Southwest Energy Efficiency Project

UC Davis Western Cooling Efficiency Center (WCEC)

SWEEP / WCEC WORKSHOP ON

MODERN EVAPORATIVE COOLING TECHNOLOGIES

July 9th and 10th, 2007
Boulder, Colorado

WORKSHOP SUMMARY

September 14, 2007

Sponsored by:

Xcel Energy and the Sacramento Municipal Utility District (SMUD)

SWEEP / WCEC WORKSHOP ON MODERN EVAPORATIVE COOLING TECHNOLOGIES
WORKSHOP SUMMARY

September 14, 2007

Executive Summary

SWEEP and the Western Cooling Efficiency Center at UC Davis held a workshop on *Modern Evaporative Cooling Technologies*, on July 9 and 10, 2007, in Boulder, Colorado. The workshop agenda, presentations and background papers are posted on the SWEEP web site, at www.swenergy.org/workshops/evaporative/. The purpose of the workshop was to identify utility-sponsored programs, incentives, research and demonstration efforts, and cooperative activities that can help advance evaporative cooling technologies, which are ideally suited to the hot dry climate that predominates in much of the Western U.S. Participants included representatives from investor-owned and public utilities, evaporative cooling equipment manufacturers, cooling equipment distributors and installers, researchers, building energy efficiency experts, and commercial end-users of evaporative cooling systems.

The workshop participants learned about and discussed advanced evaporative cooling technologies and applications in the residential, commercial and industrial sectors. The types of evaporative cooling systems covered included direct evaporative coolers, indirect-direct systems, indirect only, and hybrid evaporative-compressor based systems. The workshop addressed technical, policy, regulatory and institutional factors that are limiting the level and rate of market adoption of advanced evaporative cooling systems. Barriers to evaporative cooling that were discussed at the workshop include:

- Lack of a consistent standard for evaluating and comparing the efficiency and performance of evaporative cooling systems (i.e., relative to SEER levels for refrigerant-based central-air conditioning systems).
- Need for improved training of contractors and installers to maximize reliability and performance of advanced evaporative cooling systems.
- The need to address ongoing maintenance requirements through utility incentives and manufacturer programs (e.g., better manuals, technical assistance 'hotlines').
- Additional field demonstration and testing is needed to evaluate the performance of advanced evaporative cooling systems under a variety of operating conditions and settings.

Findings and Next Steps

The workshop participants identified the following market sectors and technology applications as potential areas for near- and long-term application of evaporative cooling systems:

Near-term:

- Develop **hybrid evaporative-condenser systems** for residential applications (e.g., the Freus system).
- Continue field testing and demonstration of **commercial packaged rooftop evaporative cooling system units and accessories** for small retail, large retail and warehouses, and manufacturing facilities.

- Develop improvements to **direct, roof-mounted evaporative systems** (e.g., control systems for fans and pumps, improved media, and changes to ductwork and building design).

Long-term:

- Develop and demonstrate **chilled water storage** systems that utilize evaporative cooling to produce chilled water during cooler, off-peak hours that can then be used to meet cooling needs, which often coincide with periods of peak electricity demand.
- Develop and demonstrate **Solar-PV driven evaporative cooling** systems incorporated into high performance homes and commercial buildings, such as residential and commercial green building projects.
- Integrate **liquid dessicant systems** and **advanced membrane media** into evaporative cooling systems to reduce moisture levels and system maintenance requirements.

The participants identified opportunities for collaboration between and among equipment manufacturers, researchers, utilities, and energy efficiency proponents, including:

- **Forming partnerships** between equipment manufacturers, researchers, and utilities to establish certification standards for evaporative cooling systems, and conduct field demonstration projects to evaluate and document performance.
- **Collaborating** with state weatherization programs, water utilities, and municipal green building programs to incorporate evaporative cooling into building energy efficiency programs and services.
- **Incorporating evaporative cooling into rating and certification systems** (e.g., ENERGY STAR, ARI), and establishing an energy efficiency rating for evaporative systems that is comparable to SEER.

The following next steps were discussed:

- Developing a vision and strategy for evaporative cooling technologies.
- Establishing an ENERGY STAR standard and possibly an ARI section on evaporative cooling.
- Developing an R&D 'clearinghouse' of information, tools, and field performance data on evaporative cooling systems.
- Establishing workgroups and subgroups to address these and other technical and policy issues related to a range of evaporative cooling technologies and applications.

For More Information

SWEEP and the WCEC, in conjunction with the workshop participants, will be conducting follow-up activities on each of these next steps. If you would like to stay informed about or be involved in these activities, please let us know.

For more information, contact Steve Dunn at SWEEP at sdunn@swenergy.org, or Dick Bourne at the WCEC, at rcbourne@ucdavis.edu.

Introduction and Background

Evaporative cooling systems are ideally suited to the hot dry climate that predominates in much of the Western U.S. When properly installed and maintained, evaporative coolers use about one-fourth (or less) the electricity of conventional central air conditioners and cost about one-third to operate. Modern evaporative coolers use less energy, less water, and require less maintenance than traditional evaporative cooling systems. Because of their superior energy performance, properly installed and maintained evaporative cooling systems can play an important role in utility demand-side management (DSM) programs aimed at reducing both regular and peak electricity demand, particularly during the hot summer months when cooling is most needed.

Evaporative coolers also offer a number of other benefits to public health and the environment. They can help improve indoor air quality by frequently exchanging air from the outside and maintaining higher humidity levels than conventional air conditioning. Evaporative cooling systems do not use refrigerants (e.g., CFCs or HCFCs), which can damage the ozone layer or lead to increased concentrations of greenhouse gases in the atmosphere if released.

Despite their significant energy cost savings and related benefits, advanced evaporative coolers have captured only a small share of the air conditioning market in the Southwest. Barriers to advanced evaporative cooling include builder and consumer preferences for conventional air conditioning systems, policy and regulatory preferences for air-cooled cooling systems, concerns about the technical capabilities and performance of evaporative cooling under a variety of climate conditions, and lack of inclusion of evaporative cooling energy efficiency programs, certification systems and incentives offered by governments and utilities (e.g., federal tax credits, ENERGY STAR, and utility incentives).

Modern Evaporative Cooling Technologies

Recent advances in evaporative cooling technology have improved the energy efficiency and performance of evaporative cooling systems, which are now available for residential, commercial and industrial applications.

- The energy and water performance of direct systems have been significantly improved through application of two-stage motors, multi-function control switches and thermostats, and improved media (e.g., cellular or rigid media pads).
- "Indirect" evaporative coolers take advantage of evaporative cooling effects, but cool without raising indoor humidity.
- Indirect-direct evaporative coolers (IDEC) add a second stage of evaporative cooling before the conditioned air enters the dwelling to further lower the temperature of the incoming air.
- Hybrid systems consisting of an indirect evaporative cooler and a DX-compressor have been developed for residential and commercial-scale applications.
- Evaporative cooling systems are capable of being powered (all or in part) by on-site PV systems, making them compatible with renewable energy applications, such as zero-energy homes.

Sources:
SWEEP, 2004 and New Buildings Institute, 2006.

Workshop Purpose and Objectives

The purpose of the workshop was to identify utility-sponsored programs, incentives, research and demonstration efforts, and cooperative activities that can help advance evaporative cooling technologies, which are ideally suited to the hot dry climate that predominates in much of the Western U.S. Participants included representatives from investor-owned and public utilities, evaporative cooling equipment manufacturers, cooling equipment distributors and installers, researchers, building energy efficiency experts, and commercial end-users of evaporative cooling systems. The workshop participants identified both promising market opportunities and applications for evaporative cooling, as well as significant technological, policy, and institutional barriers to evaporative cooling technologies.

