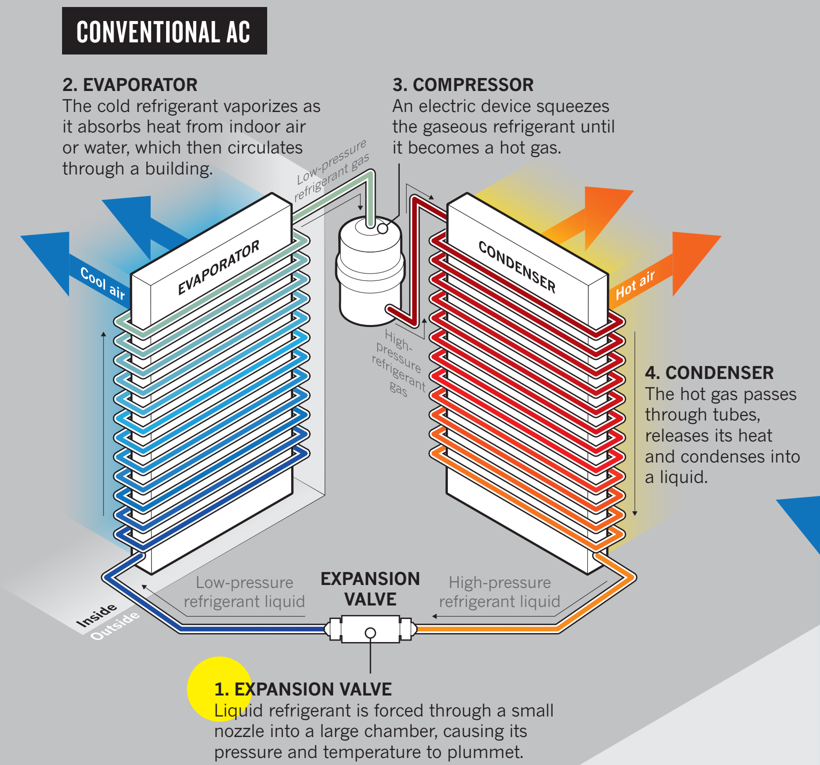
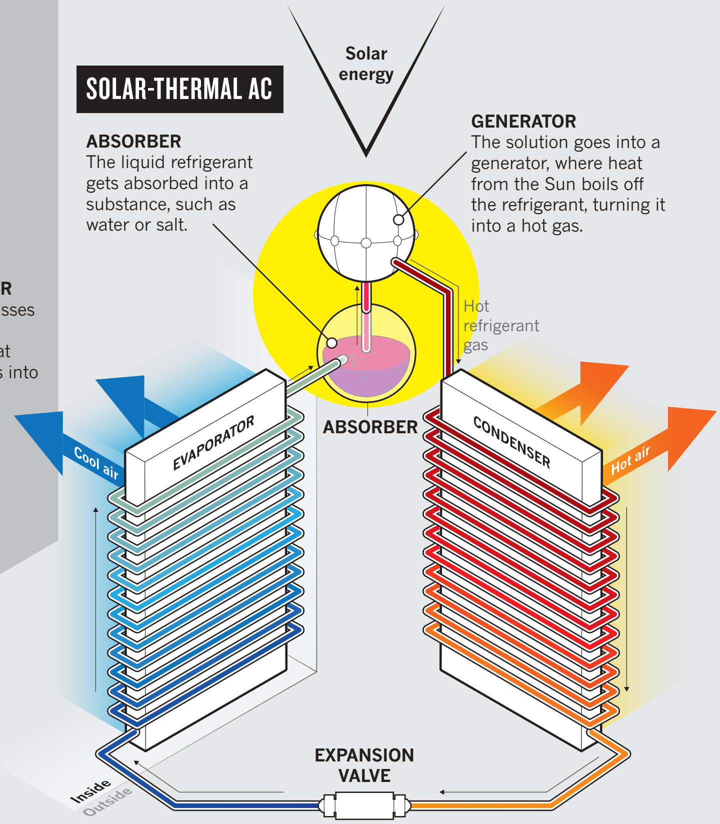
TWO WAYS TO CHILL

Conventional air conditioners (AC) rely on energy-hungry electric compressors, whereas solar absorption chillers use heat from the Sun, which reduces electricity usage.





