Southwest Energy Efficiency Project

Saving Money and Reducing Pollution through Energy Conservation

Evaporative Cooling Policy and Program Options: Promising Peak Shaving in a Growing Southwest

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N.B. All readers are invited to comment this document. Please direct comments to its author, Larry Kinney, at the address and phone below; email lkinney@swenergy.org.

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This report on evaporative cooling policy options is one in a series of technical briefs being prepared by the Southwest Energy Efficiency Project (SWEEP) in support of the U.S. Department of Energy's Building America Program. Its intended audience includes energy policy makers, program administrators, and analysts in the government and utility sectors interested in strategies that will reduce peak demand and energy consumption in both new and existing housing stock. Feedback from all readers on the form and content of this report are welcome. A companion report, "New Evaporative Cooling Systems: An Emerging Solution for Homes in Hot Dry Climates with Modest Cooling Loads," is aimed primarily at builders. It includes more detailed information on evaporative cooler technology and equipment. Both reports may be downloaded at www.swenergy.org.

Introduction

The Southwest is growing rapidly—a 37% increase in population is projected from 2000 to 2020 versus 16% for the total U.S. This is placing great pressures on an electric grid that must meet this new demand, much of which is caused by compressor-based air conditioning, a technology increasingly becoming the norm in both the residential and commercial sectors.[1] Yet much of the region's climate is ideally suited for evaporative cooling, both because of its low humidity and large diurnal temperature swings. Somewhat lower front-end costs and substantially lower energy and demand consumption characterize modern evaporative cooling systems. New sensors and controls coupled with longer-life, more-efficient, and easier-to-maintain equipment is available in today's marketplace.

Both compressor-based cooling and evaporative cooling systems are becoming more efficient, but on a Btu-of-cooling-per-kWh-of-electricity basis, the best evaporative cooling systems are on the order of five times more efficient than SEER 13 central air conditioning (CAC) systems and demand is less by a factor of four or more. Further, additional water use at the site (home) amounts to only about 3 percent of the water use of an average residential customer. This is offset by about a third by increased water use at the source (generator) reflecting much more electric energy use by CAC systems than evaporative coolers. From an overall environmental point of view in the Southwest, evaporative coolers use less fossil fuels with only a slight increase in water use relative to even the most efficient CAC systems. (Details of energy and water use by state are shown in "New Evaporative Cooling Systems: An Emerging Solution for Homes in Hot Dry Climates with Modest Cooling Loads" at www.swenergy.org.)

Nonetheless, the market trend in both new home construction and residential retrofit is strongly toward conventional CAC. According to a study published in 2000, evaporative cooling systems represented only 5.6 % of primary cooling system types installed in California homes, only one in five of which were central systems.[2] Evaporative cooling use in Utah is much more prevalent. In 2001, with 76% of homes having some form of air conditioning, 29% use evaporative coolers and 34% CAC systems.[3] In Colorado's Front Range (which includes most of the state's population), in 2001, 28% of single family residences used evaporative coolers, 27% CAC.[4] Although the penetration of evaporative coolers is likely to be at least this high in existing homes in New Mexico, Arizona, and Nevada, the trend in new housing is strongly toward packaged and split system CAC units and away from evaporative units.

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[1] See Geller, Howard et al. 2002. The New Mother Lode: The Potential for More Efficient Electricity Use in the Southwest. Southwest Energy Efficiency Project. Available for download at www.swenergy.org/nml/index.html.
[2] RLW Analytics, Inc. 2000. *Statewide Residential Lighting and Appliance Saturation Study*, www.rlw.com
[3] Utah Power, 2001. "Energy Decisions Fact Sheets 2001: Report on State of Utah Customers."
[4] Schiller Associated, 2001. "Demand Reduction Market Assessment for Xcel Energy's Colorado Front Range Service Territory."

From the points of view of state and local policymakers, utilities, builders, environmentalists, and homeowners, there are a number of reasons for reversing this trend—although many mentioned in this list are not fully aware of them. This report examines these reasons, documents current efforts toward promoting wider-spread use of modern evaporative cooler technology, and recommends further policies and programs that seem appropriate.

Evaporative cooling characteristics

When dry air is pushed (or pulled) through a wetted medium, the air becomes cooler and more humid. The degree to which the air is cooled depends on a number of factors, including:

- The difference between the dry bulb and wet bulb temperature of the incoming air. Large differences, characteristic of hot, dry air frequently found on summer days in the desert southwest, yield substantial temperature depressions of the incoming air, often 30ºF or more.

