NREL
NATIONAL RENEWABLE ENERGY LABORATORY

NREL's Energy-Saving Technology for Air Conditioning Cuts Peak Power Loads Without Using Harmful Refrigerants

The Desiccant-Enhanced Evaporative (DEVAP) air conditioner—developed by NREL, AIL Research, and Synapse Product Development LLC—combines desiccant-based dehumidification with indirect evaporative cooling to reduce cooling energy use by up to 81%.

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DEVAP Slashes Peak Power Loads

Desiccant-enhanced evaporative (DEVAP) air-conditioning will provide superior comfort for commercial buildings in any climate at a small fraction of the electricity costs of conventional air-conditioning equipment, releasing far less carbon dioxide and cutting costly peak electrical demand by an estimated 80%.

Air conditioning currently consumes about 15% of the electricity generated in the United States and is a major contributor to peak electrical demand on hot summer days, which can lead to escalating power costs, brownouts, and rolling blackouts. DEVAP employs an innovative combination of air-cooling technologies to reduce energy use by up to 81%.

DEVAP also shifts most of the energy needs to thermal energy sources, reducing annual electricity use by up to 90%. In doing so, DEVAP is estimated to cut peak electrical demand by nearly 80% in all climates. Widespread use of this cooling cycle would dramatically cut peak electrical loads throughout the country, saving billions of dollars in investments and operating costs for our nation's electrical utilities.

How DEVAP Works

Water is already used as a refrigerant in evaporative coolers, a common and widely used energy-saving technology for arid regions. The technology cools incoming hot, dry air by evaporating water into it. The energy absorbed by the water as it evaporates, known as the latent heat of vaporization, cools the air while humidifying it. However, evaporative coolers only function when the air is dry, and they deliver humid air that can lower the comfort level for building occupants. And even many dry climates like Phoenix, Arizona, have a humid season when evaporative cooling won't work well.

DEVAP extends the applicability of evaporative cooling by first using a liquid desiccant—a water-absorbing material—to dry the air. The dry air is then passed to an indirect evaporative cooling stage, in which the incoming air is in thermal contact with a moistened surface that evaporates the water into a *separate* air stream. As the evaporation cools the moistened surface, it draws heat from the incoming air without adding humidity to it. A number of cooling cycles have been developed that employ indirect evaporative cooling, but DEVAP achieves a superior efficiency relative to its technological siblings.

Modeling and Testing DEVAP

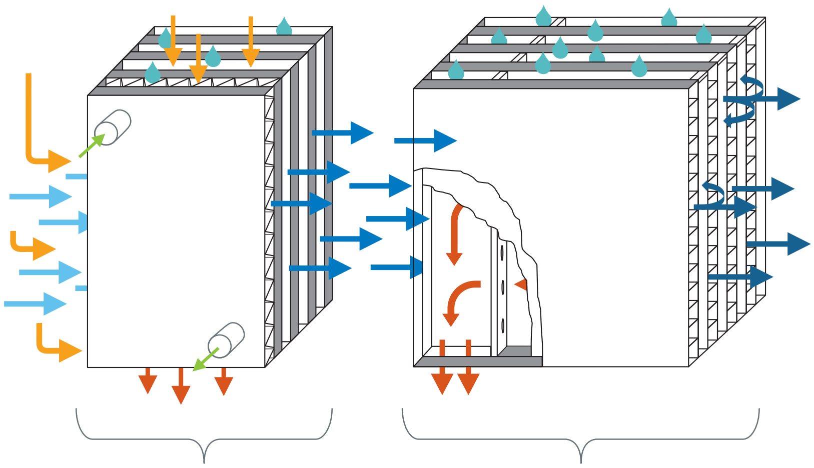
NREL used building energy simulations to model DEVAP's performance in two U.S. cities that represent the extreme cases for air conditioning: in Phoenix, Arizona, which is extremely hot and dry, and in Houston, Texas, which is hot and extremely humid. Compared to the current state of the art, DEVAP achieved estimated energy savings of 25% in Houston and 81% in Phoenix. DEVAP's excellent performance in both of these climates indicates that the technology would save energy and money anywhere in the United States, as well as in most cooling locations throughout the world. DEVAP also exhibits superior humidity control, so it could help to avoid the clammy feeling that occurs in some air-conditioned buildings, while also avoiding the need to overcool the building supply air in order to achieve good humidity control.

NREL created, validated, and perfected the DEVAP design with the help of AIL Research and Synapse Product Development, each of which built a prototype unit to NREL specifications, but using their own fabrication methods. Laboratory testing of these units allowed NREL to verify the accuracy of the computer models used for the DEVAP design and for the annual energy savings predictions. The testing also led NREL to conceptualize a more efficient second-generation design that will achieve a size, weight, and cost suitable for today's market.

How DEVAP Will Serve the Air-Conditioning Market

DEVAP is expected to initially serve the new and retrofit commercial air-conditioning market, most likely as a rooftop unit. This will make it relatively easy to supply the unit with plumbed water for evaporative cooling and an outdoor air stream to help cool the dehumidification stage. As the technology becomes more refined over time, it is also likely to enter into the residential market. Although the additional requirements of the DEVAP system may make it difficult to install in existing homes, new homes can be designed to accommodate these extra requirements, keeping the cost of the system low.

Rooftops units using the patented DEVAP design are initially expected to cost about 30% more than competing models, but the energy savings should yield a payback period of less than 3 years. As the technology matures, the technology is expected to achieve cost parity with today's state-of-the-art air conditioners. NREL welcomes the participation of commercial partners that could now help move this technology to market.



DEVAP consists of two distinct stages: a dehumidifier stage and an indirect evaporative cooling stage. Water is added to the tops of both stages, while liquid desiccant is pumped through the first stage. Some outdoor air is mixed with return air from the building to form the supply air stream, which flows from left to right through the two stages.

In the dehumidifier, a membrane contains the desiccant while humidity from the supply air passes through the membrane to the desiccant. The desiccant is also in thermal contact with a flocked, wetted surface that is cooled as outdoor air passes by it, causing the water to evaporate and indirectly cooling the desiccant. In the second stage, the supply air passes by a water-impermeable surface that is wetted and flocked on its opposite side, providing indirect evaporative cooling. A small fraction of the cool, dry supply air is then redirected through the second-stage evaporative passages to evaporate water from the flocked surface and is then exhausted.

Illustration by Jason Woods, Eric Kozubal, and Stacy Buchanan, NREL

DEVAP: The Climate-Friendly Solution to Building Comfort

For decades, air conditioning has been hindered by the realization that its refrigerants are harmful to the environment. The initial concern was with chlorofluorocarbons (CFCs), such as Freon, which were found to be damaging to Earth's ozone layer.

CFCs have been phased out and replaced with hydrochlorofluorocarbons (HCFCs), which have less impact on the ozone layer, but often have a high global warming potential, hundreds or thousands of times more powerful than carbon dioxide. HCFCs are also being phased out, replaced primarily by hydrofluorocarbons (HFCs). HFCs do not impact the ozone layer, but many HFCs still have significant global warming potential.

Amid this alphabet soup of refrigerants is another refrigerant that is known to have no negative effect on Earth's atmosphere: water. DEVAP uses water as a refrigerant, avoiding the negative environmental effects associated with today's typical refrigerants. In addition, there's no need for a bulky, expensive compressor or a pressurized system to contain the refrigerant, so DEVAP is a simpler system to maintain and service.

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