User Satisfaction with Innovative Cooling Retrofits in Sacramento Public Housing

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How do tenants of public housing respond to retrofits to improve their comfort and energy use during the cooling season? In contrast to retrofits to improve heating or lighting, cooling retrofits have been little studied, despite extensive programs by utilities and housing authorities to reduce this end use. A local utility and a housing authority have been retrofitting their buildings with evaporative coolers, ground-source heatpumps and other cooling measures. As part of an overall evaluation of the project we have conducted interviews with the residents, building managers and project staff to determine satisfaction with the performance of the systems. The initial evaluation revealed glaring defects in the design and installation of the systems, and not surprisingly, there was great dissatisfaction by the tenants and staff with their performance. Subsequent interventions and improvements to the equipment solved the technical problems, but tenant satisfaction was mixed. Further surveys revealed misunderstandings by the tenants on the nature of the evaporative coolers, their control and operation—often due to poor thermostat design—and expectations for comfort and familiarity with the technology. A significant finding from the study has been that despite the technical potential for these retrofit measures, the improper implementation of the systems, maintenance requirements and user behavior can all greatly impact the projected energy savings.

BACKGROUND

Drive through any of the old valley towns in central California and you will notice that the older residential neighborhoods appear quite different from the new housing developments springing up on the periphery of town. The first things one notices in the older neighborhoods is the landscaping: mature trees—sycamores, ash and elms—providing shade for roads, sidewalks and houses. Often you will find screened porches and balconies to take advantage of any cooling breezes that may be present. If you look harder you will see what appear to be metal chicken coops on the roofs. These are evaporative cooling units, or "swamp coolers" as they are popularly known.

Prior to the development of residential compressor-based air conditioners in the 1950s (Banham 1969) there were few strategies for keeping cool during the hot summer months. Fans, both hand-held and electric, cold drinks, screen porches and hammocks were used by residents to endure these periods. And in parts of the country where summers were hot and dry, evaporative coolers were often used as well. The basic principle for evaporative cooling goes back centuries. Throughout the Middle East, houses had water-filled vessels mounted in openings that would face the prevailing wind, which would lower the indoor air temperature by the evaporation of the water.

In recent times, with the widespread adoption of compressor-based air conditioning, electric utilities are often facing summer demand peaks. Evaporative cooling uses considerably less energy than conventional air conditioning and consequently, some utilities are testing the re-introduction of evaporative cooling systems as a way to reduce summer peak cooling loads on their systems.

While evaporative cooling has a long history, it is not clear how receptive people today are to what could be perceived as an "old-fashioned" technology. A pilot demonstration project to introduce evaporative coolers into housing provided by a public housing authority offers a chance to study not only the potential energy savings of this technology, but also issues of comfort and satisfaction among the residents.

PROJECT DESCRIPTION

The Sacramento Housing and Redevelopment Agency (SHRA) has been working with the Sacramento Municipal Utility District (SMUD) to improve the energy efficiency of their building stock. As part of this effort they are retrofitting their buildings with evaporative coolers, ground-source heat pumps and other cooling measures.

In 1994, the SHRA installed evaporative coolers in nine of their scattered site, single-family residences under a lead-abatement program. The evaporative coolers were two-stage indirect-direct coolers (IDEC). The IDEC units were installed on the roofs of the houses and share part of the ductwork with the central gas furnace.

During the 1995 cooling season occupants expressed varying degrees of dissatisfaction with the IDEC cooling performance (Davis Energy Group 1995). The SHRA contracted a local energy consulting firm to correct the problems with the equipment. Once the systems were fully operational we conducted a survey of the households to assess their satisfaction with the cooling performance.

The residents of these houses represent a typical cross-section of the population of low-income housing in California: families from Southeast Asia and Central America, single elderly often with extended family sharing living space part or full time and single mothers with children. While diverse in culture and background, this population are all low-income renters.

