Cooling systems affect resources, climate, and health

By Arunima Chatterjee and Melanie Lenart

Residential cooling and heating account for about 56 percent of the total energy consumed in the typical home in the United States, according to a 2005 U.S. Department of Energy report. In the Southwest, this energy is increasingly going toward air-conditioning rather than the traditional evaporative coolers, known as swamp coolers. The shift has implications for energy use, water use, and climate.

Energy vs. Water

Strictly in terms of energy use, the ongoing shift from swamp coolers to air conditioners has its costs. Air conditioners generally use two to four times more electricity than swamp coolers. For a typical 2,000-square-foot Tucson residence, the electricity used by a swamp cooler can be as low as 250 kilowatt-hours in an average month, while an air conditioner consumes about 850 kilowatt-hours. In Tucson, this translates to a monthly electrical cost of $25 compared with $85.

But a scarcity of water in the Southwest makes the comparison more complex, posing a challenge in determining the conservation strategy that can yield optimum savings for both energy and water. T. Lewis Thompson of the Environmental Research Laboratory (ERL) at The University of Arizona found that during summer conditions in Tucson (May–September), a swamp cooler working at 75 percent efficiency uses an average of 150 gallons of water per day, while air-conditioning units do not directly use water. The generation of electricity, however, requires water, a behind-the-scenes use that is easily overlooked.

Hydropower, which supplies about 12 percent of Arizona's electricity, consumes about 65 gallons of water per kilowatt-hour generated because of high regional evaporation rates where it is generated, according to research at the National Renewable Energy Laboratory led by Paul Torcellini. This value considers the total water evaporated from the reservoirs serving Hoover and Glen Canyon dams and the amount of electricity generated. They estimate that the coal-fired plants that supply most of Tucson's electricity consume about half a gallon of water for each kilowatt-hour of electricity produced.

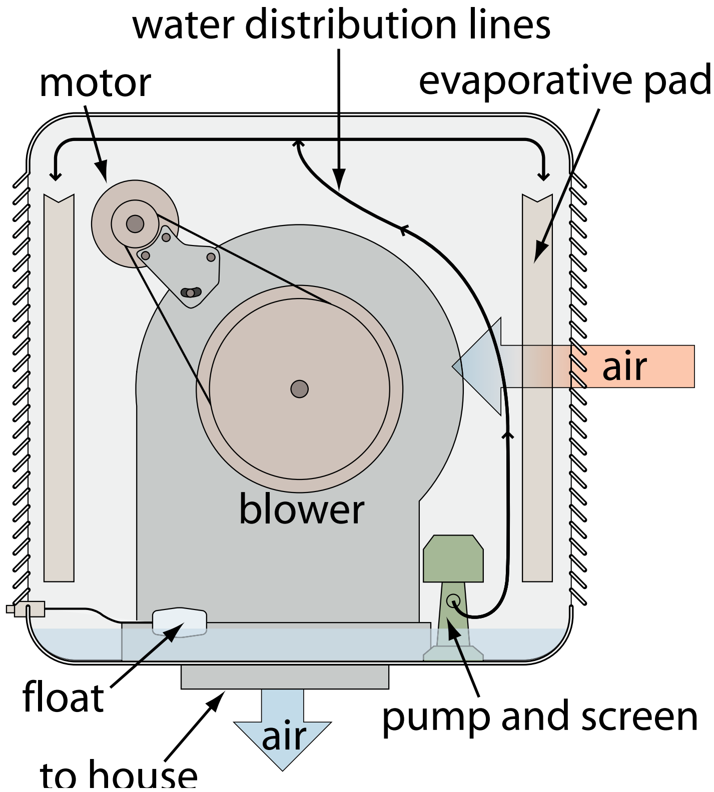

Figure 1. Swamp coolers typically consist of a box with vented sides. A fan draws ambient air through vents and through pads that are kept moist by a water supply, pump, and distribution lines. The cooled, moist air is then delivered to the building via a vent in the roof or wall. *Credit: Mike Buffington, Southwest Hydrology*

Applying the coal plant standard to the cooling of a 2,000 square-foot home, the ERL analysis found that monthly water consumption for an air-conditioning system is about 425 gallons, while an evaporative cooler requires about 4,620 gallons, including direct and indirect usage for both. The source of energy used to power air conditioning is critical to this analysis, however. If the same calculations are made using hydropower, an air conditioner uses 55,250 gallons of water per month compared with an evaporative cooler's 20,745 gallons. Overall, the water used directly by swamp coolers represents 5 percent or less of a household's annual water use, based on a study of several southwestern cities by the non-profit group Southwest Energy Efficiency Project (SWEEP).