The workshop included presentations on current research and development activities, including the results of field monitoring and performance studies, comparative analyses of the performance of a range of evaporative cooling systems, and emerging technologies and associated R&D needs. Several workshop participants participated in a tour of NREL's advanced thermal conversion lab, where NREL provided an overview of current research and testing programs, including advanced types of evaporative cooling media (e.g., durable plastic membranes that reduce maintenance requirements), indirect evaporative cooling systems, and dessicant systems that can improve the performance of evaporative cooling systems under more humid climate conditions.

Workshop Objectives

The workshop objectives were to:

- Learn about recent advances in evaporative cooling technologies and results of recent field demonstration projects.
- Discuss barriers to advanced evaporative cooling technologies.
- Identify implementation strategies for advancing evaporative cooling technologies, including field demonstration and R&D efforts, utility programs and incentives, and coordination with federal/state/local building efficiency programs
- Determine next steps for advancing modern evaporative cooling technologies, including opportunities for collaboration, information sharing, and new program development.

Evaporative Cooling Technologies and Applications

The primary types of evaporate cooling technologies currently in use are direct evaporative coolers, indirect-direct systems, indirect only systems, and hybrid evaporative-vapor compression systems. The performance, technology development status, and potential market applications of each technology are summarized in Table 1.

Benefits of using evaporative cooling systems include:

- The energy savings potential of advanced evaporative systems is significant, with potential to reduce annual building cooling energy use by 50-90%.
- Lower operating costs than conventional compressor-based technologies.

- Reduction in peak electricity demand by up to 80%. Evaporative cooling systems are most effective in afternoon hours when summer peak demand and electricity rates are high.
- Maintain indoor air quality through constant replenishment with outdoor air.
- Avoids unnecessary dehumidification of supply air. Dehumidification is not necessary in the dry climate conditions that exist in much of the West.

Table 1. Characteristics and Typical Performance of Selected Evaporative Cooling Systems

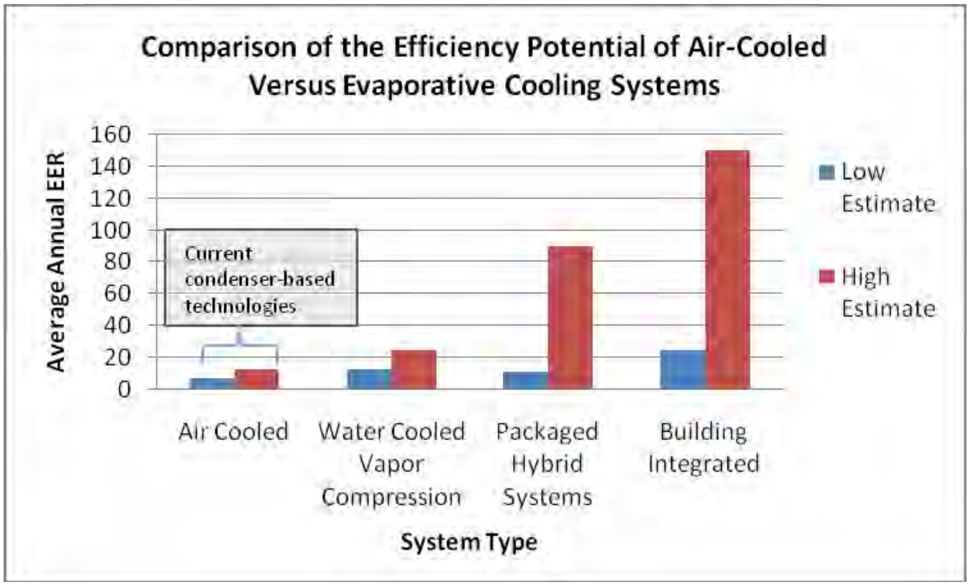
System Type	Description	Technology Status	Evaporative Effectiveness	Comfort Impact	Savings Potential*	Water Use gal/ton-hr(1)	Product Examples[1]
Direct	Adds moisture supply air stream	Mature	80%	Humidity Increase	70%	3.8	Many types
Indirect	No moisture added to occupied space	Early production	90%	No humidity increase	50%	3.3	Coolerado
Indirect-Direct	Indirect followed by direct	Early production	110%	Slight humidity increase	80%	2.8	OASys
Evaporative Condenser	Evap cooling of outdoor AC unit	Early Production	15 EER (at 95F)	No impact	35%	1.7	Freus
Hybrid Rooftop Unit	Evaporative and compressor-based cooling	Prototype	TBD	Little impact	50%	2.8	Desert Cool Aire

* Estimated for typical applications; actual values vary with conditions

(1) at 94 DB, 30 deg, wet bulb depression, 15% purge/bleed

[1] For additional information about evaporative cooling systems and performance specifications, see the '*Assessment of Market-Ready Evaporative Technologies for HVAC Applications*', prepared by the New Buildings Institute. Available at: http://www.newbuildings.org/mechanical.htm

Figure 1: Comparison of the Average Annual EER of Vapor-Compression and Evaporative Cooling System Technologies



Direct Systems

Direct evaporative coolers are an economical and viable alternative to compressor-based air conditioning (i.e., central air conditioners). Direct systems are widely available in the marketplace as whole-house, portable, and through-the-window coolers. The energy and water consumption of direct systems can be improved by incorporating the following equipment components and operating procedures:

- Use of advanced evaporative media with an effectiveness rating of 85% or greater, which delivers air that is 5 to 10 degrees cooler than conventional aspen pad media.
- Multi-function controls that allow the evaporative cooler to also function as a whole-house fan.
- Use of pressure relief dampers (e.g., 'Up Ducts'), which exhaust outside air to the attic, thereby cooling the attic space and allowing the system to operate with windows and doors closed.
- Thermostatic controls (in conjunction with pressure relief dampers) that adjust operation based on cooling requirements.
- Use of water quality management pumps that periodically purge the water system rather than continuously bleeding water through the unit.

At present, there is no certification system to differentiate energy-efficient direct evaporative coolers that incorporate the features above from traditional coolers.

Indirect-Direct and Indirect Heat and Mass Exchangers (HMX)

Indirect-direct evaporative coolers (IDEC) add a second stage of evaporative cooling before the conditioned air enters the dwelling to further lower the temperature of the incoming air. Indirect coolers utilize a unique heat and mass exchanger to reduce air temperature without adding humidity to the airstream. IDEC units have been developed for residential, commercial and industrial applications. Early versions of IDECs experienced a number of design and operation problems, which were attributable in part to improper installation and maintenance. DOE's Building America team and PG&E have tested the performance of a range of IDEC units under normal and severe climate conditions. The performance tests found that IDECs were capable of achieving energy savings of 80% or more relative to an air-cooled compressor during summer peak conditions (see Figure 2). More information about the IDEC test results is available in the presentations by Dave Springer, Davis Energy Group and Robert Davis, PG&E.

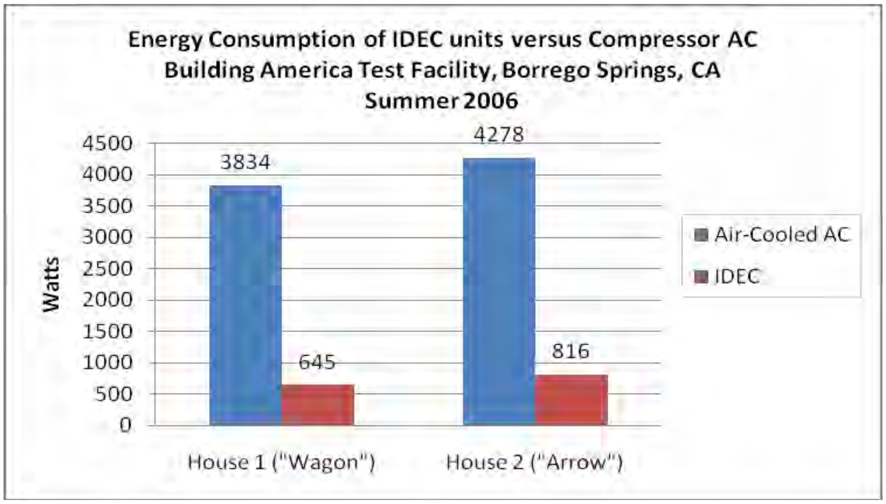
Indirect-Direct Evaporative Cooling at McCarran Airport, Las Vegas Nevada

Des Champs Technologies developed an indirect evaporative cooling system for the McCarran Airport Terminal in Las Vegas, Nevada. The system consists of 15 Des Champs IDEC units ranging in size from 8,000 cfm to 28,000 cfm, for a total of 280,000 cfm of equipment. The IEC system uses an EPX polymer heat exchanger that resists mineral buildup, which is a major challenge to the use of evaporative cooling in Las Vegas because of hard water conditions. The Des Champs system provides cold supply air with an EER of 42, which is much more efficient than refrigeration based systems.