METHODS

We designed a telephone survey to interview the households with the evaporative cooling units. Seven of the nine households were interviewed in November 1995, after the cooling season was over. (The two households not interviewed were families that did not speak, or had limited English.) The interviews were conducted with the household head, and typically lasted 12-15 minutes.

The interviews included questions about their previous residence and familiarity with air conditioning systems, about their satisfaction and behavior related to their current cooling system and about the household characteristics. The questionnaire consisted of 40 questions, both closed- and open-ended.

The respondents were mailed a letter explaining the goals of the survey and were contacted a few days later for the phone interviews. All respondents agreed to participate and were extremely cooperative in answering questions. Even though the respondents were assured of the confidentiality of their responses, it is likely that they perceived any complaints would identify them as "trouble-makers" and to their minds, could jeopardize their staying in their current homes. Nevertheless, their willingness to speak about problems with the evaporative cooling systems suggests that while the bias for not complaining was present, they could still be objective about their relative satisfaction with the systems.

Four of the houses were instrumented with data loggers that collected data on the interior and exterior temperature and relative humidity as well as the electricity consumption of the evaporative cooling unit. These data were collected over a five-month period, from July through November 1995.

FINDINGS

Based on the interviews of the seven households we can make the following summary observations:

Household characterization

All seven households surveyed had lived in the current residence less than one year. The households all had a single female head of household and between 1 and 5 children living at home. Of their previous residences, whether apartment or house, four had central air conditioning. Only two households had previous experience with evaporative coolers, both had been satisfied with the technology, and one remembered it as being "quieter than other cooling" while the other commented, "At night it did okay with the cold water, but in the day I still had to use my fans."

Malfunctioning systems

There were several problems in the design and installation of the evaporative cooling systems, and consequently several systems did not operate correctly. Four of the households mentioned problems with the evaporative cooling system not working this past summer, a problem that was later corrected by the SHRA after inspection by an energy consulting firm. One of the residents of a household that had a broken system characterized her current home this summer as "just right" once the swamp cooler was fixed. "It was nice and cool by mid-July—really cool." But clearly the period when the systems were not operating caused the residents both discomfort as well as a feeling that the technology was not as good as conventional air conditioning.

Satisfaction with temperature, humidity and air movement

Three of the households that had problems with their evaporative cooling systems described their homes as too hot and a little too humid during the summer months. One resident said she was always too warm this past summer, and she would adjust her clothing, use a portable fan, leave the home, open a window, close drapes and drink something cold to improve her comfort. These actions sometimes enabled her to achieve a satisfactory temperature. The other four households expressed satisfaction with the temperature this past summer. Air movement, whether too much or too little was not considered to be a problem. All respondents said that their current comfort (at the time of the interview) was satisfactory. One respondent added that the unit was okay, but she didn't think it was "right for Sacramento."

Satisfaction with thermostat controls and settings

Two of the households expressed dissatisfaction with the thermostat, the others were either somewhat or very satisfied with it. Those who expressed dissatisfaction were households that had experienced non-functioning cooling systems. From all the respondents, however, it was clear that—for the most part—the households typically left the thermostats alone. Most said they kept it at 70°F all the time, although several said they would often turn it off as well. Regarding her thermostat one woman said "These computer things—I couldn't do anything other than turn on the heat. Now I know which way to turn it. She said she was now somewhat satisfied with the thermostat. Another mentioned she felt she was well informed on how to use it once she got started, but that at the beginning, "Modernization [the Housing Authority staff] didn't even know how to use it."

Satisfaction with noise

The residents' satisfaction with noise from the unit was mixed. Two householders thought their units were the same as other cooling systems, two thought they were noisier and two thought they were quieter. The ones who thought it was noisier said they could hear it near the kitchen going off and on and that they needed to turn up the TV when it was on. (This last response is true for many air distribution systems.)