- The type, cross-sectional area, thickness, cleanliness, and wetness of the medium. In efficient coolers, old-style media made from aspen has been replaced by engineered, plastic-coated cellulose rigid cooling pads that clean the air and clean themselves while cooling air efficiently. Greater thickness is associated with larger pressure drops for a given air velocity but also with higher cooling efficiency. The lifetime of modern media is five to ten times that of older excelsior.

- Air velocity. The lower the velocity of air, the cooler it becomes in traversing the medium and the lower the pressure drop across it. So operating evaporative coolers at lower fan speeds raises the system efficiency of the process. Well-designed fans and efficient, variable-speed motors with automated controls also contribute to good system efficiencies.

One and two-stage evaporative cooling

Direct evaporative systems cool and humidify outside air and blow it inside a home either directly or via ducts. Since this tends to pressurize the home, the air is directed to openings in the conditioned envelope, typically windows or dampers in the ceiling. This controls the distribution of cool air since larger openings are associated with greater flow. Ceiling dampers, also called "up ducts," typically consist of grills in the ceiling connected to short ducts that traverse attic insulation. They have a hinged lid on the top that opens when the home is pressurized by the evaporative cooler blower—and closes when the home is not pressurized. Air passes through the attic above the insulation and exits the home through existing vents. A system that uses up ducts can effectively direct cooling air to where it is needed without having to open windows. This provides a measure of security and allows for the cooler to be safely controlled by a thermostat. This arrangement also cools the attic, thereby lowering the temperature gradient between the home and the attic.

Indirect evaporative coolers use an air-to-air heat exchanger to cool outside air without adding humidity. The "dry" passages of the heat exchanger allow air to flow from outside to inside via a path that directly touches the "wet" passages of the heat exchanger. The wet passages are cooled by the movement of outside air thorough water vapor, but the humidified air that served to cool the air flowing through the dry passages of the heat exchanger is exhausted outside of the home. The dry cooled air can be either supplied to the home immediately or first be further cooled (and humidified) via a direct cooling element. Such a two-stage system is called an "indirect-direct" evaporative cooler. It can produce air that is two to five ºF lower than wet bulb temperature, thereby providing comfort even in quite hot climates except during periods of high temperature and high humidity, which are quite infrequent in the Southwest.

There are very efficient two-stage systems with smart thermostats that vary fan speeds to meet the load. Under most circumstances, they operate at less than full capacity where their efficiency (cooling energy delivered versus electric energy consumed) is maximized.

Modern evaporative coolers have a number of characteristics that make them more desirable than their forebears. A bulleted list is included beginning on page 13 of this report. Details are discussed in the companion to this report, "New Evaporative Cooling Systems: An Emerging Solution for Homes in Hot Dry Climates with Modest Cooling Loads."

Market Potential

It is both quite cost-effective and comfortable to use energy-efficient evaporative cooling systems in new home construction as well as retrofit in those regions in which 99 percent of the time wet bulb temperatures are 72ºF or below. Yet the disturbing market trend is toward using more compressor-based CAC systems. The market penetration of whole-house evaporative coolers in new construction is no more than 4 percent throughout the Southwest region (including California). The retrofit market is largely similar. Home owners without cooling tend to select conventional CAC systems when upgrading, rather than evaporative coolers. Further, many home owners with old-style evaporative units tend to upgrade to CAC units rather than more efficient evaporative coolers.

But what if these market trends could be reversed? Toward evaluating options, it is useful to examine potential savings in the fast-growing states in the Southwest: Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. Projections are that there will be about 2.9 million new housing units built in the Southwest between 2000 and 2020, 17% of the U.S. total. Of these new housing units, 23% are projected to be in multi-family buildings, the remainder in single-family structures.

Table 1 shows electric and demand savings achieved *in the year 2020* (not cumulative) at 20% and 40% penetration rates of energy-efficient evaporative coolers versus SEER 13

CAC units in new homes whose energy efficiency exceeds the year 2000 International Energy Conservation Code by 45%.

Table 1. Electric Energy and Demand Savings in 2020 Versus SEER 13 CAC under Two Scenarios of Evaporative Cooling Market Penetration in New Homes built between 2000 and 2020[5]

State	New Housing units between 2000 and 2020 (thousands)	Elec Savings in 2020 @ 20% Evap Cool (GWh)	Demand Savings in 2020 @ 20% Evap Cool (MW)	Elec Savings in 2020 @ 40% Evap Cool (GWh)	Demand Savings in 2020 @ 40% Evap Cool (MW)
Arizona	1,127	1,233	563.5	2,466	1127
Colorado	617	204	308.5	409	617
Nevada	399	337	199.5	674	399
New Mexico	351	151	175.5	302	351
Utah	380	189	190	377	380
Wyoming	71	21	35.5	42	71
Totals	2,945	2,135	1,473	4,271	2,945

This analysis is quite conservative, for it assumes a high level of energy-efficient homes (that is, savings would be greater to the degree that new homes are not as efficient as assumed.) Nonetheless, estimates of energy savings under the 40% scenario translate to a dollar savings in the year 2020 of $338 million, a figure that also accounts for water use. The demand savings is equivalent to avoiding the building of four 740 MW power stations.

