Tucson/Pima County

Net Zero Energy Code

Energy versus Water
Evaporative Coolers as part of a Net-Zero Home

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Net Zero basics

Net-zero is the term for a building that produces as much energy on site as it uses over the course of the year. Tucson has one of the first documented Net-Zero energy homes in then nation in Armory Park del Sol[1]. Currently, the City of Tucson Office of Conservation and Sustainable Development and Pima County Development Services Building Safety and Sustainability, with the assistance of the University of Arizona, College of Architecture and Landscape Architecture, are developing a voluntary Net-Zero Energy Code. This code will provide guidance on building homes, offices and shops that produce as much energy as they use.

Cooler basics

Evaporation of water has been a traditional source of cooling in hot dry climates for thousands of years. The familiar swamp cooler of the desert southwest was patented in 1945[2]. Cooling is accomplished by evaporating water in a stream of dry outside air that is then distributed through out the building. As most residents of Tucson who have used "Swamp Coolers" know, evaporative coolers work best with dry outside air. During the monsoon season, traditional coolers have a harder time maintaining comfortable indoor temperatures. Recently, two factors have improved cooler performance: first, evaporative coolers are getting more efficient which results in a better cooling when the humidity is high, and second, well-insulated homes have a lower cooling load, therefore the work that a cooler has to do is greatly reduced from the homes of a generation ago. Below is a performance chart for a modern 85% efficient cooler.

Evaporative Cooler Performance Tables[3]

SOLAR CHILL with 8" Thick Celdek or Kuul Pad																		
	HUMIDITY																	Cooler Efficiency = 0.85
		2	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
AMB TEMP	75	50	52	54	55	56	58	60	61	62	63	64	66	67	68	69	70	71
	80	54	55	56	58	60	61	63	65	66	67	69	70	72	72	73	75	76
	85	57	58	60	61	64	65	67	68	70	71	73	74	76	77	78	79	81
	90	59	60	63	65	67	69	70	72	74	76	77	79	80	82	83	84	86
	95	62	64	66	68	70	72	75	76	79	80	81	81	83	84	86		
	100	64	66	69	71	74	76	78	80	82	88	83	86	88				
	105	67	68	72	74	77	79	82	84	86								
	110	69	71	75	79	80	83	86	88									
	115	72	76	77	79	82												
	120	75	77	79	83													

= 82 Degrees F or BELOW

Energy efficiency

Compared to air conditioners or heat pumps, coolers use 70 to 80% less energy to cool the house[4]. In the past, many considered the evaporative cooler to be the environmentally friendly choice because of this electricity savings. Based on the following table regarding energy use reported in a recent study by the Southwest Energy Efficiency Project (SWEEP), an air conditioner in Phoenix will use 11.5 kBtu/sf/yr. A swamp cooler will use 1.1 kBtu/sf/yr. A swamp cooler in Phoenix would save 10.4 btu/sf/yr over a SEER 13

air conditioner[5]. This is a 90% savings and a significant amount considering that the target energy budget for a net-zero house in the Net-Zero Energy code[6] is 29 kBtu/sf/yr.

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Table 2. Water and Energy Use in the Southwest

City	Cooling Energy DX (kWh/yr)	Cooling Energy Evap (kWh/yr)	Energy Saved (kWh/yr)	DX Source Water Use (gal)	Evap Source Water Use (gal)	Water Saved at Source (gal)	Evap Site Water Use (gal)	Net Evap Water Use (gal)	Annual increase HH water use due to evap cool (%)
Albuquerque	2,487	334	2,153	1244	167	1,077	3,470	2,394	2.6%
Cheyenne	1,773	287	1.485	886	144	743	2,435	1,692	1.4%
Denver	1,935	279	1,656	968	140	828	2,685	1,857	1.7%
Las Vegas	4,722	497	4,225	2361	249	2,112	6,696	4,583	2.6%
Phoenix	6,043	574	5,469	3022	287	2,735	8,619	5,884	5.1%
Salt Lake City	2,839	357	2,483	1420	178	1,241	3,981	2,739	2.1%
SW Average	4,063	438	3,625	2,032	219	1,813	5,754	3,941	3.3%

Source: Increasing Energy Efficiency in New Buildings in the Southwest, SWEEP, 2003; SWEEP estimates

For Phoenix:

Annual Energy Saved =	5,469	kWh/yr
x	3.412	kBtu/kWh
Annual Energy Saved =	18,660	kBtu
Home size=	1,800	sf
Energy Savings =	10.4	kBtu/sf/yr

Water Use

In recent years, the water consumption of swamp coolers has become an environmental issue. By their very nature, swamp coolers only work in dry climates. Therefore the mining of fossil water (wells that tap underground aquifers) or importing water (CAP canal) is required for coolers to function. Studies vary on the amount of water used in a cooler. A 1995 study in Phoenix found an average use of 23,638 gallons per season. A study by the University of Arizona found 150 gals per day[7], or 18,000 gallons for a 120 day cooling season.