Photo: Nick Des Champs

For more information, see presentation by Nick Des Champs on Commercial Advanced Evaporative Cooling Systems, at:
http://www.swenergy.org/workshops/evaporative/presentations/index.html

Figure 2: Comparison of Energy Use of IDEC units versus compress AC, Borrego Springs, CA



Hybrid Systems

Advanced hybrid systems have been developed that provide added flexibility for residential applications, particularly in areas with seasonal humidity conditions (e.g., Arizona). Products include the Freus unit (see Figure 3), which is designed for residential applications, and the DesertAire, which is designed for the packaged rooftop market for commercial applications.[2]

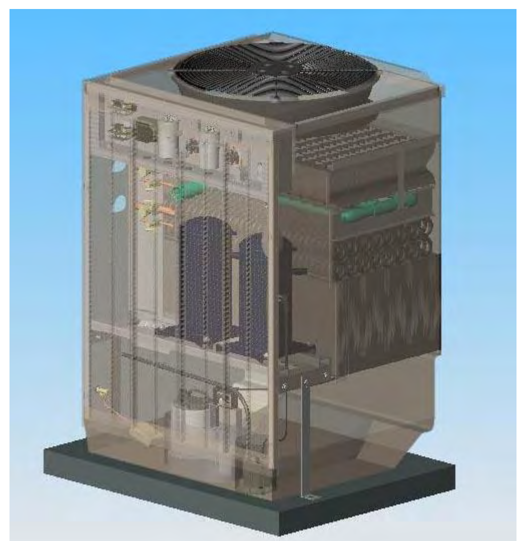


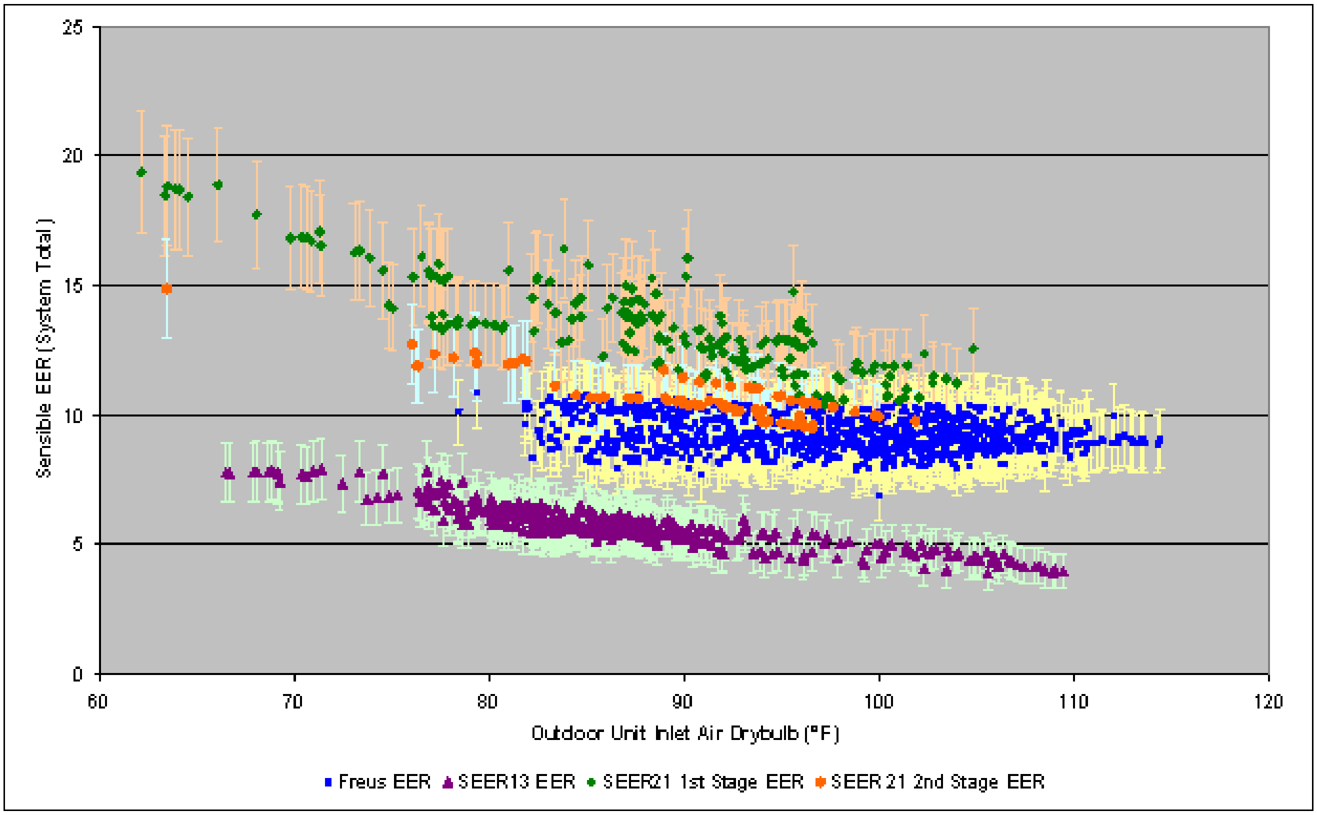
Figure 3. Freus Evaporative-Condenser Unit

Innovative applications of evaporative cooling systems include reducing the size of refrigerant-based compressor systems, or eliminating the need for compressors altogether. In the residential market, hybrid systems can directly replace air-cooled condensers with minimal retrofit (i.e., adding a water line to the unit). PG&E and SMUD have both expressed intent to initiate pilot incentive programs for residential evaporative condensers by the end of 2007, but details are not yet available.

The DOE Building America team is also conducting tests of hybrid systems at its Borrego Springs test facility. Hybrid systems are capable of achieving energy savings of 40-60%, while continuing to meet the comfort conditions specified by ASHRAE for residential homes (Standard 55). Unlike vapor-compression systems, the performance of the evaporative-condenser hybrid does not degrade with hotter temperatures, as shown in Figure 3.

[2] For more information about the DesertAire unit, see the New Building Institute's report, "Package Unit Technical Assessment", at: www.newbuildings.org/downloads/papers/DesertCoolAireExecutiveSummary_6-30-07.pdf

Figure 4. Evaporative-condensers are 40-50% more efficient at delivering cooling on hot days than SEER 13 system vapor-compression technologies, and provide equivalent performance to the SEER 21, which is the most advanced vapor-compression technology currently available in the marketplace.



Source: David Springer, Davis Energy Group and U.S. DOE / Building America Team
http://www.swenergy.org/workshops/evaporative/presentations/David_Springer_Davis_Energy_Group.pdf

Utility Incentives and Programs

Several utilities in the west offer rebates programs for evaporative cooling. Most of the utility rebate programs are targeted at the residential sector, although some utilities also offer rebates for commercial customers. PG&E had offered an evaporative cooling rebate program from 2001 to 2006, but suspended the program because of declining participation rates. Factors cited by PG&E for declining participation include:

- Market demographics didn't favor a customer program (i.e., low income, seniors, non-English speaking)
- Application process was too complex
- Contractors did not promote the rebates
- No active industry support

A PG&E survey also found that the majority of rebates (51%) went to customers that already had an evaporative cooler installed in their home).[3] Evaluations of other utility rebate programs found similar results (e.g., Xcel Energy, CO; Rocky Mountain Power, UT).