This potential is the key reason to take actions to stimulate the adoption of efficient evaporative cooling in new homes and in the retrofit of existing homes.

Utility Programs

Meeting demand for electric power during peak periods in the summer is a major problem for most utilities in the fast-growing southwest. Population influx has fueled a major building boom. Most new homes in the region are generally more energy efficient than those which preceded them, but the large majority of them include unitary air conditioners whose demands are at least 3 kW, sometime much more. Since these machines tend to run a substantial percentage of the time on hot weekdays in the summer, they contribute directly to utilities' peak demand problems. Given the advantages of modern evaporative cooling systems, meeting electricity demands in new homes that use evaporative coolers rather than conventional air conditioners is more desirable.

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[5] Details of assumptions for this analysis are in Kinney, Larry, Howard Geller, and Mark Ruzzin. 2003. *Increasing Energy Efficiency in New Buildings in the Southwest: Energy Codes and Best Practices.* Southwest Energy Efficiency Project. Available for download at http://www.swenergy.org/ieenb/index.html.

There is also a trend to retrofit existing homes that have never been cooled (or which have old, inefficient evaporative equipment) with conventional air conditioning. This trend is leading to peak demand rising faster than total electricity sales throughout the Southwest. From the points of view of both demand on the grid and cost to the homeowner, it would be best to install whole-house, energy-efficient evaporative coolers rather than unitary air conditioners.

Given these considerations, a number of utility companies have initiated demand-side management (DSM) programs that provide incentives to owners of both existing and new homes to install energy-efficient evaporative cooling equipment.

Both the Pacific Gas and Electric Company (PG&E) and Southern California Edison (SCE) in California have programs that provide incentive payments of $300 to $500 that apply to energy-efficient evaporative coolers. Specifically, units must have saturation efficiencies of 85% or better, utilize sump water removal systems (no water-wasting continuous bleeding systems), and be configured to automatically exhaust air through pressure relief dampers (up ducts) into the attic, then to the outdoors. SCE requires a variable speed fan and a dedicated thermostat remote from the cooler. If the customer elects to install a two-stage evaporative cooler, its system efficiency must be 100% or greater (that is, it must deliver air to the home at a temperature equivalent to outside air wet bulb or below). PG&E allows either a "multifunction manual control switch or a programmable thermostat specifically designed for evaporative cooling." The utility sets the system efficiency standard for multi-stage coolers at 95% or higher. Importantly, both utilities offer an additional rebate of $100 for the installation of pressure relief dampers in the attic. In 2003, SCE provided rebates for purchasing energy efficient evaporative coolers to approximately 1600 of their residential customers, and PG&E approximately 400. Both utilities expect higher penetration rates in 2004.

Xcel Energy in Colorado ran a small-scale evaporative cooler pilot project aimed at new housing that began in the Spring of 2003. Receiving an incentive payment of $500 required the installation of an evaporative cooler whose saturation efficiency was at least 85%, that did not use a water-wasting continuous bleed system, and that was controlled by a remote thermostat. In spite of the substantial incentive payment, only 21 applicants were served under the 2003 pilot project, achieving an estimated net demand savings of 15 kW. In 2004, the utility anticipates lowering the incentive to $250, but is opening the program to more applicants by providing incentives for retrofit as well as new installations and lifting the criteria for saturation efficiency and method of water cleaning. Accordingly, the utility is working with big box retailers like Home Depot, Sears, and Lowes to make that market segment the focus of its campaign for evaporative coolers. Goals for Xcel Energy's 2004 program are 1,300 installations at up to $250 each. The utility projects 300 kW of net coincident summer peak demand savings and 269 MWh of net annual energy savings at the generator.

Utah Power is expanding its DSM program in the evaporative cooling area. In March of 2003, PacifiCorp, through Utah Power, launched the Cool Cash Incentive program for all of its residential customers in Utah. The program includes incentives for retrofit and new units including high-efficiency evaporative cooler units as well as high-efficiency unitary CAC units. An evaluation of the 2003 program revealed that evaporative cooler applications were only 28% of projections (1600 customers participated in the program; 5700 were anticipated) due in part to an abnormally cool spring and early summer. Nonetheless, since free ridership was much lower than projected, the evaporative cooler program achieved 80% of projected savings. (Free riders were predicted to be 85% for new homes and 95% for replacement coolers, but actual figures were 63% for new and 80% for replacement.)[6] Accordingly, the Cool Cash Incentives Program is being expanded in 2004, with incentive levels as shown in Table 2 below:

Table 2. Incentive Levels for the Utah Power Cool Cash Incentives Program in 2004. The notation "sized to specifications" under the air conditioning equipment heading represents an additional incentive to avoid installing larger equipment than necessary to meet the cooling needs of the dwelling, an energy-savings tactic for the customer and a peak-load shaver for the utility. Note that dealers are given an incentive only if the system is "sized to specifications."