COOLING WITH HEAT

AS DEMAND FOR AIR CONDITIONING CLIMBS, SOME SEE A SOLUTION IN THE VERY THING THAT MAKES US SWEAT: THE SUN.

BY XIAOZHI LIM

At Hotel Star Sapphire in Dawei, Myanmar, guests sip from coconuts in cool, air-conditioned comfort as the steamy tropical night rolls on. Seven thousand kilometres to the west, in dry Khartoum, Sudan, patients rest in a United Nations Hospital, cocooned from the baking desert heat.

In both buildings, the pleasant conditions come courtesy of air-conditioning units that rely in part on dark glass tubes that turn sunlight into cooling power. These aren't the familiar solar panels that harvest light to make electricity. Instead, they harness heat from the Sun to chill buildings through a neat bit of thermodynamic sleight of hand. Researchers and some energy experts say that this form of cooling — known as solar thermal — could help to slake the growing global demand for fuel to run energy-hungry air conditioning. The Intergovernmental Panel on Climate Change predicts that by 2100, the need for electricity to power cooling will have surged to more than 30 times what it was in 2000.

Hopeful that solar-thermal technology is nearing a crucial turning point, research groups are showing off their systems at a growing number of hotels, shopping centres and other buildings across the world. Today, there are some 1,200 installations — more than 10 times the total from a decade ago. Companies that produce solar-thermal chillers say that they use 30–90% less electricity than the conventional air conditioners that operate in most buildings, depending on the type and size of the installation. And researchers are working to make the systems more efficient and cheaper to build.

But the technology faces daunting hurdles, and some experts doubt that it will ever be more than niche in a world that each year adds 100 million conventional air conditioners, which rely on compressors powered by electricity. Solar-thermal chillers are just too expensive, typically costing about five times more than conventional ones, says Daniel Mugnier, an engineer with the solar-technologies company Tecsol in Perpignan, France. Although the price is dropping, the technology lacks the subsidies and investment it needs to make it more competitive, he says.

That is a pity, he adds, because thermal systems have several advantages. They could lower peak demand on the electrical grid, reducing blackouts and the need to tap dirtier energy sources. They are also silent, and typically use environmentally friendly refrigerants — a point that took on new importance in October, when more than 170 countries

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agreed to phase out the hydrofluorocarbon chemicals used in most air conditioners and refrigerators. And solar heat is available in large quantities just where demand for cooling is highest. "It's almost like a marriage made in heaven," says Christos Markides, a solar researcher at Imperial College London.

ALL IN THE PHASE

The key to air conditioning is evaporation: the cooling occurs when a liquid absorbs energy from its surroundings and changes phase to evaporate as a gas. That's how perspiration cools our bodies and it also happens in nearly every air conditioner, from small window units to the 8-metre-long giants used to chill large buildings in Qatar.

In modern electrical air conditioners, a liquid refrigerant is forced through a small nozzle into a large chamber. That causes its pressure to plummet, so it evaporates rapidly and removes heat from the indoor air. The gaseous refrigerant then travels to another chamber, where a mechanical compressor powered by electricity squeezes the gas to drive up its temperature further. That hot, gaseous refrigerant then passes through a condenser — often a coil of thin tubing — where it changes back into a liquid and expels heat outdoors. The liquid refrigerant is then squirted back into the evaporation chamber and the cycle repeats.

The gas-squeezing step is needed because to shed heat outdoors efficiently, the refrigerant must be very hot before it goes through the condenser, explains Colin Chia, co-founder of the Singaporean company Ecoline, which developed Hotel Star Sapphire's air-conditioning system. In electrical units, this is done mechanically. But there is another way — simply using heat.

One of the oldest air conditioners to be built on this principle burned wood to supply the heat and was introduced at the World Exhibition in Paris in 1878. It was "a marvellous old machine", says Christian Holter, chief executive of SOLID, a company in Graz, Austria, that specializes in large-scale solar-thermal cooling and heating systems. Called absorption chillers, the devices use heat from the Sun to boil the refrigerant out of a solution — typically water from a salt solution, or ammonia gas from water. Then the gaseous refrigerant goes through condensation and evaporation stages similar to those in compression systems (see 'Two ways to chill').