Commercial evaporative cooler rebate programs are offered by PG&E, SCE and Idaho Power. The PG&E and SCE programs provide a rebate for each ton of existing A/C tonnage removed or disabled after the evaporative cooling equipment is installed (currently $123 per ton). The Idaho Power program offers three levels of commercial incentives, with a similar requirement for replacing standard AC units: 1) evaporative pre-coolers; 2) direct evaporative systems and 3) indirect evaporative systems. The pre-cooler incentive applies to air cooled air conditioning package units and split systems with evaporative pre-coolers added to the condenser coils. The direct and indirect cooling system incentive applies to equipment that replaces a roof-mounted

Utility Programs and Incentives for Evaporative Cooling

The following utilities offer cash rebates for evaporative cooling systems:

- Rocky Mountain Power (Utah): $300 - $750 for residential installations
- Pacific Gas & Electric (California): multi-family housing: $300 - $600; pilot contractor rebate program for homes initiated in 2007 with $300 - $600 incentives.
- Southern California Edison (California): $300 - $600 for residential systems; $123 per ton for advanced evaporative coolers for commercial systems.
- Xcel Energy (Colorado): $200, residential systems only
- Idaho Power (Idaho and eastern Oregon): Offers commercial evaporative incentives for equipment replacing standard AC units: evaporative pre-coolers: $100; direct evaporative systems: $200; indirect evaporative systems: $300. Residential incentives are offered at $150 for systems with a minimum efficiency rating of 2,500 cfm

Utilities conducting R&D and field demonstrations of advanced evaporative cooling systems include:

- Pacific Gas & Electric (California)
- SMUD (California): Indirect-Direct and Indirect HMX systems (e.g., Coolerado)

[3] See presentation by Robert Davis, at: http://www.swenergy.org/workshops/evaporative/presentations/Robert_Davis_PG&E_Evaporative_Cooling_Programs.pdf

standard direct expansion air conditioning package unit. For these measures, the tonnage on the application is based on the capacity of the unit being replaced.[4] Idaho Power just recently announced a new incentive program for residential evaporative cooling systems (effective September 10th, 2007). The residential program is available to permanently installed units in single-family homes, manufactured homes, and multi-family units.[5]

Evaporative cooling and other HVAC rebates have traditionally been offered as 'downstream' incentives to customers, such as homeowners that are replacing an existing evaporative or central A/C system, or adding evaporative cooling to their home. In 2007, PG&E will be conducting an 'upstream', contractor-level rebate program in Fresno, CA. The results of the PG&E pilot should indicate whether offering an upstream incentive is a more effective model for evaporative cooling rebates.

Some utilities include prescriptive requirements for evaporative cooler installations or additional incentives for supplemental controls, such as pressure relief dampers. The advantage of including prescriptive requirements is that the installed equipment is more likely to achieve delivered energy savings. The disadvantage is program participation rates may be lower, because of higher overall installation costs.

Utilities are also partnering with research institutions and equipment manufacturers in performance testing and evaluation of advanced evaporative cooling systems. A list of research reports sponsored by utilities and other organizations is provided at the end of this report.

Market Barriers and Implementation Strategies

The workshop speakers and participants identified multiple technological, policy, regulatory and institutional barriers to evaporative cooling, particularly for newer, advanced systems that have not yet become widely established in the marketplace. The primary barriers to evaporative cooling, and potential ways to overcome them, are summarized below and in the subsequent sections on findings and recommendations and next steps.

Technological barriers

Technology Performance and Field Verification

There has not been enough experience in the field with some types of advanced evaporative technologies to adequately characterize their performance in real-world environments. Laboratory studies of equipment performance are essential to promoting a new technology. But field studies are even more critical, because the performance of the systems in the real world is often quite different than in the lab. Without a solid track record, it will be difficult to move this technology forward. Workshop participants identified the following specific issues:

[4] For more information, see: http://www.idahopower.com/pdfs/energycenter/EasyUpgrades/worksheet_HVAC.pdf

[5] For more information, see: http://www.idahopower.com/energycenter/energyefficiency/YourHome/heatingcooling/evaporativeCoolers.htm

- There is a need for additional field monitoring and testing of advanced units. Currently data exists for only a limited number of trials, and many of these trials included earlier versions of equipment that have been significantly improved. A concerted effort to conduct field evaluations of this equipment should be undertaken.

- Because of the climate-responsiveness of this equipment, performance mapping and testing under a variety of climate conditions should be done.

> "The ultimate evaporative cooling system would have the serviceability, reliability and comfort of conventional DX systems yet operate at a fraction of the cost."
>
> - Quote from SMUD customer, presentation by Dave Bisbee

- There is currently a lack of modeling tools and software for evaluating and comparing the performance of evaporative cooling systems.

- Past field studies have sometimes neglected the issues of water consumption and water quality. More information on this aspect of advanced evaporative technologies is essential, especially since this is one of the areas where the general public has the greatest concerns.

Reliability and Serviceability

Dave Bisbee of SMUD noted several system reliability and maintenance problems in their advanced evaporative cooling pilot program.

Recommended actions for improving system reliability and serviceability include:

- Overcoming bad reputation from failures and industry bias (DX systems are well established)
- Develop a program for factory-provided training on installation procedures, maintenance, and troubleshooting and repair
- Describe maintenance and service procedures in detail, including procedures for replacing media, internal parts (e.g., pumps, motors, pulleys, and water distribution systems)
- Providing better customer and technician manuals, technical assistance (e.g., toll-free hotline), water treatment and start-up/shutdown guidelines

Water consumption and water quality

Concerns about water consumption remain a barrier to evaporative cooling. Some municipalities and water utilities in the west have begun to discourage evaporative cooling through education campaigns, or in some cases offering incentives for homeowners to remove evaporative cooling systems. Better information and analytic tools for evaluating the water consumption of evaporative cooling systems is needed. Larry Kinney emphasized that the consumptive use for a residential evaporative cooling system could be more than offset by installing a low-flow showerhead in the home. Nick DesChamps noted that the amount of water consumed for providing cooling via an evaporative cooling system is less than the water that would be consumed by a power plant providing electricity for a compressor-based air conditioner. A workshop participant noted that classifying water used for evaporative cooling as a beneficial use, rather than consumptive use, may help alleviate water rights concerns in regions of the west where water supply allocations are determined based upon the amount of beneficial versus consumptive use.

Water quality poses challenges for evaporative cooling systems, particularly in areas with hard water that contains high concentrations of minerals and salts. Nick Des Champs described a system that his company designed which is capable of operating under severe water quality conditions (e.g., the Nevada desert and in Death Valley, CA). This system uses polymer membranes as filter pads. There are various strategies for addressing water quality problems, including filtering, magnetic, electromagnetic, electrostatic, catalytic and mechanical. It should be remembered that water consumption and water quality are integrally linked: water-related problems can be virtually eliminated if pure water is delivered to the cooling system.   However, pure water is usually costly to procure. The optimal water treatment strategies that minimize the sum of maintenance and water costs, while maintaining minimal energy use, are not yet clearly identified. This is an area of active interest, and the Western Cooling Efficiency Center is launching an initiative to determine some of the best approaches for common evaporative cooling applications.

Policy, regulatory and institutional barriers

Building codes and design practices

Most new residential and commercial buildings built today are designed and built to use compressor-based cooling technologies. In homes, installed systems and ductwork are designed around 'split systems', which are not readily suited to evaporative cooling systems. Residential and commercial building codes are oriented around conventional cooling equipment (e.g., specifications for ductwork, system sizing, and ventilation). Retrofitting an evaporative cooler into HVAC systems designed for split systems may cause performance issues, such as inadequate cooling in some rooms.