Equipment Type	Customer equipment incentive	Dealer incentive
Replacement evaporative cooler	$100	$25
New evaporative cooler	$300	$50
Premium whole-house evaporative cooler	$500	$50
12 SEER CAC	$150	
12 SEER CAC sized to specifications	$250	$25
13 and higher SEER CAC	$250	
13 and higher SEER CAC sized to specifications	$350	$50

Source: Utah Power & Light Company

For purposes of the incentive, the premium evaporative coolers must be indirect, indirect/direct, or single inlet direct systems, but in all events must deliver cooling through a whole-house distribution system. If homeowners elect to avoid the use of a whole-house distribution system, their incentives are fixed at the lower $300 level.

Utah Power expects the Cool Cash Incentive program to cost about $2.7 million in 2004, with $1.8 million going to incentives, $125,000 to evaluate results, and the remainder to marketing and program administration. Anticipated unit and program savings based on projected participation rates are shown in Table 3.

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[6] Personal correspondence with Brian Hedman of Quantec, LLC, evaluator of the Cool Cash Incentives Program, March 9, 2004.

Table 3. Estimated net savings and participant rates by measure for the Utah Power Cool Cash Incentives Program in 2004. All program measures are assumed to have a lifetime of 15 years. Total savings estimates at the generator reflect line (distribution) losses of 11.73%. Net savings for 13+ SEER CAC units are lower than 12 SEER systems because of higher anticipated free riders. The total figure for net savings by measure is weighted by expected participant levels.

Measure	Net savings at the site (kWh/yr)	Net savings/ incentive payment (kWh/yr/$)	Expected participants	Total savings at the generator (MWh/yr)
Replacement evaporative cooler	395	3.16	1,035	463
New evaporative cooler	731	2.09	805	667
Premium whole-house evap cooler	1,482	2.69	50	84
12 SEER CAC	375	2.5	2,525	1,073
12 SEER CAC sized to specs	509	1.85	101	58
13 and higher SEER CAC	337	1.35	3,638	1,389
13 & 13+ SEER CAC sized to specs	444	1.11	146	73
Program Totals	404	2.11	8,300	3,806

Source: Quantec, LLC[7]

Note that the net savings figure for the premium whole house evaporative cooler measure are almost four times greater than the savings anticipated for the efficient CAC units that are *not* appropriately sized. Percentage savings in demand are similar in magnitude to energy savings. Higher incentives to the contrary, the substantially greater savings potentials of both premium whole house evaporative coolers and appropriately-sized efficient CAC units are projected to have but little effect on overall program totals because of low participation. Nonetheless, on average, the expected electricity savings per utility incentive dollar is greater for evaporative cooler options than for the CAC options.

This raises a key question. Given that premium whole house evaporative coolers make excellent economic sense over their lifetimes to homeowners and utilities alike—and high-efficiency evaporative coolers can achieve comfort throughout typical Utah summers—why is demand for the product so limited?

The answer is no doubt complex, but at base it appears to be a number of market limitations and weaknesses—lack of product availability and awareness, and the difficulty in getting accurate information in useful forms to the right people. As a result, many builders, HVAC contractors, and the general public either don't know about or have a distorted view of modern, efficient evaporative coolers. In addition, the

[7] Quantec, LLC. 2003. "Evaporative Cooling and Central Air Conditioning Incentives Program: Economic Analysis in Support of Utah Tariff Filing for 2004." Prepared for PacifiCorp.

availability of direct/indirect evaporative coolers for residential use has been quite limited, although new products coming on the market may help solve this problem.

Toward addressing these issues, the paragraphs below outline a four-tiered approach to substantially increase the market share of energy-efficient evaporative cooling in residential markets in the Southwest and other appropriate weather regions. SWEEP's recommendations involve expanded incentive programs coupled with support for the other three approaches: tailored research; testing and demonstrations with forward-looking production builders; and vigorous marketing efforts.