Satisfaction with energy use

Three of the households thought their current house used less energy than their previous residence and four thought they used more. Those who thought they were using less mentioned the improvements to the house during the renovations. Those who thought their bills were higher mentioned using the washer and dryer more and that they were living in larger homes than previously. None of the residents mentioned the evaporative cooler as a reason their bills might be lower.

Overall comfort satisfaction

The only household that expressed dissatisfaction with its general comfort was the one where the evaporative cooling system was not working at the time of the interview. All others expressed satisfaction, with the qualification that they were not happy at first, but that now things were okay. One added that "At first, I was very dissatisfied. I had to go for months [without cooling]. Now everything is okay. [But I] have to find out why my bills are so high—they are as much as my rent."

Least favorite features

The least favorite features of the cooling systems were the "wet air" which one respondent described as "the water [cooled-air]—it's not cold at all. It's somewhat cool. My clothes turn black with mildew." Another woman mentioned she thought the systems were wasteful: "you have to open the windows. That's wasting my electricity. You have to open every window a little." Another resident commented that what she didn't like about the system was "The noise—I have to turn the TV up because it's loud. But I wouldn't trade it for an air conditioner—it's cooler and you can have the windows open."

Favorite features

The features identified as most favorable were that the systems were quiet, they provided enough cooling, the vents in the room allowed for control by room, they could leave the thermostats on automatic and not worry about them and that they could leave windows open which allowed them to remain in contact with their children playing outside: "I can leave the windows open and keep touch with my kids—and it keeps us nice and cool". She would suggest using it in other homes: "I don't want to move—I don't want to risk not having it."

Indoor Conditions

Four of the households were instrumented by SMUD to collect data on the energy consumption of the evaporative coolers, as well as indoor and outdoor temperature and relatively humidity. These data will be used in a later stage of this study to evaluate the energy savings from the retrofits. Our concern here is to look at the environmental conditions indoors to see whether residents were keeping their homes comfortable.

The outside summer temperature and relative humidity for Sacramento are shown in Figure 1. The daytime temperature is typically over 90°F and often over 100°F. If we look at one of the sample houses, the indoor temperatures ranged from 75° to 85°F before September 16 at which date the resident was shown how to use the evaporative cooler (Figure 2). After this date the temperatures range from 70° to 80°F, with a corresponding increase in relative humidity (Figure 3).

DISCUSSION

The findings from the surveys have raised several issues which go beyond questions of whether the systems save energy compared to conventional air conditioning. Questions of user understanding, comfort, satisfaction and health all

Figure 1. Exterior Temperatures in Sacramento, California, July–September, 1995.

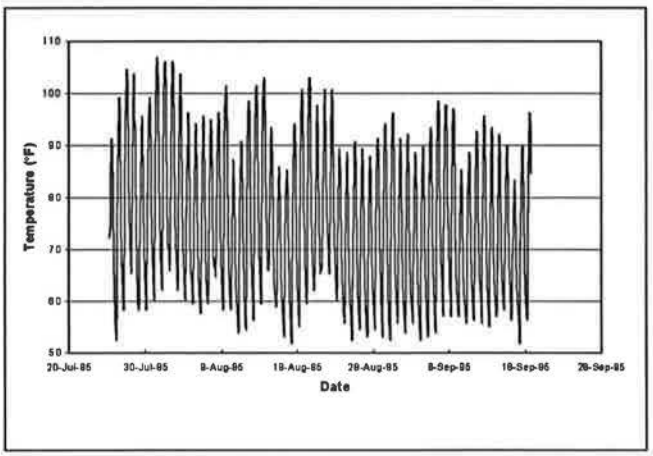


Figure 2. Indoor Temperatures From August to October, 1995.