State and local codes also do not take into account evaporative cooling. Homeowners associations (HOAs) have placed restrictions on roof-mounted evaporative coolers, citing architectural concerns. This could restrict the ability to install evaporative coolers in new homes, or retrofit systems into existing homes. Advanced units (IDECs and hybrid evaporative-compressor units) that are mounted at ground-level may help overcome this problem.

Certification and standards

Unlike compressor-based cooling, there is no national system of certification and standards for evaporative coolers. The lack of standards and certifications means evaporative cooling equipment is often not included in engineering design specifications for heating and cooling systems, and is not included in national rating programs, such as ENERGY STAR.

There are several reasons why evaporative cooler energy efficiency ratings have not been established. Perhaps the most significant has been weakness in the evaporative cooling industry. Manufacturers have not had the financial strength to organize and support an industry organization like the American Refrigeration Institute (ARI) that promulgates standards for compressor-based air conditioning systems. Also, there are difficulties regarding relative performance between single-stage direct evaporative cooling (DEC) systems and indirect or multi-stage systems that add less moisture to the occupied space. Also, the energy efficiency of evaporative cooling systems varies widely depending on whether the system is applied to cooling incoming ventilation air (an application where EC's shine) or in substitution for a compressor-driven recirculating air system (as in residential applications). In the latter, the EC may be cooling 100 degree outdoor air to perhaps 75 degrees, but since it forces indoor air (perhaps at 80 degrees) to leave the building, it's cooling value in these conditions is based on the 5 degree range between the supply and leaving air streams. California has recently developed the "ECER" rating which reflects EC value on the latter terms. However, the ECER does not reflect relative humidity impacts of the various EC configurations.

Industry and customer perceptions

Many people still view evaporative cooling systems as 'swamp coolers', with associated humidity and indoor air quality problems. A few workshop participants noted anectodally that evaporative systems are considered a 'secondary choice' for cooling, as opposed to vapor-compression systems. There also is a growing bias toward evaporative cooling systems within the HVAC industry and by homeowners, driven by concerns about higher humidity levels and concern about liability for perceived problems with mold and indoor air quality (IAQ). In some cases, the HVAC industry has also conducted public education campaigns promoting central AC cooling over evaporative cooling systems.[6] Advanced evaporative systems (and properly installed and maintained direct systems) do not pose mold or IAQ issues, but the perception persists in the minds of industry and many end-users.

Utilities and state agencies (e.g., Rocky Mountain Power, State of New Mexico, and PG&E) have developed fact sheets and educational materials about the benefits of evaporative cooling, and proper installation and maintenance procedures. Information about these and other education materials are provided in the information resources section at the end of this report.

Findings and Recommendations

The workshop provided an opportunity to bring together manufacturers, utilities, HVAC industry representatives, and cooling and building energy efficiency proponents to assess the status of advanced evaporative cooling technologies and identify ways to advance the commercialization of these technologies through technology development and R&D, policy and regulatory actions, and utility programs. The main findings and recommendations from the workshop are summarized below.

[6] Examples include newspaper editorials and billboards promoting central AC over evaporative cooling.

Technology Development and R&D

Equipment manufacturers and the evaporative cooling research community now have more than a decade of experience developing and testing advanced evaporative cooling units. The results of field tests were summarized by multiple workshop presenters (Bourne, Davis, Reichmuth, Springer, DesChamps). The following technology development and R&D needs for individual evaporative cooling technologies (e.g., IDECs, indirect HMX systems, and hybrids) were identified:

- Industry needs to develop or refine sizing methods (i.e., at the design ambient conditions, how many air changes per hour are needed for comfort?).
- Research and develop versatile, calibrated research & design performance models that can be used to evaluate alternate technologies, and/or used in building simulation tools to evaluate whole building energy impacts of technology selections.
- Establish a new R&D focus on low-cost water storage systems that can facilitate nighttime and off-peak cooling of water using cooling towers and other evaporative processes. In extreme conditions when direct water cooling by evaporation might not satisfy cooling loads, an off-peak chiller can be applied to the low-cost storage system.
- Conduct field testing and performance mapping to verify the performance of evaporative cooling units under a range of operating modes, applications climates, and water conditions.

The presenters also emphasized the need to conduct analyses that compare and evaluate the performance of evaporative cooling systems relative to each other and to other cooling technologies (e.g., air-cooled or water-cooled compressors). Specific research needs and topics include the following:

- Better performance models are needed to determine energy and demand savings over A/C while providing adequate comfort.
- Developing an efficiency metric for evaporative coolers appropriate to the western region that is comparable to the SEER metric used for compressor-based cooling equipment.
- Develop tools for analyzing full cycle water use and management for cooling, and conducting comparative analyses of the water consumption requirements of evaporative cooling systems.
- Conduct field demonstrations to document the performance of evaporative cooling systems under 'real world' conditions.

Policy and regulatory

The main policy and regulatory barriers facing evaporative cooling systems stem from the fact that evaporative cooling technologies and system design needs are not incorporated into building codes, standards and certification systems, and federal, state and local incentive programs. For example, the 2005 Energy Policy Act provides a $300 tax credit for high efficiency cooling equipment, but only equipment that meets CEE's high efficiency tier (i.e., SEER 15 central A/C or better) is eligible for the tax credit.[7] Similar problems occur at the state and local levels, where evaporative cooling may not be eligible to receive credit under green building programs, or for zero or low-interest loans that are offered to homeowners and businesses for energy efficiency improvements.

Policy and regulatory recommendations for creating a more 'level playing field' for evaporative cooling systems include:

- *Establish a regional commitment to cooling efficiency & demand goals in the Western region, with comprehensive tracking of progress.* Establishing an aggressive goal and tracking progress toward the goals will help drive utility programs, state and local governments and the HVAC industry toward low-energy cooling strategies, including evaporative cooling.

- *Establish national recognition of climate-specific HVAC needs*. Establishing a regional cooling standard for the west will facilitate the use of alternatives to air-cooled systems. Establishing a climate-specific standard will also help.

- *Establish an ARI section and dealer contractor network for evaporative cooling systems.* Certifying evaporative cooling systems under ARI will help integrate evaporative cooling into the HVAC industry by providing equipment certifications and a centralized list of qualified evaporative cooling system distributors, installers and servicers. Evaporative cooling equipment manufacturers should work with the HVAC industry to develop training and certification requirements for installers, particularly for advanced systems.

- *Developing an ENERGY STAR specification and label for highly-efficient evaporative coolers.* Establishing an ENERGY STAR specification and label will allow manufacturers to differentiate highly-efficient evaporative cooling systems in the marketplace, and will help distributors, installers, and consumers identify and choose energy-efficient options for evaporative cooling equipment.

Utility programs

Although a few utilities in the West offer incentives for evaporative cooling, many currently do not include evaporative cooling in their DSM programs. Where utilities do offer incentives, the incentive level and quantity offered may not be high enough to transform the market toward advanced units, or advanced units may not meet the eligibility criteria established by the utility. Utility rebates have primarily helped customers replace existing evaporative coolers, rather than displacing central A/C systems or upgrading existing direct coolers to advanced indirect-direct cooling systems. Several workshop speakers emphasized the need to improve maintenance

[7] For more information about the federal tax credit for HVAC, see: http://www.energystar.gov/index.cfm?c=Products.pr_tax_credits#s2

practices and provide better support to contractors and customers for equipment installations and follow-up technical assistance, particularly for advanced systems that are newer to the marketplace.

Findings and recommendations for utility rebate programs are as follows:

- *Address installation and maintenance issues.* Utilities could collaborate with equipment manufacturers and the HVAC industry to establish and support a dedicated network of evaporative cooling equipment installers. Utilities can also create maintenance programs for existing evaporative coolers, similar to programs that exist for tune-ups of air-cooled systems (e.g., rebates for checking refrigerant charge), and require that advanced evaporative cooling systems be installed by qualified HVAC contractors.