Recommendations

Utility incentive programs

Utilities have a great deal at stake in limiting peak demand in hot weather. Keeping conventional CAC systems off the grid by means of efficient evaporative coolers whose demands are four to five times less than CAC systems would be a big help. The question then becomes what evaporative cooler systems should be incentivized and how to set the levels of incentives. There's a broad spectrum of options open to a utility interested in promoting evaporative coolers over CAC systems. At one end of the spectrum lies the option for maximizing resource acquisition (primarily achieving demand savings) in which all evaporative cooler sales are subsidized. At the other end of the spectrum lies the market transfer option, where only high-end, water-and-energy-efficient equipment sales are subsidized. The former option will attract more customers to participate in the program and likely yield more peak shaving per utility dollar invested. The market transfer option will result in fewer customers participating, but better savings per customer. If no incentives are provided for lower-end systems while substantial incentives are associated with high-end systems, manufacturers and retailers will receive (and likely act upon if the incentive structure and associated marketing material are well designed) a very clear message. This will expedite market transformation toward the best, most efficient equipment to the ultimate benefit of all parties save for evaporative cooler manufacturers who produce only lower-end "swamp coolers."

While recognizing the short-term advantages in incentive programs that promote all evaporative coolers (e.g., higher rates of participation), SWEEP believes that developing a robust evaporative cooler market focused on efficient, modern equipment is generally the best approach for the long term. In particular, for most areas of the Southwest—especially those with quite hot summers—we favor programs that focus on single-inlet, energy-efficient evaporative cooling equipment that achieves saturation effectiveness of greater than 80% under all operating conditions and offers variable speed motors, a sump-dump feature for effective cleaning with minimal water use, and thermostatic controls.

Of course, there are plenty of in-between places in the spectrum. It may be useful to give a modest incentive (say $100) for conventional evaporative coolers in order to help stem the migration from evaporative cooling to compressor-based cooling in the region for now. At the same time, substantial incentives should be offered for direct systems designed to meet the whole cooling load of a home, with larger incentives for indirect/direct systems that provide better cooling and comfort. Since material prices for the former range from $700 to $1,100 and the latter from $1,800 to almost $3,000, setting incentive levels at $500 and $1,000 would likely cause a substantial upturn in the market for the most efficient (and peak load reducing) systems. Justification for $1,000 incentives flows from decreases in peak demand of 2.5 kW or more. Over time as the availability of and demand for higher end evaporative cooler products grows, incentives for conventional units can be phased out.

Product and incentive literature prepared for consumers, builders, and suppliers should concentrate on these systems and focus on the advantages of modern evaporative coolers over both CAC systems and lower-end, conventional evaporative coolers. Additionally, even if a utility elects to conduct an incentive program for efficient compressor-based equipment, we believe it is best to keep the evaporative cooler program separate from the air-conditioning program to the degree practical in order to deliver clear, strong messages about the advantages of evaporative coolers. Since many vendors sell both classes of equipment, complete separation is not always possible, but program material designed for consumers (media ads, brochures, bill stuffers, information on web sites, and the like) should avoid mixing references.

A key element in incentive programs for higher-end evaporative coolers is to communicate with the large retail outlets like Sears, Home Depot and Lowes. Providing quite modest incentives for lower-end evaporative coolers (most of which waste water as well as energy and are subject to maintenance problems, including short media lifetimes) while providing substantial incentives for higher end units which are not subject to these problems could play a key role in moving the marketplace toward better-performing equipment. Supplying marketing and sales tools to the big box retailers and others will also help support this position, as will other promotional avenues open to utility companies such as bill stuffers and mass media advertising

Carefully-designed and evaluated pilot projects working with progressive builders willing to install and market modern whole-house evaporative cooler systems would likely be a fruitful approach to increase the market penetration of the most efficient units while achieving good overall demand reduction.

Of course, program evaluation is critical in measuring the degree of success achieved by any incentive program, whether tailored toward maximum demand savings, market transformation, or both. Information on degrees of success achieved as a function of such relevant variables as districts within the service territory and new versus retrofit installations is invaluable in upgrading marketing materials, improving relations with vendors, builders, and retrofit contractors, and deciding on the magnitude and balance of future incentives.

In addition to these incentive and marketing efforts, we also recommend that utilities in the Southwest region support research and demonstration efforts such as those outlined below, as well as play a strong role in the promulgation of results.

Research and Development

Desiccants integrated into evaporative cooler systems offers a potentially attractive method of dealing with higher humidity, increasing comfort levels, and expanding evaporative cooler use into areas of the country that experience higher latent loads. Research of one promising system is underway at NREL and other organizations are involved in related desiccant research.

