, were first sold into high-end niche markets before they could be manufactured at a large scale to reach mass markets.

"The problem with off-grid refrigerators is that there is no high-end niche market to justify technology development – wealthy folks have electricity. We are therefore trying to support the technology development that is needed to bring a new product to market."

SEEING THE TALENT IN THE MAJORITY WORLD

Traditional Western aid efforts often take a top-down approach, but the Chill Challenge was open to anyone, anywhere.

"We didn't care who developed the technology, but we wanted design to be targeted for the hard-to-serve, low-income markets that are typically overlooked," Bentley explains.

"We were very glad to see many entries from Majority World nations, but the awards went to ideas that we think can best serve those areas of the world."

Often the degree of engineering talent and innovation capability in majority world nations is overlooked.

Bentley recalls an incident in rural Honduras.

"I spotted a centrifugal fan of wood and sheet metal handmade by a farmer who probably didn't have past a sixth-grade education," says Bentley. "He used it to increase the temperature of an earth oven, as well as to separate the chaff from the grain he was growing – dual purpose at that!

"We have seen a reluctance of international NGOs to offer design work to national engineers in Africa.

"While the quality of their education institutions can vary widely, those nations also produce some very talented engineers as well as having a lot of innovative minds, many of whom often can't afford the education they could use.

"A wise man said, 'Talent is universal, opportunity is not'."

GOING WITH THE MAJORITY

Those of us in the West often talk about the third world, the developing world, or the global south. Another term, used in this article, is "Majority World", which encompasses countries in Africa, Asia, South and Central America and the Caribbean and acknowledges that they represent the majority of the world's population.

THE STAR PROPOSALS

EWB-USA received 43 proposals from 36 teams from universities, companies or NGOs, and individuals in the USA, Cameroon, Ethiopia, France, Germany, Nigeria, South Korea, Switzerland, Uganda and the UK. The final judging saw six teams awarded grants.

WINNING WITH WASTE

India's **New Leaf Dynamic Technologies** was awarded a grant for its GreenCHILL refrigeration system, which utilises biomass to provide safe storage and cooling of perishable agricultural produce. It is being manufactured in Noida, Uttar Pradesh, from locally sourced components and can be powered by farm waste including straw, cow dung cakes, biomass pellets, wood and hay.

The units can cool up to 1,500L of milk or 15 tonnes of perishable goods, and are also being used for drying, ripening and other applications.

"Our vision with use of biomass as the primary source of energy for refrigeration was to serve farmers with a safe storage space installed at farm, powered by farm waste and being able to operate 365 days on farm waste," explains New Leaf director Akash Agarwal.

He says that to fulfill the energy requirements of a storage capacity of more than 5MT, solar PV would not be self-sufficient, and would need a backup of a grid or diesel generator. The technology is already being deployed, with 40 units installed on farms in four Indian states so far.

Agarwal says that as the number of installations increases at greater distance from the New Leaf factory, they envisage a large infrastructure or network will be built to provide on-time service to customers.

The company is also looking beyond the Indian sub-continent to African nations and South America for the various applications of cooling using biomass – places where there is an abundance of farm waste and biomass to run the units and a need for this kind of technology.

The technology can also be locally serviced and maintained. The current installations in India are being serviced by technicians with a basic diploma degree.

In a recent paper on the technology, New Leaf managing director Anurag Agarwal said that the unit can also meet cooling needs at a village level as an alternative to using grid electricity.

"It is a simple reliable machine that can compete with conventional grid-powered refrigeration systems with their capital cost while the running cost is one-tenth of diesel-powered and one-third of grid-powered refrigeration systems," he wrote.

"Not only do these systems replace fossil fuels, they reduce the chances of villages adopting conventional grid-powered or diesel-powered cooling systems."

The team from New Leaf Dynamic Industries.

ICE FROM THE SUN

Solar Cooling Engineering UG in Germany won a grant for its solar ice-maker which is specifically aiming to meet the need for cooling in places like the tropics and subtropics where access to grid electricity is unreliable or non-existent.

Spokesperson Julian Krüger says they aim to do a field trial test on the coast of Kenya, where a high demand for cooling exists.

"So far, we have an early prototype running on PV in Stuttgart, Germany, as part of our testing," Krüger says.

He explains that ice is an affordable and easy way to store the energy from solar PV.

"Ice is widely used in the global south every day as an easy to transport 'cooling battery'," says Krüger.

"Applications are, for example, cooling of beverages or keeping fish fresh. Offering ice to fishermen can be a good opportunity for generating a local income."

The unit combines solar PV modules, SelfChill unit and energy storage, giving it potential for multiple applications.

"We usually equip our systems with an LED light and the possibility to charge via a USB connector," Krüger adds.

"Because there is a need to use most of the battery capacities to guarantee a maximum running duration per day, running additional appliances should take place during daylight with an energy surplus."

They are focused on minimising the equipment that needs to be exported from Germany, instead wanting the Solar Ice Maker to be built in target countries by local partners using local materials and the company's key component, the SelfChill unit.

"This is because they want to empower our partners to be able to maintain the systems, and also be able to do customising according to local demand, for example by up- or downscaling the systems," Krüger says.

Solar Cooling Engineering UG in Germany sees ice being used as a "cooling battery".

It would also reduce export, customs and transport to remote areas, which immediately lowers the CAPEX of the system, as well as lowering the CO_2 footprint.

"We will offer presence and online hands-on training to build local capacity to build our Solar Ice-Maker with key components combined with local material," says Krüger.

"The required skills are constructing an insulated box and basic cabling of our DC voltage electrical system. So, a basic skillset is enough to get started."

THE OTHER GRANT WINNERS

Passive solution by Ove Arup and Partners, London, UK

Arup submitted a proposal for a passive cooling box that relies on radiative cooling materials as a cold source and phase change materials as cold storage. The box aims to be capable of achieving the 3°C target temperature and maintaining that temperature across several days of adverse weather conditions.

Xergy Fridge-X: Off-the-Grid Refrigerator Utilising Solid-State Refrigerants

The Delaware, USA-based company will be building a refrigerator utilising an intermittent adsorption refrigeration cycle driven by solar thermal energy. It will use hydrogen and metal hydride as the working pair, and employ an advanced heat exchanger design, storing hot water to provide refrigeration on days there is no solar energy input.

Two ideas from Purdue University, West Lafayette, Indiana

Researchers at the Ray W. Herrick Laboratories at Purdue University proposed developing and testing two refrigeration technologies: a cold-storage battery for domestic refrigeration that uses the heat from clay or brick cookstoves to drive an intermittent sorption refrigerator; and a combined heating and cooling vapour-compression system to produce ice and to dry crops.

Imperial College London, Clean Energy Processes (CEP) Laboratory

This team, in partnership with Solar Polar, has been developing a thermally powered technology, Diffusion Absorption Refrigeration (DAR), which can be easily integrated with low-cost solar thermal collectors or that utilise waste heat to provide cooling. The DAR has no moving parts and a simple construction that promises low costs and a long lifetime. Their proposal will experiment with replacing the ammonia-water pair typically used in DAR devices with alternative working-fluid pairs in optimised unit designs. The ice-maker they prose to build using the DAR technology will use hot water from solar-thermal collectors, making it suitable for remote or off-grid communities. ■