- *Promote evaporative cooling through education and outreach programs.* Increase awareness of builders, contractors, and customers of evaporative cooling equipment types, installation procedures, and maintenance practices through educational and outreach campaigns.

- *Consider offering 'upstream' incentives at the contractor/supplier level.* For example, beginning in summer 2007, PG&E will be conducting a pilot program for evaporative coolers in Fresno, CA that will offer incentives to contractors and installers.

- *Consider offering incentives to additional customer classes.* Utility programs that currently offer residential incentives only should consider adding incentives for commercial and industrial customers.

- *Consider offering a higher incentive tier for advanced evaporative cooling systems*. Utilities can consider offering a higher incentive level for installing advanced systems, such as indirect-direct coolers, indirect-only, and hybrid evaporative-condenser systems. Incentives for residential systems range from $300 to $600 for new installations of direct systems, and up to $750 for advanced systems.

- *Target key receptive markets and coordinate programs with state and federal efficiency programs (e.g., low-income housing, weatherization).* High-priority target markets in the commercial sector are small retail (e.g., commercial strip malls), warehouses and manufacturing facilities, and large retail (e.g., 'big box' retailers and warehouse-style discount stores).

Next Steps

The workshop concluded with a discussion of next steps, including the development of a coordinated strategy for advancing the commercialization of advanced evaporative cooling systems in the western U.S. SWEEP and the WCEC, in conjunction with workshop participants and other interested parties, will pursue the following next steps in each of the following areas:

- Technology development and R&D , including field testing and performance verification

- Policy and regulatory

- Utility programs and incentives

Next steps in each of these areas are summarized below and in Table 2.

Technology Development, R&D and Field Testing

Next steps for technology development and R&D focus on conducting real-world field evaluations, improving and refining system designs, and improving modeling tools and the associated ‘knowledge base’ about the performance and design features of advanced evaporative cooling systems. Specific next steps include the following actions:

- Focus on reliability and cost reduction of advanced indirect heat exchangers.
- Develop improved controls: In the short term, focus on improved control of dual systems. Long term research should focus on effective control of hybrid systems.
- Conduct a Western rooftop unit competition to solicit development of evaporative/hybrid units aimed at Western markets.
- Identify improvements needed to existing modeling tools and software used for designing and evaluating building cooling systems, including a water cycle analysis tool and a cooling system performance metric/map.
- Establish an R&D and “emerging technologies” clearinghouse that provides impartial information on the performance and status of new low-energy cooling technologies.

Policy and Regulatory

The participants identified several actions that could help overcome policy and regulatory barriers to evaporative cooling. The highest priority area for action was establishing a nationally recognized set of standards and certification for evaporative cooling equipment, through creation of an ARI section on evaporative cooling, and developing an ENERGY STAR label for efficient evaporative coolers.

The participants also expressed interest in developing collaborative workgroups involving equipment manufacturers, building energy efficiency and cooling systems design experts, and utilities to address specific topics and issues related to evaporative cooling systems. An ad hoc workgroup was created to develop a communications and outreach strategy for evaporative cooling, with initial emphasis on developing a unique ‘brand’ and marketing slogan for evaporative cooling (e.g., climate-friendly cooling, natural cooling, etc.).

Other policy and regulatory actions that state and local governments can take are:

- Include evaporative cooling as eligible equipment in “beyond code” programs, such as green building programs.
- Develop building design and code guidelines that recognize the potential benefits of advanced evaporative cooling systems.

- Integrate evaporative cooling into HERS ratings and related building energy efficiency design software.

Utility Programs

Currently, only a few utilities in the west offer incentives for evaporative cooling (e.g., Rocky Mountain Power, SCE, and Xcel Energy). Utilities that currently offer incentives for evaporative cooling can review and evaluate the incentive design, including offering a higher tier of incentives for advanced systems. Utilities should also begin to incorporate seasonal maintenance, development and support of evaporative cooling equipment vendor and maintenance networks, and coordinate incentive programs with large retailers.

Utilities that do not currently offer incentives for evaporative cooling can consider including such incentives in their DSM portfolios at either the contractor/supplier level ('upstream') or at the customer level ('downstream').

Utilities also participate in field tests and demonstration projects of advanced technologies, and collaborate with equipment manufacturers and energy efficiency proponents to integrate evaporative cooling equipment into national standards and certification programs, such as ENERGY STAR.

Industry Collaboration

The Evaporative Cooling Institute (ECI) has been in existence for many years but is virtually inactive. The WCEC with its "affiliate membership" structure offers an opportunity for manufacturers of advanced evaporative cooling systems to work in partnership with buyers, utilities, and governmental organizations toward more rapid implementation of their products. This organizational model appears more likely to accomplish change than the ECI. However, a stronger "industry only" group might also be of value.

In any event, it is important that efforts to implement advanced evaporative cooling systems network with other key stakeholder groups including ASHRAE, BOMA, BOCA, and others, to coordinate design, demonstration, code, and verification-related activities.

Table 2: High Priority Next Steps for Evaporative Cooling
✓ = group involved ☆= lead role

		Who is Involved					
Topic	Priority Actions	Manufacturers	HVAC Industry	End-Users	Building EE Researchers/ NGOs	Utilities	Government (Fed / State / Local)
Technology R&D							
Technology development	• Develop improved modeling tools and software • Establish R&D clearinghouse • Establish a collaborative technology	✓ ☆	✓		✓ ☆	✓	✓ ☆

	partnership between manufacturers, researchers/labs, the HVAC industry, and utilities						
Field testing and Performance mapping	• Conduct additional field trials on advanced units • Develop performance maps under varied climate and operating parameters	✓ ☆	✓		✓	✓ ☆	✓ ☆
Tools and software	• Incorporate evaporative cooling technologies into building design and simulation software tools	✓ ☆	✓		✓☆		✓

Topic	Priority Actions	Who is Involved					
		Manufacturers	HVAC Industry	End-Users	Building EE Researchers/ NGOs	Utilities	Government (Fed / State / Local)
Policy / Regulatory							
Standards and certification	• Establish ENERGY STAR specification • Establish ARI certification for evaporative cooling systems • Include evaporative cooling in HERS ratings	✓ ☆			✓ ☆		✓ ☆
Building codes	• Develop code provisions (or code references) that address evaporative cooling systems				✓ ☆		✓ ☆
	• Incorporate evaporative cooling into green building guidelines						✓ ☆
Utility and Government Programs							
Utility Incentives	• Provide a higher incentive tier for advanced evaporative cooling systems and ensure advanced systems are eligible for incentives • Develop a system maintenance component of incentive programs • Consider ‘upstream’ incentives to HVAC contractors	✓	✓	✓	✓ ☆	✓ ☆	
Education and outreach	• Develop tailored fact sheets and information materials for the HVAC industry, builders, and building operators and homeowners	✓ ☆	✓		✓	✓ ☆	✓
Technical assistance and training	• Develop a network of certified installers for advanced evaporative cooling systems • Provide better technical assistance to end-users (i.e., building operators, homeowners)	✓ ☆	✓ ☆		✓	✓	

Information Resources on Evaporative Cooling Technologies

The following reports and web sites provide additional information about evaporative cooling. Presentations from the workshop are available online at the SWEEP web site: www.swenergy.org/workshops/.