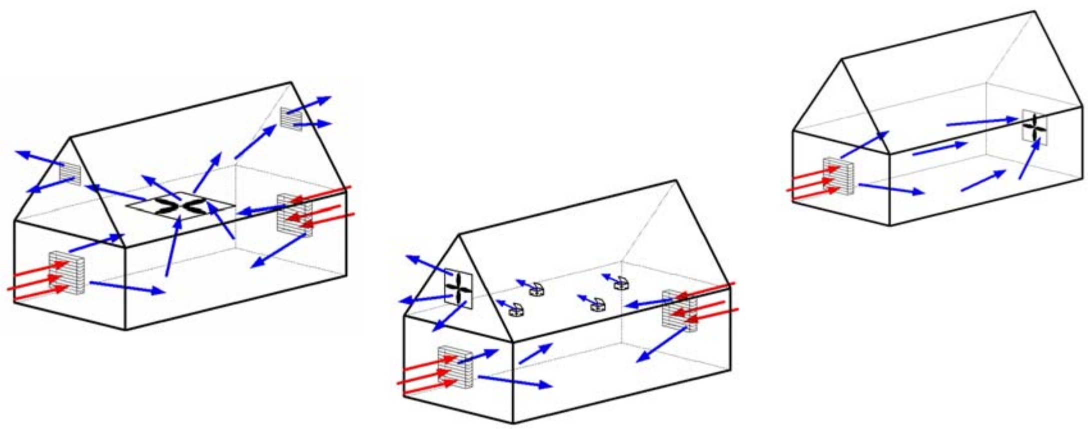
Up ducts installed in the ceiling of the top floor of a home cooled by a whole-house evaporative cooling system can help achieve good distribution of cooling air without the need for opening windows. On the other hand, the up ducts currently in wide use are somewhat flimsy and are uninsulated. Further, their tops are spring loaded to open even when the home is only slightly pressurized. Since up ducts are connected directly between the conditioned space and a vented attic, these characteristics can compromise the conditioned envelope, causing both convective and conductive losses during the heating season. Securing needed improvements is important, but the research, testing, and production processes should be neither unduly costly nor long. Up ducts with insulating louvers that could both control flow during the cooling season and achieve a thorough insulating seal during the heating season would be optimal.

Smart electronic controls are becoming the norm with many efficient evaporative coolers, but further improvements are desirable. To our knowledge, controlling electronically-commutated, efficient motors to optimize energy efficiency as a function of the difference in thermostat set point and indoor air temperature is presently accomplished by only one U.S. manufacturer (Speakman CRS). Evaporative cooling systems produced by others need similar improvements to both motors and controls. In addition, adding several inexpensive sensors would enable tracking the saturation effectiveness of the evaporative cooler, setting a flag (via a flashing yellow light-emitting diode, for example) if this tell-tale index of performance dropped past some minimum, thus signaling the need for maintenance. Since modern electronic thermostats make use of dedicated micro controllers, such an improvement would not add significantly to product cost, but would help ensure efficient operations over what might thereby become a longer, better-maintained product life.

Separating the media from the blower can yield simple, efficient evaporative cooling, but devices suitable for the new and retrofit residential markets have not yet been developed. But perhaps they should be. Imagine the design of an evaporative cooler that relied on air flow from a remote location like a whole-house attic or window fan. It would employ the single-inlet design of existing evaporative coolers that employ high-efficiency media; exterior air would enter on only one side and cooled air would exit the other. Such units could be narrow, since they need no large blower and associated motor. They could be placed in a window opening or be mounted between studs in a wall opening of three to seven square feet of cross sectional area. A small sump, media, pump, wetting mechanism, and controls could be fitted into the thickness of the wall or window well. An operable insulating shutter, say R = 15, could be installed on the outside and an attractive grill with elements formed to ensure good air distribution on the inside wall.

Several such devices with a combined cross sectional area of six to eight square feet would be adequate for a large whole-house fan. Figure 1 illustrates three potential arrangements of fans and media.

Figure 1. Three possible configurations of residential evaporative cooling systems where the air-moving function (provided by a fan or blower) is at a distance from the cooling media. The configuration on the left uses a whole-house fan in the attic floor along with conventional attic vents. An insulating shutter should be employed during the heating season. The configuration in the center achieves cooling distribution with back-draft dampers, up ducts. The configuration on the right with a window fan may be particularly applicable to apartments.



A key market may be existing homes with whole-house fans where homeowners are considering adding cooling. The system envisioned may be a practical, cost-effective alternative to installing conventional compressor-based CAC units.

Incidentally, Adobe, a large manufacturer of evaporative coolers, is introducing for the 2004 cooling season a through-the-wall unit that is combined with a blower (Figure 2). The company is optimistic that there will be a good market for the product because of simplified installation and improved aesthetics. Accordingly, it may be that taking the next step of isolating the fan function would enable the profile of the evaporative cooler to be even slimmer, while achieving better control over the distribution of cooling air.

