HVAC&R Nation
AN AIRAH PUBLICATION

BROUGHT TO YOU BY AIRAH GIVING BACK TO THE INDUSTRY SINCE 1920

One country, many rules

Working across borders in Australia

Skills WORKSHOP

Air measurement techniques

Smashing the performance ceiling

Meet the winning AC systems of the Global Cooling Prize

June 2021 / ISSUE 138

PRINT POST APPROVAL NUMBER PP 727272/60606 FREE

SMASHING THE PERFORMANCE CEILING

The organisers of the **Global Cooling Prize** set out to find the impossible: an affordable room air conditioner that could redefine performance and help save the world. As **Willow Aliento** reports, they succeeded.

As the world heats up due to climate change, experts predict the growing demand for residential air conditioning worldwide could generate around 0.5°C of temperature rise by 2050 just trying to keep people comfortable. The Global Cooling Prize aimed to change those numbers by fostering the development of advanced technology that can smash the ceiling of performance.

The competition was launched in 2018 by the Rocky Mountain Institute, the Department of Science and Technology, Government of India, and Mission Innovation. There were 139 entries that met the requirements around detailed technical design, out of which eight became finalists and moved onto the final stage of building prototypes. Six of those finalist teams succeeded in delivering working prototypes for final testing.

The prize set ultra-demanding performance parameters. Prototype designs had to demonstrate they could operate effectively in hot, humid environments, have five times less global warming impact than conventional units currently on the market, and be affordable. Some called it impossible – but the HVAC&R industry rose to the challenge and smashed it out of the ballpark.

RMI Senior Fellow Iain Campbell.

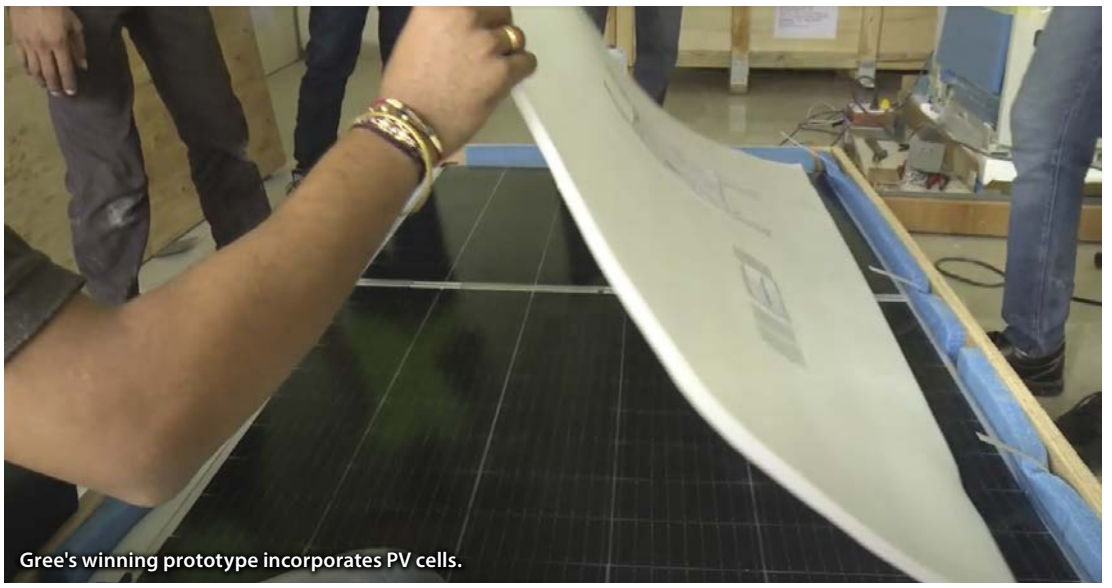
FINDING THE NEEDLE

Speaking at the awards ceremony on April 29, RMI Senior Fellow Iain Campbell compared the search for better technology to looking for a needle in a haystack.

He said although the industry has progressed with the phase-down of HFC refrigerants with high global warming potential (GWP), this only addresses one-fifth of an HVAC unit's emissions footprint. The other four-fifths are from operational energy use, and that is the missing piece the GCP sought to tackle.

The humble air conditioner hasn't changed a lot since it was invented 100 years ago. By holding the prize, Campbell says the organisers were creating a situation where "the needle may just come and find you".

And it certainly did.



Gree's winning prototype incorporates PV cells.

Two of the finalists demonstrated such exceptional performance, the judges announced them as joint winners of the million-dollar prize: Gree Electric Appliances, Inc. of Zhuhai with partner Tsinghua University; and Daikin with partner Nikken Sekkei Ltd. Both exceeded the five times (5X) less impact benchmark and met all other criteria.