Modern evaporative coolers are more efficient in their water use than traditional coolers, converting 80% of the potential for cooling in a direct cooler and up to 110% in an indirect-direct cooler[8]. The SWEEP study found that a cooler in Phoenix would use 8,619 gallons per year. This is a 5.5% increase in the household water use[9]. Using the water use value from the SWEEP study, the embedded energy in the water use is 0.24 kBtu/sf/yr.

Evap Water Use =	8,619	gals/yr
Embedded energy in water =	0.0503	kBtu/gal
Annual Embedded Energy in water =	434	kBtu/yr
Energy Use =	0.24	kBtu/sf/yr embedded energy in water

When the embedded energy is subtracted from the direct energy savings, the net energy savings is:

10.4 kBtu/sf/yr direct savings – 0.24 kBtu/sf/yr energy in water = 10.16 kBtu/sf/yr Net Energy Savings

Water Embedded in Energy Savings

In the above SWEEP table, the column "Water Saved at the Source" accounts for the water not used to generate the electricity saved by the cooler vs. the air conditioner. The embedded water in energy has various values depending on the source from 0.32 gallons per kWh to 0.67 gallons per kWh. Embedded water in

energy savings for the Phoenix example above is 2.735 gallons per year. Therefore the net water use is 5,884 gallons per year or a 5.1% increase in water use.

The embedded water in electricity is saved at the generating plants. In the case of the electricity suppling Tucson, the Four Corners and Springerville plants provide this power. These plants are located in the Colorado River water shed and ultimately benefit our supply of CAP water.

Other Potential Benefits of Cooler Use

Urban heat island: evaporating one gallon of water results in 8,700 btus or 2/3 of a ton of cooling[10] Air conditioners generate heat as they consume electricity to move heat from inside the house to outside of the house. ASU researchers have surmised that coolers contribute to lowering the urban heat island temperature.[11]

Peak energy usage reduction: because coolers use less energy, this can reduce the peak summer afternoon load on the electrical grid, thus reducing the need for utilities to buy electricity on the open market or building "peaking generators".

Whole house fan: a cooler can be used as a whole house fan to use cool, night time air to pre-cool a home. This strategy, called "pre-cooling" works best with high thermal mass houses and can further reduce the need for cooling energy.

Conclusion

Evaporative coolers, even when considering the embedded energy in water use 90% less energy than air conditioners while only adding 5.1% additional water use. They can reduce peak energy requirements thereby reducing peak costs to electric companies. There is modest increase in overall household water use associated with a cooler. Because of the potential to use a cooler as a whole house fan for night time pre-cooling, a cooler can make a cost efficient and effective cooling system for a well insulated, high thermal mass home.

Regarding the additional water use: this can be easily offset by simple passive water harvesting and xeriscaping, low flow fixtures or rainwater harvesting.

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[1] http://www.toolbase.org/Home-Building-Topics/zero-energy-homes/tucson-zeh
[2] http://en.wikipedia.org/wiki/Evaporative_cooler
[3] http://www.southwest-solar.com/humiditycoolerperformance/

[4] http://wcec.ucdavis.edu/images/stories/projects/sweep%20workshop%20final%20report.pdf, page 5. TEP reports "average annual use for its customers went from 9,066 kilowatt-hours 14 years ago to 11,129 kilowatt-hours last year [2007]. Air conditioning – which is gradually replacing swamp coolers in southern Arizona – is the biggest reason" http://tucsoncitizen.com/morgue/2008/06/24/89114-culprit-behind-higher-electric-bills-is-us/

[5] http://www.swenergy.org/publications/documents/Evaporative_Cooling_Systems.pdf, page 8
[6] The current draft of the code is available at: www.pimaxpress.com/green.
[7] http://www.climas.arizona.edu/feature-articles/september-2007
[8] http://wcec.ucdavis.edu/images/stories/projects/sweep%20workshop%20final%20report.pdf, page 5
[9] http://www.swenergy.org/publications/documents/Evaporative_Cooling_Systems.pdf, page 8
[10] http://www.swenergy.org/publications/documents/Evaporative_Cooling_Systems.pdf, page 7
[11] http://www.climas.arizona.edu/files/climas/pdfs/feature-articles/2007_sept_coolingsystems.pdf, page 2