

# POTENTIALS OF NIGHT SKY RADIATION TO SAVE WATER AND ENERGY IN THE STATE OF NEW MEXICO

## GOVERNOR RICHARDSON'S WATER INNOVATION FUND

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**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

Mark Chalom Architect  
Bristol Stickney Consulting



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# 1

## Executive Summary And Conclusions

The Executive summary explains the justification of Night Sky Radiant Cooling, its technology and its potentials for the state of New Mexico. Not all our statements are quantitative data but observations, conclusions and projections explaining how NSRC could be utilized in New Mexico and it's benefits beyond water and power. NSRC has the possibility of becoming another sustainable industry in our state and is another renewable energy source to be harvested.

Our conclusions are straightforward and explanations simplified to allow the non-technical person to understand the major points of our research. These simplified conclusions are further explained and quantified in detail as this report progresses.

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## EXECUTIVE SUMMARY

Through this grant process we have shown that Night Sky Radiant Cooling (NSRC) has great potential for utilization in the state of New Mexico as an alternative to air conditioners or swamp coolers. Utilization of NSRC can reduce the use of water and power at the time when the power grid is most stressed and water use is maximized for agricultural purposes in the state. The use of NSRC can have a positive economic benefit to the state, its future growth and help it grow in a sustainable way..

The goal of this grant was to explore the natural phenomenon of Night Sky Radiant Cooling (NSRC) as a way to save water and energy in the state of New Mexico. Our goal was to quantify the potentials within the state and how effective it is in the 11 climate zones in New Mexico. We were able to Develop correlation's between actual data collected from testing radiators and weather data collected on site. With this we were able to substitute weather data from the various climate zones to document and quantify the statewide potentials. From this we were able to project savings in water and energy and potential savings for each zone.

Our basic premise for savings is based on a well designed energy conserving home which makes the use of NSRC effective. This house would have a radiant heated slab that we cool with unglazed swimming pool collectors on a flat roof to serve as our cooling radiators.

We have found, through our research, that we can cool an efficiently designed home in the hottest of climate zones in New Mexico with NSRC. The average existing home in New Mexico is well below these standards requiring more heating and cooling. This inefficient home could easily use and save 2 times what we have shown but the system cost and complexity would also be twice and far from being realistic. See comparison heat loss of the 2 houses.

HEAT LOSS FOR AN EFFICIENT NEW MEXICO HOME					
floor area	1800				
		Lngh or Area	R value	U value	HL/hr/degree
AREA					
	PERIMETER	180	8	0.125	22.5
	WALLS	1653	21	0.047619	78.71429
	WINDOWS	464	3.03	0.330033	153.1353
	DOORS	42	2.5	0.4	16.8
	ROOF	1800	38	0.026316	47.36842
VOLUME	cu'		.018 x V x AE x alt factor		
	infiltration	15300	0.5		104.652
				total HL BTU/DEGREE/HR	423.17
				BTU/Day/SQ.FT./degree F	5.642267
				BTU/DD	10156.08
This energy efficient home has been designed to the standards of the Passive Solar Guidelines. It is 20% more efficient then the requirements of the Model Energy Code and 25% better then the Base Case model in the Energy 10 model. These standards are simple to achieve and will recoup the extra expense in energy savings in just a few years and is well worth the cost. This efficient home makes the use of alternative energy systems simple and cost effective.					

HEAT LOSS FOR A INEFFICIENT NEW MEXICO HOME					
floor area	1800				
		Lngh or Area	R value	U value	HL/hr/degree
AREA					
	PERIMETER	180	3	0.333333	60
	WALLS	1653	11	0.090909	150.2727
	WINDOWS	464	1.25	0.8	371.2
	DOORS	42	2.5	0.4	16.8
	ROOF	1800	19	0.052632	94.73684
VOLUME	cu'		.018 x V x AE x alt factor		
	infiltration	15300	0.75		156.978
				total HL BTU/DEGREE/HR	849.9876
				BTU/Day/SQ.FT./degree F	11.33317
				BTU/DD	20399.7
This home represents a typical home built in New Mexico 20- 30 years ago It has 2x4 walls w/ R=11 insulation (the roof has 6" of insulation the windows are single glazed and the building is not as air tight. This home will require 2 times the energy needed to heat or cool then our base case efficient home. This would show twice the energy and water saved over Air conditioning or swamp cooler. The radiators needed for cooling would also be twice what would be needed for the efficient home.					