Judges noted that when scaled, these kinds of technologies can prevent 132GT of CO_2e emissions cumulatively between now and 2050 and mitigate over 0.5°C of global warming by the end of the century.

THE PRIZE AND THE PANDEMIC

Due to COVID-19, the awards ceremony was held virtually, with people from around the world tuning in via zoom. RMI presenters from the US, China and India along with HVAC and energy experts, climate action leaders, business leaders and the teams themselves shared the digital podium.

Well before the awards ceremony, virtual collaboration had been used to manage pandemic travel restrictions, lockdowns and other barriers. For example, the Transaera Team from the US couldn't access their labs due to the California lockdown, so team members used their garages to build prototypes.

Campbell says COVID-19 caused both supply chain and personal logistical issues. It was particularly challenging because onsite installation and testing of prototypes in India was a competition judging criteria.

"In the early days of the pandemic, many of the finalist teams that depended on China began feeling the COVID-19 impact on the supply chain and procurement of parts and components," says Campbell. "A few months later, most of the other teams were also affected due to shutdown orders limiting their access to workshops and labs."

To give teams additional time to deliver their prototypes, the prize timeline was pushed back by four months.

Another major impact was that none of the core members of the finalist teams could travel to India and oversee the installation and commissioning of their prototypes. To address this, a remote commissioning process was facilitated by hiring an experienced local installation and commissioning team, along with a videography agency to live-stream the prototype installation inspection and start-up.

"This enabled the finalist teams to ensure that installation had been undertaken as per their instructions," says Campbell, "and allowed them to participate in any necessary troubleshooting."

HVAC&R has been in the spotlight during the pandemic, particularly the role of ventilation in managing the risks of airborne spread. Campbell said this was not, however, an added factor in judging.

"While COVID-19 presented some challenges and brought some additional parameters to our attention, it would have been unfair to change the criteria in the middle of competition," he says. "By the time COVID-19 had hit, the finalist teams had already started working on their prototype development.

"We do believe though that ventilation and filtration will become important aspects that will be incorporated in technologies more broadly, and that these will necessarily result in increased cooling loads further increasing the need for more energy-efficient solutions."

COUNTING THE COST

In addition to the onsite operational tests, the units were subjected to extensive laboratory testing to verify their energy use and performance. The supply chain and price point also played a role in the judge's decisions.

Affordability was one of the primary criteria of the prize, Campbell says.

"It required the technologies to cost no more than two times the installed cost of standard AC units sold on the market today. The affordability assessment was used together with the 5X lower climate impact criteria to determine winning technologies."

Campbell is confident manufacturing and supply chain capacity exists to see mass deployment.

"The winning technologies are essentially advanced versions of the widely adopted vapour compression technology for which the supply chain is already established around the world," he says. "The two winning teams are among the world's largest air conditioner manufacturers globally. So, we do not see major challenges to scale up from the supply side."

The materials criteria for entries also considered the footprint of the proposed solution, looking to minimise the use of materials with excessively high embodied carbon or rare earth materials.

MEET THE WINNERS

DAIKIN (INDIA) WITH NIKKEN SEKKEI (TOKYO)

This cooling system used a multi-split method to connect two indoor units with one outdoor unit. This helps optimise refrigerant flow rate for each of the two indoor units depending on ever-changing cooling load and uses refrigerant control technology to closely modulate the capacity. The use of low-GWP (global warming potential) refrigerant HFO-1234ze(E) is proposed. The system also incorporates evaporative cooling, which improves the system's efficiency by using the heat of vaporisation to lower the temperature of the air that the outdoor unit takes in. The system uses control technology that measures the outdoor temperature with sensors and applies the control system to automatically spray water when ambient temperatures are high, and cooling load is therefore also high.

GREE ELECTRIC APPLIANCES, INC. OF ZHUHAI (CHINA) WITH PARTNER TSINGHUA UNIVERSITY (CHINA)

The team's "Zero Carbon Source" cooling technology integrates advanced vapour compression refrigeration, photovoltaic direct-driven technology, evaporative cooling, and ventilation, efficiently utilising renewable energy sources and free cooling sources. It has automatic, climate-smart operation with three unique modes – vapour compression refrigeration, evaporative cooling, and ventilation – that can operate individually or in parallel depending on the outside weather conditions to provide optimised indoor cooling and dehumidification. The vapour compression refrigeration system adopts a parallel compression cycle with dual evaporation temperature. It uses an ingenious compressor with a low-GWP (global warming potential) refrigerant in conjunction with an improved design of evaporator and evaporative condenser to control indoor temperature and relative humidity more effectively. The photovoltaic direct-driven technology further lowers the overall grid electricity consumption. ■

RESIDENTIAL REMIT

The Global Cooling Prize focused on the residential sector. As Campbell points out, residential demand for cooling is expected to jump by almost four times over the next three decades.