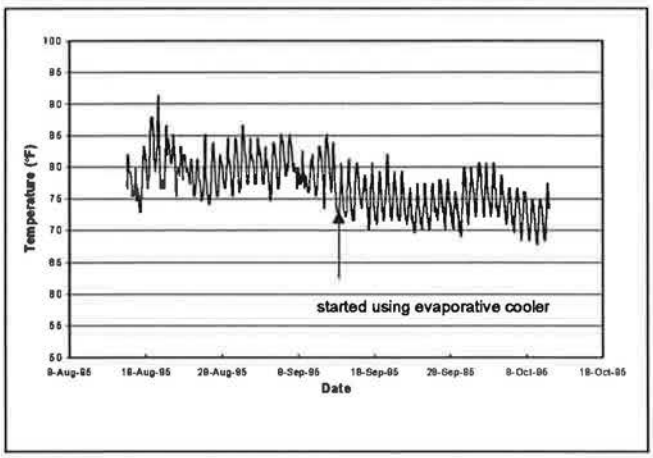
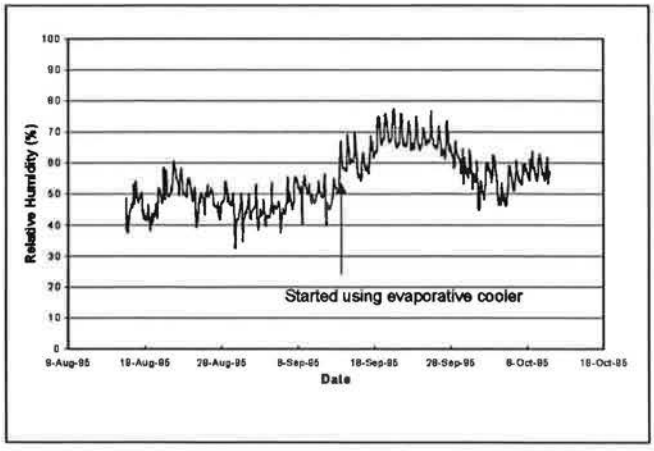


Figure 3. Indoor Relative Humidity From August to October, 1995.



need to be answered before the technology will receive widespread adoption.

Are the users satisfied with the systems?

For a new (or in this case, old) technology to be adopted it has to work for the owner. In a rental situation we have a user who is not the owner, so we have a case where both tenant and owner need to be satisfied. Presumably the owner, the SHRA, will be satisfied if the evaporative cooling systems provide sufficient cooling, the tenants are satisfied, the maintenance is minimal, and the energy costs are lowered. For the tenants, satisfaction is a combination of whether the systems provide sufficient cooling and are easy to operate. But there is also the issue that evaporative cooling may be perceived as an "inferior" technology. Do these low-income residents feel marginalized by having a different type of cooling system in their house?

None of the residents mentioned or indicated that they thought their status was lowered because they had these systems. There is also the issue that renters may have lowered expectations for comfort, because this is something that they don't expect to be able to control. The classic example is in the apartment building where there are no individual controls for the heating system and tenants have lower expectations for their comfort because they don't have any direct control over their temperature (Becker 1977).

Noise and size and appearance could all prejudice the users against these systems, but none of the residents mentioned that these were important factors. While a few mentioned that they could hear the systems turn on, no one was terribly bothered by the noise. The issue of appearance and size was minimized perhaps by the design which had most of the units mounted at the rear of the house, typically over the kitchen or garage.

One of the findings from the pilot program is that while the systems are in theory low maintenance, they do require maintenance twice a year to clean the pads and to switch the dampers to winter mode. In an owner-occupied residence these activities would be taken care of (or not) by the resident. But in the scattered-site houses owned by the SHRA, this would be a time-consuming activity beyond the resources of the limited maintenance crews. A service contract for a third-party maintenance provider could be one possibility, but issues of cost and quality control would still exist.