Evaporative cooling works best in the dry months of summer. During the monsoon, when outside air is already moist, the effectiveness of swamp coolers is limited. One benefit of air conditioning is its ability to cool to a thermostatically controlled temperature regardless of the humidity. At some level, though, the cooling of a home usually equates to a warming of the planet, with air conditioners doing more damage than swamp coolers when the electricity source, such as coal or oil, produces greenhouse gases.

Climate Considerations

The collective choice of cooling equipment can affect the local climate as well as the global one. While air conditioners merely eject heat from the interior of a home or office into the outside air, swamp coolers can actually contribute to cooling the environment, indoor and outdoor. An evaporative cooler pulls

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air through moist pads, lowering the incoming air by as much as by 30 degrees (Figure 1). Because people cooling their homes with swamp coolers must leave some windows open, some of this cooled air permeates outdoors.

A typical swamp cooler converts about 1 billion joules of energy a day from heat into other types of energy, including kinetic and latent energy. As heat, this amount of energy could warm a six-foot deep, twelve-by-twelve-foot pool by 20 degrees Fahrenheit. Meanwhile, a typical air conditioner ejects about 63 million joules of energy per hour into the outside air, or a billion joules for every 16 hours of operation.

Arizona State University (ASU) researchers were surprised to find daytime temperatures in parts of metropolitan Phoenix were no higher, and in some cases actually lower, than those in the surrounding desert despite the expected urban heat island effect. They surmised that their results reflected the evaporative cooling from pools, urban lakes, landscaped vegetation, and perhaps even swamp coolers. Joseph Zehnder, a researcher who worked on this topic while at ASU, noted that the ongoing shift from swamp cooling to air conditioning may eventually reduce some of that daytime cooling.

Once the sun goes down, the desert cools down more quickly than the city, which is carpeted by heat-trapping pavement and vegetation. Some Phoenix-area urban temperatures averaged up to 20 degrees F warmer than those in the nearby desert, so in this case the

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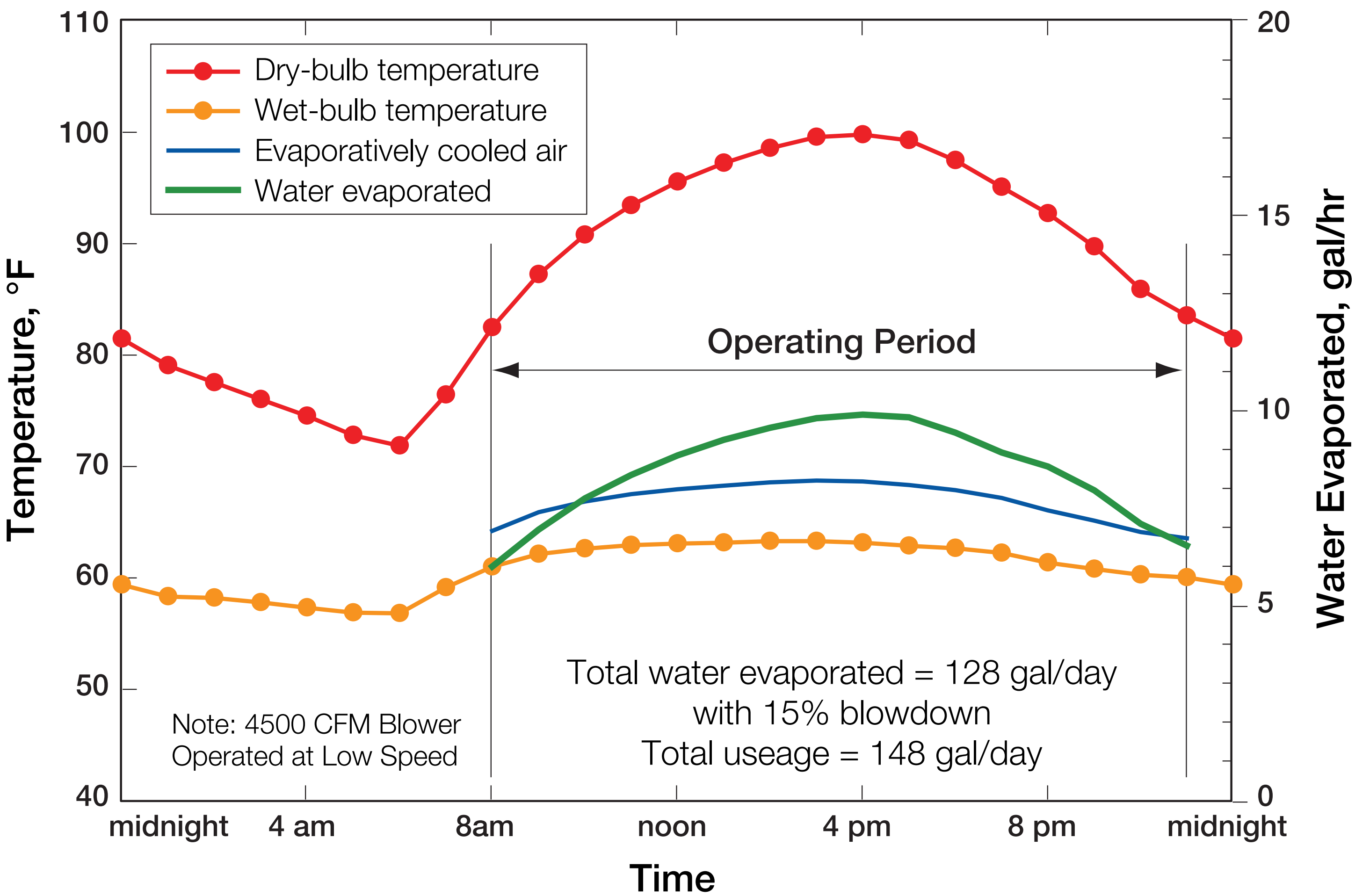