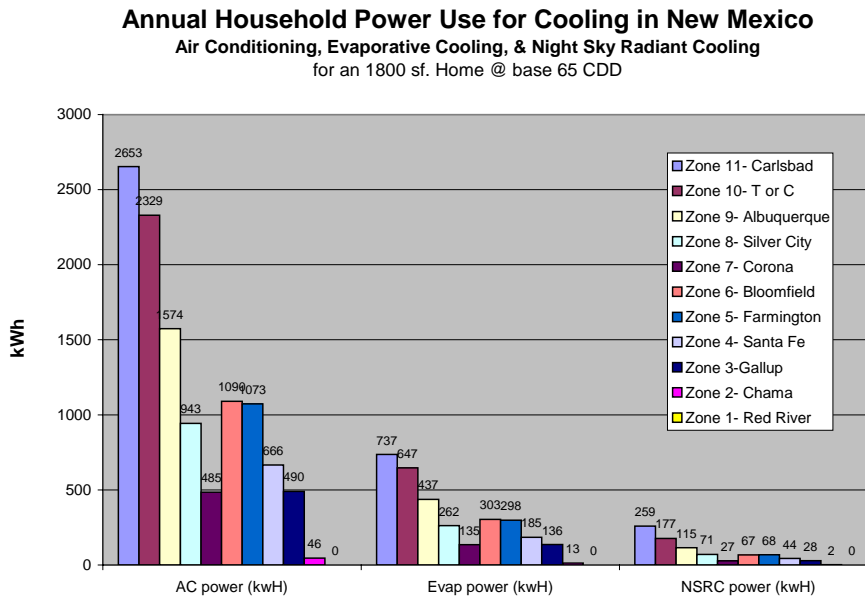
The coolest Climate zones in New Mexico may not need this extensive system for cooling. Just open windows and nighttime ventilation is enough for the comfort needed. In climate such as Albuquerque and warmer, NSRC can have substantial savings.

Our goal was not to design the ultimate radiant cooling system but to quantify the cooling potentials in the state and tie that to potential savings in water and energy by substituting NSRC in place of evaporative coolers and air conditioners.

To do this we spent 2 summers actually testing radiators in Tesuque, NM. We were able to test 10 different collectors of various materials and properties for 2 weeks each to document the actual BTU's being radiated. We averaged each unit and then all to come up with an overall average "U" Value of 1.66. See the section on radiator/collector testing. We have supplied, a summary sheet for each radiator tested. This tested data was correlated to actual weather data collected on site, both at 5-minute intervals. From this we were able to find correlations between the weather data, the radiator and what we call the white plate potential. We were then able to substitute the weather data from the 11 various climate zones in New Mexico to project savings.

This final report is broken up into various sections dealing with the phases we went through to reach our final conclusions and tabulations. Please see the table of context for explanations of the various sections for a more in-depth explanation of our process and results.

The cost of energy is not that hard to document. With each KW saved, it corresponds to a direct dollar savings to the homeowner. These savings in KW's also relate in the water savings used at the power plant, which range from .67 gallons per KW for a new coal fired plants to .33 gallons for a gas fired plant. PNM uses a published number of .74/gal/KW for an average for its production and this is the number we have used. The spreadsheet we developed allows this number to be changed. These savings in KW's also directly relate to NOx, So2, Co2 and other pollutants associated with power production. It is also well documented that the cost of energy has risen on average about 16% per year over the past 4 years and is expected to continue to rise. As the cost of fuel rises the economics of these alternative systems become more cost effective. The efficient 1800 SQ FT home, power savings can range from 25% in Albuquerque to 89% in Carlsbad.