"In the post COVID-19 world, this factor may be even higher," he says. "And by meeting this rising demand in a climate-friendly manner that can effectively neutralise the environmental impact of this growth, we can enable access to cooling for billions of people around the world while avoiding the climate impact that would be consequent with today's products."

With demand predicted to escalate so dramatically, the scalability of the solutions was an important criterion. They had to be capable of being deployed in an existing mid- to high-rise apartment building in a dense urban setting with minimal changes to the existing building structure or envelope.

"We are thrilled to see that the winning technologies met this criteria," says Campbell. "Moreover, they look very much like the mini-split ACs available on the market today."

There are likely to broader benefits too. Other sectors and applications are expected to see an increased cooling demand as the planet heats and populations grow.

"Much of the innovation we saw from the winning technologies can be transferred to cooling solutions more broadly across sectors and other applications for the larger benefit," says Campbell.

Because the winning technologies are "quite like the ACs we know today", the existing HVAC&R workforce should be comfortable adopting and maintaining the winning designs.

"Also, due to COVID-19, the installation and commissioning was undertaken by a local third party with only remote guidance by the teams," says Campbell. "So with some routine training, we believe this will not be a challenge with the winning technologies."

Where capacity building may be required is in aspects such as advanced control systems and refrigerant handling – R152a and R1234ze (used in the Daikin protype) are new refrigerants for the residential AC product category. But, as Campbell points out, they are relatively safe in terms of flammability and toxicity.

Having major manufacturers involved in the prize will help the new products get to market faster.

Unboxing the Gree prototype. Because of COVID-19, the units had to be commissioned by local technicians in India, with the teams providing instructions over video links.

THE REAL PRIZE

In addition to supporting innovation, the Global Cooling Prize has raised awareness of both the challenge and the opportunity in a sector like cooling that is impacting our climate.

It also demonstrates what is possible from a technical perspective, and how high the ceiling of performance can be. This has broader applications around testing standards, performance standards and consumer education.

Campbell says there is now an opportunity to link product performance ladders to the best available technology and have this inform Minimum Energy Performance Standards (MEPS). In this way they could align with the best rather than building from the worst with no reference to the ceiling of performance.

> "The performance ladders and rating systems that we use need to catch up with what technology can actually do

"Simply put, the performance ladders and rating systems that we use need to catch up with what technology can actually do," he says.

"Isn't that the whole point of performance ladders, rating systems and MEPS, to inform and protect consumers? It's like we are giving them a 20-year-old guidebook to selecting the right air conditioner today!"

If policies take the higher performance perspective, consumers could gain the knowledge to purchase cooling equipment that saves them money over the unit's life-cycle, provides more comfortable indoor conditions, and also drastically reduces the climatic impact of its use.

COMING TO A HOME NEAR YOU

The prize money of US$1 million aims to support commercialisation of the two winning technologies. And that could be as soon as 2025, according to Ms Dong Mingzhu, chairperson and president of Gree Electric Appliances, Inc. of Zhuhai.

"We are pleased that we were selected as a winner of the prize and we are committed to delivering the Race to Zero Breakthrough for Cooling: to bring to market affordable residential AC units using this new cooling technology (which has 5X lower climate impact than today's units) by 2025."

Whether the winners eventually appear in their prize-winning forms, as enhanced versions, or as smaller innovations in existing units, we hope to see the impacts of the Global Cooling Prize around us soon. ■

HONOURABLE MENTIONS

Other finalist teams explored entirely new approaches to cooling. The solution developed by Kraton Corporation in partnership with IIT Bombay, Porus Labs and Infosys, uses zero refrigerant. Instead, it prototyped a hybrid cooling solution using a membrane dehumidification system based on Nexar polymer. This removes moisture from the room air and ejects it outdoors. The unit uses water evaporative cooling, by which the moving air loses its heat as it evaporates water, then reduces the temperature.

As Dr Gabrielle Dreyfus from the GCP Technical Review committee noted in her presentation during the ceremony, humidity is as pressing an issue in many regions as heat, with some places already reaching "the limits of human survivability" due to the impact of global warming.

Start-up M2 Thermal Solutions from the US is also addressing both, with a combination of evaporative cooling and membrane technology that cools the air and then removes the moisture, or operates to supply ventilation. It uses no compressor or refrigerant, and the water collected through dehumidifying is used to supply the evaporative cooling function.

Another humidity-focused team was Transaera, a start-up out of the Massachusetts Institute of Technology (MIT). It collaborated with Qingdao Haier Air Conditioner Gen Corp. Ltd. to develop a cooling solution using a new type of solid desiccant material.

The UKs Barocol team, comprising researchers at the University of Cambridge's Department of Materials Science and Metallurgy in the UK, shifted away entirely from refrigerants, developing a solid-state cooling technology using a phase change material. ■