Compression dominates the market because "it is easy to buy, plug and start", says Holter. But as far back as the 1980s, growing concern over the ozone-depleting refrigerants used in compression air conditioners revived interest in thermal systems. They never caught on, however, because they could not compete with those powered by cheap electricity and because their heat source — burning biomass or natural gas — is difficult to manage.

Heat from the Sun doesn't have those problems. In modern solar-thermal systems, special collecting tubes or plates absorb energy from the Sun's rays and then transfer that heat to an absorption chiller. So far, SOLID has installed large-scale systems in 18 schools, offices and warehouses in 10 countries. One of these, the world's largest solar-thermal cooling system so far, has since 2014 been chilling a high school in Arizona, where air conditioning typically makes up a significant fraction of an annual electricity bill.

Academic researchers and companies are also trying to improve performance in other ways. Most absorption chillers, including SOLID's, heat the refrigerants to around 80 °C. If the temperature could be raised to 120–170 °C, then more refrigerant would evaporate and circulate as gas in the system at the same time, making the unit more efficient.

That means the solar collector must concentrate the Sun's heat more effectively. Some specialized collectors can follow the Sun and achieve temperatures of up to 400 °C, but they are expensive. To develop a cheaper alternative, a team led by engineer Roland Winston at the University of California, Merced, is improving the design of the collecting tubes. The team's tubes contain a special metallic piece that transfers heat rapidly to a glycol fluid in an inner copper pipe.

Winston's team also puts curved sheets of reflective material under the outer tubes, which helps them gather solar energy as the Sun moves through the sky. The system can heat the glycol to 200 °C and is now being tested with different chillers.

Other teams are leaving absorption chillers behind and building entirely new systems. A group led by Stephen White at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Newcastle, Australia, has developed a desiccant-wheel system that since June 2016 has been cooling a shopping centre in Ballarat, Victoria. First, ambient air passes through a slowly rotating wheel containing a material that adsorbs moisture, leaving the air hot and dry. This dry air moves into a chamber where it causes water to evaporate, thereby lowering the temperature. The chilled, moist air is used to cool air from the building that runs through a separate conduit. That moist air is then expelled outside, and solar heat is used to dry the moisture-adsorbing material in the wheel.

"IT'S ALMOST LIKE A MARRIAGE MADE IN HEAVEN."

Fresh approaches are in order because absorption chillers are expensive and complicated to build, says Mike Dennis, a private solar consultant in Canberra. "They don't make any sense," he says. It is easier to use photovoltaic panels to turn sunlight into electricity, which can then run standard compression air conditioners. Falling prices for photovoltaics are making that kind of system increasingly attractive.

Photovoltaics now benefit from economies of scale, as well as from massive government subsidies and investments that solar-thermal technologies do not have, says Mugnier. "My fear is that the competition is unfair."

Another approach is to create a hybrid: a conventional electrical compression machine that uses heat from the Sun to help the energy-guzzling compressor. Ecoline's air-conditioning system at Hotel Star Sapphire is an example.

To create the system, Chia inserted a U-shaped loop of copper into each solar collector tube and then linked up the copper pipes into a long ribbon. Glycol inside the pipes quickly transfers heat from the tubes to a glycol tank. Another set of copper pipes containing refrigerant snakes through the tank, heating up the refrigerant. The refrigerant then passes through a compressor. It turns into a gas much more easily than in a standard system because it's already piping hot.

The company has installed more than 1,000 air-conditioning units in 6 countries and, in mid-2018, will be air conditioning a dormitory at Singapore's Nanyang Technological University. In side-by-side tests, Ecoline says, its air conditioner delivered 35% energy savings compared with a standard high-efficiency air conditioner. The hybrid systems cost 15% more to install but are cheaper to run and recoup the extra expense in 2 years, based on electricity prices in Singapore, says Chia.

Proponents are confident that costs would drop significantly if the market for solar thermal expanded. Winston's postdoc Lun Jiang notes that in the 1990s, evacuated tubes used for solar water heating cost more than US$100 per metre, but they now cost just $2–3 because of mass production driven by widespread use of the systems in China.

Others say that thermal technologies can access waste heat that photovoltaics, which collect only light, cannot. They could mop up energy that concentrates in hot cities, industrial plants and data centres. In fact, Ecoline is now working with a data-centre management company in Indonesia to cool facilities using its own waste heat.

That kind of approach makes good thermal sense, says Chia. "The hotter the better." ■

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