Fact Sheets

- Arizona Cooperative Extension, University of Arizona, Tucson
  Evaporative cooler water use. http://ag.arizona.edu/pubs/consumer/az9145.pdf

- Colorado Springs Utilities. White Papers and Fact Sheets (see information on evaporative cooling applications)
  http://www.csu.org/environment/conservation_bus/energy/library/index.html

  Flex Your Power (California). Evaporative Coolers Product Guide
  http://www.fypower.org/com/tools/products_results.html?id=100157

- New Mexico Office of the State Engineer, Water Use and Conservation Bureau. A Waterwise Guide to Evaporative Coolers. http://www.ose.state.nm.us/water-info/conservation/evap-coolers-brochure.pdf

- Pacific Gas and Electric. 2004. Energy Efficient Ducted Evaporative Coolers.
  http://www.pge.com/docs/pdfs/res/rebates/EEDECTechSheetv5.pdf

- Pacific Gas and Electric. Advanced Evaporative Coolers.
  http://www.etcc-ca.com/download/results/EvapCooler_072805.pdf

Articles

- Federal Energy Management Program (FEMP). 2007. Coolerado Cooler Helps to Save Cooling Energy and Dollars. http://www1.eere.energy.gov/femp/pdfs/tir_coolerado.pdf

- Felver, T., Scofield, M., Dunnavant, K. March 2001. Cooling California's Computer Centers: An air-handling unit design that conserves energy, improves IAQ, and increases reliability. HPAC Engineering, pp. 59-63

- Karl, Elka. Home Energy Magazine. The Cool Solution: Fresno's Housing Authority keeps energy expenditures low and economic savings high with its new evaporative coolers. www.homeenergy.org (subscription required)

- Kinney, L. Home Energy Magazine.September/October 2004. Modern Evaporative Coolers.
  http://www.eere.energy.gov/buildings/building_america/pdfs/db/38096.pdf

- Scofield, M. Indirect/Direct Evaporative Cooling: How Sonoma State University used an IEC/DEC system with an energy-efficient design to cool a building without the use of chilled water. HPAC Engineering, July 2005

- Springer, D. Kicking the Air Conditioner Habit. July/August 2003. Home Energy Magazine. http://homeenergy.org/hewebsite/graphics/HomeEnergy_20-4_feature.pdf

- Otterbein, Roy, Installing and Maintaining Evaporative Coolers. May/June 1996. Home Energy Magazine. http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/96/960511.html

Presentations

- ASHRAE Rocky Mountain Chapter. 15th Annual Technical Conference. May 18 2007. Evaporative cooling overview presentation. http://www.rockymtnashrae.com/pdf/2007TechConf/Evap_Cooling.pdf

- Kinney, L. Cutting Edge Cooling. Boulder Green Building Guild. May 2006. Powerpoint presentation.

- Colvin, T. and Kisebach, K. 2006. Commercial Evaporative Cooling. Utah Evaporative Cooling Workshop. August 8, 2006. www.utahcleanenergy.org/EnergyEfficiencyWG/documents/CommercialEvaporativeCoolingpresentation_000.pdf

- Davis Energy Group. 2004. Compressorless Cooling http://www.aceee.org/conf/04et/tt1deg.pdf

Technical Reports

Bonneville Power Administration.

- Energy Efficiency Technology Roadmap. July 2006. Low energy cooling technologies, Chapter 2.6. http://www.bpa.gov/corporate/business/innovation/docs/2006/RM-06_EnergyEfficiency-Final.pdf

California Energy Commission. Public Interest Energy Research Program (PIER)

- The Next Stage in Evaporative Cooling. http://esource.com/esource/getpub/public/pdf/cec/CEC-TB-12.pdf

- Development of an improved two-stage evaporative cooling system. Technical Report # P500-04-016. Prepared by the Davis Energy Group. March 2004. http://www.energy.ca.gov/pier/final_project_reports/500-04-016.html

- Advanced evaporative cooling white paper. Technical Report # P500-04-016-A1. Prepared by the Davis Energy Group. Prepared for the California Energy Commission. March 2004 http://www.energy.ca.gov/reports/2004-04-07_500-04-016_AT1.PDF

National Renewable Energy Lab (NREL)

- NREL. 2006. Projected benefits of new residential evaporative cooling systems: progress report # 2. NREL / TP-550-39342. http://www.nrel.gov/docs/fy07osti/39342.pdf

- Lessons Learned from Case Studies of Six High-Performance Buildings. NREL Technical Report # TP-550-37542. P. Torcellini, S. Pless, M. Deru, B. Griffith, N. Long, and R. Judkoff. http://www.nrel.gov/docs/fy06osti/37542.pdf

- *See also Utah case study, Zion National Park Visitor Center*

New Buildings Institute

- New Buildings Institute. June 2007. Desert CoolAire™ Package Unit Technical Assessment – Field Performance of a Prototype Hybrid Indirect Evaporative Air-Conditioner. Final Report – Executive Summary. Prepared by: Cathy Higgins – Program Director, Howard Reichmuth – Senior Engineer. Prepared for: Jeff Harris, Northwest Energy Efficiency Alliance, Dave Bisbee and Jim Parks, Sacramento Municipal Utility District.

- New Buildings Institute. 2006. Assessment of Market-Ready Evaporative Technologies for HVAC Applications. Prepared by: Howard Reichmuth, Cathy Turner, and Cathy Higgins. Prepared for: Southern California Edison, R. Anthony Pierce and Henry Lau, Design & Engineering Services.

- New Buildings Institute. 2006. Assessment of Market-Ready Evaporative Technologies for HVAC Applications, Appendix B. Prepared by: Howard Reichmuth, Cathy Turner, and Cathy Higgins. Prepared for: Southern California Edison, R. Anthony Pierce and Henry Lau, Design & Engineering Services. http://www.newbuildings.org

Pacific Gas and Electric.

- Laboratory Evaluation of the Coolerado Cooler™ Indirect Evaporative Cooling Unit. Application Assessment. Report #0402. http://www.etcc-ca.com/database/download/ETCC_Report_304.pdf

- Laboratory Evaluation of the OASys™ Indirect/Direct Evaporative Cooling Unit. Application Assessment Report #0510 http://www.etcc-ca.com/database/docs/ETCC_ProjectDoc_7.pdf

- Evaluation of Advanced Evaporative Cooler Technologies. February 2004. Report Number 491-04.7. http://www.etcc-ca.com/database/download/ETCC_Report_208.pdf

Southern California Gas Company

- Measure Information Template: Residential Evaporative Cooling. May 2006. 2008 California Building Energy Efficiency Standards. http://www.energy.ca.gov/title24/2008standards/documents/2006-05-18_workshop/2006-05-11_COOLING.PDF

Southwest Energy Efficiency Project

- New Evaporative Cooling Systems: An Emerging Solution for Homes in Hot Dry Climates with Modest Cooling Loads. Prepared by Larry Kinney. 2004 http://www.swenergy.org/pubs/Evaporative_Cooling_Systems.pdf
- Evaporative Cooling Policy and Program Options: Promising Peak Shaving in a Growing Southwest. Prepared by Larry Kinney. 2004. http://www.swenergy.org/pubs/Evaporative_Cooling_Policy_Options.pdf

Stabat, P., Ginestet, S., Marchio, D., 2003. Limits of Feasibility and Energy Consumption of Desiccant and Evaporative Cooling in Temperate Climates. Proceedings of 2003 CIBSE/ASHRAE Conference (24-26 Sept) http://www.cibse.org/index.cfm?gozhome.show&PageIDz366&TopSecIDz4&L1z0&L2z0u3d

Yu, F.W. and Chan, K.T., 2005. Application of Direct Evaporative Coolers for Improving the Energy Efficiency of Air-Cooled Chillers. Journal of Solar Energy Engineering; Transactions of the ASME 127(3): 430-433.