A final issue in assessing user satisfaction relates to the cultural backgrounds of the population in these low-income households. As mentioned earlier, renters may have a culture of not complaining because of a fear of eviction by the building owner. In these houses, several residents were from

Southeast Asia and Central America, and they may have had cultural reasons for not wanting to criticize any aspect of their housing for fear of appearing ungrateful. There is also the issue of how salient cooling comfort is in the context of these householders' daily lives. Several of the residents during the interview made reference to current or recent hardships (loss of previous housing, death of a child, financial uncertainty) that made questions about cooling comfort seem superficial. Again, the issue here is whether it makes sense to ask about user satisfaction about something they do not spend much time thinking about.

Do the tenants operate the systems correctly?

The evaporative coolers are controlled by an automated thermostat that provides several functions for heating and cooling. In addition to the bewildering variety of settings, these thermostats have a light that comes on when the cooling systems are first activated to indicate that the pads are being wetted and that cooling will not be immediately available. (One resident mentioned turning off the system when that light came on.)

Several researchers have studied the problems of thermostat design (Diamond 1984; Kempton et al. 1992; Lutzenhiser 1992). From the interviews it was clear that the residents do not have any interest in tinkering with their thermostats to optimize performance. For them the systems are either on or off. Some residents recognize the advantage of a systems that they never have to touch. But it is likely that the systems are not always operated in the most optimal fashion.

The issue of needing to open windows during the operation of evaporative coolers is also interesting as this behavior may be contrary to people's idea that you only air condition a house that is sealed (Hackett and Lutzenhiser 1993). Some residents mentioned that they hated having to open windows with the systems running, as it wasted electricity, while others appreciated having the windows open so that they could communicate with their children outside.

Are the systems energy efficient?

Surprisingly, none of the residents indicated that they knew the systems were supposed to be more energy-efficient than conventional air conditioning. While we haven't completed the evaluation of the energy consumption of the units, it is curious that the users were not aware of why they had this technology. The residents mentioned several actions that they knew would raise or lower their energy consumption, such as changes in household size, frequency of using major appliances, and that their house had good insulation, so they were clearly cognizant of how energy was being used, but they were not aware that their cooling systems were designed to lower their utility bills.

Are there health and environmental issues?

There is a limited number of studies on the health effects of direct evaporative coolers. Since most systems use a recirculating water reservoir, there is a potential for biological growth within the reservoir and on the evaporative pads (Arens et al. 1993, 29). Field observations (cited in Arens et al. 1993) have found that although the water used to wet the pads was contaminated with bacteria and fungal material, apparently the evaporative cooler pads do not produce aerosols, and consequently, there is little spread into the occupied spaces. We did not interview the households about their health-related symptoms, but perhaps a later survey (and measurements) could be made to determine if there were higher levels of mold in the households with evaporative coolers compared to conventional air conditioning. Of course going to an indirect evaporative cooler would lower the indoor humidity levels and make this less of a potential problem, but at greater system cost and complexity.

One of the environmental issues related to evaporative cooling is the availability and cost of water. In the Sacramento area, residential water is not metered, but in other areas, there would be higher costs associated with the water needed for these systems (Huang 1992). While it was not a factor in this study, water availability may play a role in customer satisfaction with this technology.

CONCLUSIONS & MORE QUESTIONS

The single-most obvious lesson from the project is the need to have the systems working correctly from the beginning. The user's perceptions of the "new" cooling system was not favorable given that the systems did not work for several months during the hot summer. Nevertheless once the systems were fixed they were generally well received.

Most of the residents felt they had been well educated in how to use the systems, but it was clear that this step may take several iterations before the residents use the systems correctly. Information on opening windows, length of the start up time before cool air is available and other topics should be explained during several visits. In addition to the one-on-one information, residents should have a user's manual, with good illustrations of how the systems should be operated to provide maximum comfort at minimum cost.

The overall resident satisfaction with the evaporative cooling systems shows that these systems can be attractive alternatives to compressor-based cooling in hot dry climates and that energy savings can be realized from their use. We would propose a follow-up study in a few years of both the house-