Figure 2. Adobe's new through-the-wall evaporative cooler

Market Research of the kind used in introducing new products should also be undertaken. Focus group-style research allows time for acquainting screened participants with key characteristics of a product about to be introduced. It also allows for carefully measuring consumer response versus alternatives. Accordingly, it can be employed to identify areas of particular interest ("hot buttons") by different group members as well as areas of perceived disenchantment.

Findings should be introduced both into the hardware R&D process (to build on strengths and try to eliminate weaknesses) and be used in planning and executing subsequent marketing initiatives.

Demonstration Projects

In spite of the fact that energy-efficient evaporative coolers have been on the market for over a decade (although a new generation is being developed), there is a dearth of information on actual energy and comfort-producing system performance in energy-efficient homes. There is a need for well-designed demonstration projects, particularly in fast-growing areas of the southwest like Albuquerque, Denver, Las Vegas, Phoenix, and Salt Lake City. In the case of new homes, well-known production builders who routinely produce energy-efficient homes should be involved in the demonstration projects, both to prove to the builders that excellent results can be achieved and to ensure that customer satisfaction is achieved. Demonstration homes of the same floor plan and orientation using evaporative coolers on the one hand and SEER 13 CAC units on the other should be similarly instrumented. Identical testing protocols should be employed in all regions. Data on energy performance, cooling distribution achieved, control manipulation, and comfort issues should be gathered and analyzed in parallel with economic factors associated with initial construction costs, maintenance costs, and lifetime energy costs.

A similar set of demonstrations should be accomplished in existing homes. Ideally, both the subgrantee network of the Weatherization Assistance Program in appropriate weather regions in the Southwest and skilled private-sector contractors should be used to accomplish the retrofits. Two general cases should be chosen for demonstration projects: those with window or whole house fans but without either evaporative or CAC cooling; and those with inefficient, older evaporative systems ("swamp coolers") in need of replacement. The measurement protocol in these cases should reflect energy measurements and comfort issues before and after retrofits, ideally with a control group that is not retrofitted over the period of analysis.

Information from these new and retrofit demonstration projects should be disseminated widely to the building, energy professional, utility, and policy-making communities.

Education and Promotion

Following successful demonstrations of the energy and comfort advantages of modern evaporative systems appropriately integrated into efficient home designs, large-scale marketing efforts should be undertaken. Manufacturers, builders, utilities, state energy organizations, appropriate federal agencies, and other interested parties should all find important roles to play—concerted efforts are most likely to be successful.

A marketing blitz aimed at promoting energy-efficient new homes in the Las Vegas area over the summer of 2002 provides an instructive model. Prior to then only a few large builders in the Las Vegas area were involved in the Building America Program or ENERGY STAR® Programs. The local utility, the State Energy Office, a number of key builders, and the federal programs banded together to undertake a major ENERGY STAR home promotion campaign. There was extensive media coverage of various builders and home designs in the local newspapers—and a healthy competition ensued. As a result, there are now 42 builders that are official ENERGY STAR partners in Nevada, 12 of which are now producing only ENERGY STAR homes. Importantly, many builders who have committed to producing only ENERGY STAR and Building America homes tend to be large production builders. By 2003, close to half of the new homes built in the metropolitan Las Vegas market were ENERGY STAR.

For the present case, the manufacturers of high-quality evaporative cooling equipment and promoters of energy efficiency in buildings have their work cut out for them, for they must overcome the perceptions borne of inferior equipment that's often poorly installed and poorly maintained. Toward overcoming this substantial barrier, the best strategy may be to simply deal forthrightly with problems associated with older equipment while highlighting distinguishing characteristics of the new generation of evaporative coolers.

Some key points that need to be effectively conveyed include the following:

- **Media**. Instead of aspen fibers (excelsior) which tend to descend with use, causing inefficiency and short lifetimes, modern evaporative cooling media is made of special plastic-coated cellulose or similar material formed into a rigid rectilinear shape typically between 4 and 24 inches thick. Air passageways are fluted to maximize cooling effectiveness while minimizing pressure drop (and fan power). The thicker the media, the greater the temperature drop of the air from entry to exit. Efficient units have at least 8 inch thick media; 12 or more is better. The media resists scale and algae, is easy to clean, and has a lifetime of many years, especially in regions in which water is largely free of impurities.

- **Appearance**. Instead of air coming in from all four sides, efficient machines that use thick media are designed for air to flow into an entrance on one side, with conditioned air opening out the far side or the bottom. This allows units to be placed in attics, on side walls, or on small pads outside the home instead of on the roof.

- **Air quality**. Conventional CAC systems are most effective when homes are tightly sealed and fresh air makeup is at a minimum. Typical fresh air rates are only 1/3 of an air exchange per hour, sometimes much less. Modern evaporative coolers literally wash and filter incoming air, leaving it substantially free of pollen, dust, and most pollutants. Typically, they provide fresh air at rates of 2 to 3 air changes per hour.