Book

Watt, John R., P.E. and Will K. Brown, P.E. Evaporative Air Conditioning Handbook, Third Edition, Fairmont Press, 1997. https://www.aeecenter.org/store/detail.cfm?id=633&category_id=6

Product Information, Performance Studies and Technology Profiles

See also: *Assessment of Market-Ready Evaporative Technologies for HVAC Applications*', prepared by the New Buildings Institute. Available at: http://www.newbuildings.org/mechanical.htm

- Adobe Air MasterCool
  - Web site: www.adobeair.com
  - Fact sheet: http://www.adobeair.com/brochures.html

- Champion / Essick Air
  - Web site: www.championcooler.com and www.essickair.com
  - Fact sheet: http://www.championcooler.com/eac/pdfs/bro_usa.pdf
- Coolerado
  - Web site: www.coolerado.com and www.idalex.com
  - Fact sheet: http://www.coolerado.com/Products/Coolers/R600/CooleradoR600brouchure.pdf
    Field evaluations
    Laboratory Evaluation of the Coolerado Cooler™Indirect Evaporative Cooling Unit. Application Assessment. Report #0402.
    http://www.etcc-ca.com/database/download/ETCC_Report_304.pdf
    and
    SMUD Customer Advanced Technologies Program, Technology Evaluation Report. 2006
    http://www.smud.org/education/cat/cat_pdf/Coolerado%20Cooler%202006.pdf

- Desert Aire
  - Web site: www.desert-aire.com

- Field evaluations
  New Buildings Institute. June 2007. Desert CoolAire™ Package Unit Technical Assessment – Field Performance of a Prototype Hybrid Indirect Evaporative Air-Conditioner. Final Report . Prepared by: Cathy Higgins – Program Director, Howard Reichmuth – Senior Engineer. Prepared for: Jeff Harris, Northwest Energy Efficiency Alliance, Dave Bisbee and Jim Parks, Sacramento Municipal Utility District.
- Final Report: http://www.newbuildings.org/mechanical.htm
- Fact sheet: http://www.nwalliance.org/research/documents/DesertCoolAireFactsheet.pdf

- Freus
  - Web site: www.freus.com
  - Fact sheet: http://www.smud.org/education/cat/cat_pdf/FREUS%202006.pdf
  - Field evaluations
    http://www.smud.org/education/cat/cat_pdf/Freus%20(SMUD%20Report).pdf
    and
    http://www.smud.org/education/cat/cat_pdf/Freus%20Report%20(ADM).pdf
    and
    http://www.cee1.org/cee/mtg/12-05_ppt/bacchus.pdf

- OASys Air Conditioner
  - Web site: www.oasysairconditioner.com
  - Fact sheet: http://www.esource.com/esource/getpub/public/pdf/cec/CEC-TB-12.pdf
  - Field evaluations
    NREL / Building America. May 2005. EVALUATION OF ADVANCED SYSTEM CONCEPTS. Deliverable 8.A.2. TASK ORDER KAAX-3-33411-08. Prepared by Consortium for Advanced Residential Buildings (CARB).
    www.oasysairconditioner.com/pdf/MagnaDRAFTCARBEvaluationOASys.pdf
    and
    SMUD Customer Advanced Technologies Program, Technology Evaluation Report. Dec. 2005
    http://www.smud.org/education/cat/cat_pdf/OASys.pdf

- Phoenix Manufacturing
  - Web site: www.evapcool.com
  - Fact sheet: http://www.evapcool.com/pdf/AerocoolIndustrial_2-2003.pdf

Case Studies

California

- Clarum Homes, Borrego Springs Demonstration Homes.
  http://www.clarumzeroenergy.com/
  Press release: http://www.clarum.com/Borrego%20ZEDH%20General%20Release.pdf

- Sacramento Municipal Utility District (SMUD)

Customer Advanced Technologies Program Technology Evaluation Reports.
http://www.smud.org/education/cat/index.html
Includes evaluation reports on the Freus, Coolerado Cooler, and OASys evaporative cooling systems.

- Santa Rosa Junior College. Evaporative Cooling Case Study. Report to PG&E. Prepared by Davis Energy Group. 2002.
  http://www.pge.com/pec/resourcecenter
  and
  http://www.des-champs.com/library/document_detail.php?document_type_ID=13&document_ID=147

- Victor Valley Water District
  http://www.ornl.gov/sci/eere/international/Website/Advanced%20HVAC%20Design.htm

Colorado

- Colorado Springs Utilities
  Evaporative Pre-Cooling of Large Air-Cooled HVAC Equipment. White Paper #19.
  http://www.csu.org/environment/conservation_bus/energy/library/11421.pdf

Nevada

- University of Nevada – Las Vegas Zero Energy Home
  http://www.nswep.org/proj_unlv_bldgs_zero_energy.html
  and http://www.nswep.org/proj_unlv_bldgs_zero_energy.html

- Western Nevada Community College. Des Champs Oasis Indirect-Direct Two-Stage Evaporative Cooler Des Champs Technologies.
  http://www.des-champs.com/library/document_detail.php?document_type_ID=13&document_ID=142

New Mexico

- U.S. Forest Service Western Regional Headquarters. Albuquerque.
  http://www.swenergy.org/casestudies/newmexico/Forest_Service.pdf

Utah

- NREL. 2002. Zion National Park Visitor Center: Significant Energy Savings Achieved through A Whole-Building Design Process
  http://www.nrel.gov/docs/fy02osti/32157.pdf

- Consortium for Advanced Residential Buildings. 2006. Field Evaluation Report: Evaporative Cooling. Prepared for the Community Development Corporation of Utah.
  http://www.carb-swa.com/PDF%20files/CNOctober06.pdf

Utility Programs

- Fort Collins Utilities – Loan Program (Colorado)
  http://fcgov.com/utilities/pdf/zilch-application.pdf

- Idaho Power
  - Commercial evaporative cooling retrofit program
    http://www.idahopower.com/energycenter/energyefficiency/YourBusiness/easyUpgrades.htm
    and
    http://www.idahopower.com/pdfs/energycenter/EasyUpgrades/worksheet_HVAC.pdf
  - Residential incentives
    http://www.idahopower.com/energycenter/energyefficiency/YourHome/heatingcooling/evaporativeCoolers.htm

- Pacific Gas and Electric
  http://www.pge.com/res/rebates/whole_house/evap_coolers/index.html

- PNM (New Mexico); proposed program
  http://www.pnm.com/news/2007/0131_fact_sheet.htm

- Rocky Mountain Power (Utah)
  - Program information
    http://www.utahpower.net/Article/Article25681.html
  - Qualifying equipment
    http://www.utahpower.net/File/File48799.pdf
  - Fact sheet (Utah Power)
    English: http://www.utahpower.net/File/File75023.pdf
    Spanish: http://www.utahpower.net/File/File75024.pdf

- Rocky Mountain Power (Idaho)
  http://www.homeenergysavings.net/idaho/evcoolers.html

- Sacramento Municipal Utility District (SMUD)
  http://www.smud.org/education/cat/index.html

- Southern California Edison (California)
  http://www.sce.com/RebatesandSavings/Residential/_Heating+and+Cooling/EvaporativeCooling

- Xcel Energy (Colorado)
  http://www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-2_738_18787-11864-2_77_158-0,00.html

Web sites

Consumer Energy Center (CEC)

- http://www.consumerenergycenter.org/home/heating_cooling/evaporative.html

DOE Building America

- http://www.eere.energy.gov/buildings/building_america/

National Renewable Energy Laboratory (NREL)

- Distributed Thermal Technologies Program
  http://www.nrel.gov/dtet/

- Residential Building Design and Performance
  http://www.nrel.gov/buildings/res_building_design.html#evaporative

HUD / Partnership for Advanced Technology in Housing

- PATH Technology Inventory: Two-stage Evaporative Coolers
  http://www.toolbase.org/TechInventory/TechDetails.aspx?ContentDetailID=789

- Evaporative Coolers: A PIH-Approved Alternative to Air Conditioners
  http://www.hud.gov/offices/pih/programs/ph/phecc/newsletter/jan06.pdf

- Public Housing Energy Conservation Clearinghouse
  http://www.hud.gov/offices/pih/programs/ph/phecc/strat_H11.cfm

Southwest Energy Efficiency Project (SWEEP)

- http://www.swenergy.org

Western Cooling Efficiency Center (WCEC), UC Davis Energy Efficiency Center

- http://wcec.ucdavis.edu