Figure 2. Evaporative coolers work by converting some of the heat energy in air into latent heat and kinetic energy that is trapped in the process of evaporation of water. A modern swamp cooler with an 85 percent efficiency can cool 100 degrees F daytime air down to about 68 degrees F. In the process, it uses about 145 to 150 gallons of water a day, assuming it operates on low during the day and is turned off at night. This data is for Tucson in June 2006. *Credit: T. Lewis Thompson of The University of Arizona Environmental Research Laboratory*

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urban heat island effect operates mainly at night.

Health

When it comes to health issues, central air-conditioning may not be the best choice. Evaporative cooling contributes to better indoor air quality. The moist pads through which the outside air flows act as effective air filters, trapping dust and pollen. Since the pads are continually moistened, trapped particles are flushed out with the water cycle. Evaporative cooling also adds moisture to the air, which helps keep wooden furniture, fabrics, and plants from drying out along with skin, eyes, and throats.

Swamp coolers actually work best when given plenty of ventilation to the outside air. This system thus provides an ongoing stream of fresh air, as long as outside air is not contaminated from a nearby wildfire or excessive pollution levels.

Air-conditioners, in contrast, are more efficient when recirculating indoor air. Thus air-conditioning systems can magnify indoor pollution, especially in households that permit smoking. Even in non-smoking households, central air-conditioning units can pull in contaminants from walls and concentrate volatile organic compounds from carpets, cosmetics, and cleaning products, among other materials.

Researcher Michael Lebowitz and his colleagues at the UA College of Medicine conducted a series of studies on how indoor air quality varies with factors including type of cooling equipment. They concluded that sensitive populations, such as asthmatics and people with cardio-vascular problems, should only use central air-conditioning if the units have a high-efficiency filter, such as a High Efficiency Particulate Air (HEPA) filter. Otherwise, they should use swamp cooling supplemented with window-mounted air-conditioners as needed.

Alternative Options

Many factors influence total water consumption in an evaporative cooling system, including residential design, location of the cooler, and the use of vegetation and other features to cool air before it enters the cooling system. The cooling efficiency of such a swamp cooler can increase dramatically by sensible cooling of the air before it goes through the moist pads of the cooler. Sensible cooling can be achieved by strategic landscaping, rock beds, and water channels.

On a typical summer day in Tucson, air entering an evaporative cooler with 75 percent efficiency at a temperature of 100 degrees F can exit with an air temperature of 75 degrees F. Many newer evaporative cooling systems have an 85 percent efficiency (Figure 2).

For residences at the design stage, cool towers are a way of using the principle of downdraft evaporative cooling. Cool towers usually have a wet pad in the top of the tower. The cool air is heavier than warm air and sinks by means of gravity, creating its own airflow and eliminating the need for blowers or fans. The only power required is for a 12-volt pump to circulate water over the cooler pads. Generally, cool towers without fans are 20 to 30 feet tall and between 6 and 10 feet wide. These systems require 100 to 150 watts and cool 1,000 to 2,500 square feet.

The need to consider energy as well as water demand for cooling options seems likely to increase during this century. The Intergovernmental Panel on Climate Change projects that average summer temperatures in the Southwest will rise by at least several degrees in decades to come, and even more if society fails to stabilize greenhouse gas emissions. As temperatures rise, individuals will continue to seek a cool indoor refuge from outdoor heat—a cycle that could force society to seek energy- and water-saving solutions to cooling.

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