- **Water**. Evaporative coolers use water, but well-designed, modern coolers use a batch flushing process to clean the sump rather than a continuous bleeding technique. The result is better cleaning and substantially lower water use. Modern coolers in efficient homes in the Southwest use an average of 5,750 gallons of water per year in the Southwest, about 3.3% of average annual residential water use. This amount of water costs $5 to $20 per cooling season. However, since evaporative coolers save on the order of 3,600 kWh per year, about 1,810 gallons of water are saved at the power station on average in the Southwest, for a net water use of evaporative cooling of 3,940 gallons. (State-by-state details are shown in "New Evaporative Cooling Systems: An Emerging Solution for Homes in Hot Dry Climates with Modest Cooling Loads.")

- **Security**. Systems that rely on back-draft dampers (up ducts and related devices) to control the flow of evaporatively-cooled air allow the windows in a home to be closed and locked.

- **Controls**. Systems that make use of dampers which open when the home is pressurized by an evaporative cooler blower are typically equipped with digital thermostatic controls to turn the system on and off; vary the blower speed to maximize energy efficiency in the light of local weather conditions, indoor temperature, and the thermostat's set point; and control sump flushing functions both during normal operations and at the end of the cooling season. End-of-season maintenance is thus facilitated and typically reduced to a chore of only a few minutes duration.

- **Comfort**. The combination of increased efficiency achieved by modern evaporative coolers—especially two-stage models—and digital controls mean that comfortable temperatures can be achieved in most climate zones in the Southwest throughout the cooling season. Short-term discomfort in very hot regions that occasionally experience periods of high humidity (e.g., the monsoon season in the low desert regions of Arizona) cannot be fully avoided. The solution of back-up conventional CAC is undesirable from a policy perspective since these periods typically correspond to peaks on the electric grid.

- **Energy**. SWEEP estimates that the owner of an 1,800 square foot home in the Southwest that is about 48% more energy efficient than a home built to just meet the year 2000 International Energy Efficiency Code for residential structures will save 3,625 kWh per year by using an efficient evaporative cooler rather than a SEER 13 central air conditioning system. Savings run from 1,485 kWh in Cheyenne to 5,469 kWh in Phoenix. Demand savings are about 2.5 kW. Homeowners save an average $287 per cooling season, $434 in Phoenix. Those who live in less efficient or larger homes save much more.

Overall Market Transformation Strategy

To achieve the goal of 40 percent market share in new homes will require incentives and effective educational and advertising campaigns. We believe that both should heavily emphasize the best evaporative cooling technologies. Although more expensive at the outset, they are generally less expensive than conventional whole-house air conditioning systems. Most important, higher-end equipment is likely to yield greater comfort, lower energy bills, and longer lives than older evaporative cooler technology.

Utility companies in the region can play an important role not only in providing cash incentives for the purchase of high-efficiency evaporative coolers but also in publicizing their advantages to the building community and the public at large. Forming partnerships between local utility companies and production builders to write down construction costs of efficient, evaporatively-cooled homes will stimulate the marketplace and help give credibility to modern evaporative cooler systems appropriately integrated into a well-designed home. Benefits to the utility should include both improved customer relations and substantially-improved load profiles from new homeowners.

Guaranteed energy savings is another approach favored by several utilities in the Southwest. Better load profiles (as well as good relations with both builders and customers) are key benefits achieved by the Tucson Electric Power (TEP) Guarantee Home Program. TEP staff works with builders to ensure their new homes are particularly energy efficient, then guarantees to new home owners that for the first three years, their heating and cooling costs will be below a threshold that is a function of home size.[8] For example, a 1,600 square foot home may be guaranteed not to exceed $1.00 per day for heating and cooling costs, whereas a 2,000 square foot home may be guaranteed not to exceed $1.70. Since guaranteed cost thresholds could be much lower with energy-efficient homes that incorporate modern evaporative cooling equipment rather than

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[8] See Kinney, Larry. 2003. "Tucson Utilities' Efficiency Programs for New Homes" at http://www.swenergy.org/programs/profiles/Tucson_0212.pdf.

conventional CAC, potential new homeowners will be given a clear economic message that should prompt strong responses.

Finally, retrofitting homes with inefficient conventional air conditioning systems or old evaporative coolers with modern evaporative coolers should be actively promoted through DOE's Weatherization Assistance Program, various state, local, and utility-sponsored home retrofit programs, and contractors throughout regions where weather conditions particularly favor evaporative cooling. There is a role for modern evaporative cooling in existing homes as well as new homes. Promoting the technology in both markets will maximize energy savings and peak demand reduction.