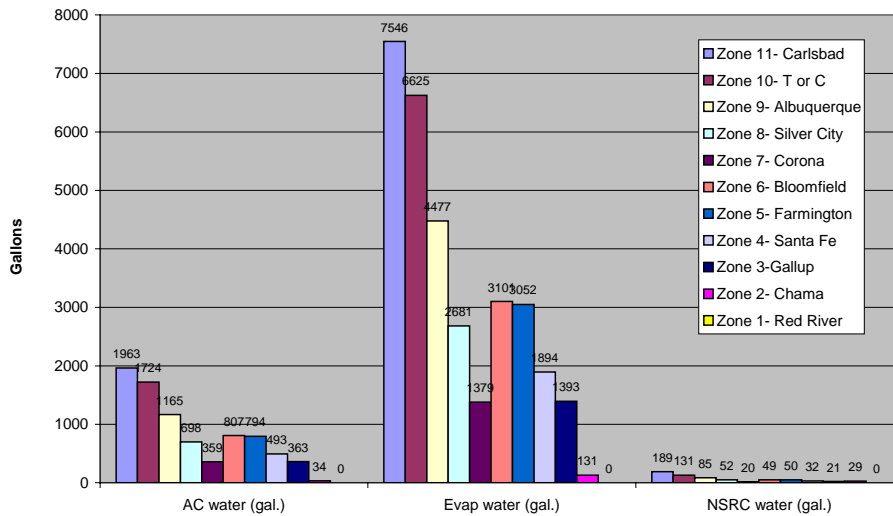


The cost of water is a question we were not able to quantify reasonably. Although we are able to quantify the water savings in gallons, the actual cost of water in dollar amounts is well beyond the scope of our grant. We will try, in various ways, to show the amount of water we can save with NSRC and what that means to the average homeowner and statewide usage.

We have found many municipal water utilities and private subdivision water associations bill in various ways. First there is a flat fee for connection, sometimes these are shared w/ trash/ recycle collection. Then a cost of \$1.86/1000 gallons used and up to \$15/ per 1000 gallons. These rates

change with amount of water used, tap size and whether the use is residential, commercial, industrial or agricultural. We have heard of water rights selling for \$20,000 to \$40,000 per acre-foot of water rights. Amortize this over 20 years, the cost is about \$6.14/1000. The extreme is buying water at the local convinces store. This rate is as high as \$4.50 per gallon if bought in 10 oz. bottles or \$4500 /1000 gal. And people are paying this for water. There are also political and environmental costs to water, which we again do not quantify. Water is a major factor in the future growth of the Southwest. Water cannot be created. With this in mind, any substantial savings is very important to the economic growth of our state. We have utilized the PNM average of .74 gal/KW water usage at the power plant to quantify the water usage for power production. The efficient 1800 SQ. FT. home shows savings in water over air conditioning strictly based on water at the power plant NSRC saves 96% in Carlsbad and 73% in Albuquerque. Evaporative cooling will use 40 times the water and air conditioners will use 10 times the water that NSRC would use

**Annual Household Water Use for Cooling in New Mexico**  
 Air Conditioning, Evaporative Cooling, & Night Sky Radiant Cooling  
 for an 1800 sf. Home @ base 65 CDD



in Carlsbad. In Albuquerque, those numbers are 53 times and 14 times.

For quantitative and comparative analysis, in this report, we have designed an efficient 1800 Sq. Ft. home with 400 and 600 SQ. FT of radiator on the roof. In Albuquerque we saved 4,477 gallons of water during an average season. In Carlsbad we saved 7500 Gallons of water. In many sub-divisions in New Mexico, water usage is restricted to ¼ acre-foot of water per year or 81,463 gallons per year per home. This equates to 5.5% and 9.2% savings annually respectfully. If the house was 3200 Sq. Ft. these savings could rise to 11% and 18.4% savings respectfully of that ¼ acre foot. Again if the house is not as well designed as our test unit the savings could grow from there. If 10% of all water used in New Mexico is used in municipalities, then we are affecting a substantial savings potential. These savings relate to providing cooling only when needed to temper a residence. Cooling for large commercial buildings that utilize cooling for most of the year and year-round process industrial cooling can save even greater amounts if utilized for these longer periods of time and when the outside temperatures are cooler.

All of our numbers were generated from actual field-testing over time and data published from other sources. In all cases we noted how or where we found the number we utilized. In as many cases we utilized a range of numbers and our data manipulating spreadsheets were written so we could adjust our input numbers. See the explanation of inputs with the description of the spreadsheet. The data presented in our summaries were carefully chosen to best represent regional averages. The test house we designed was 20% more energy efficient then the average New Mexico Code standard as per the Model Energy Code and 25% better then the base case

home in Energy-10. We are not a certified testing laboratory. Our numbers should only then be used as a guide and not as certified testing results like those posted by the Florida Solar Energy Center. In as many cases as we could we checked our data from running various checks and comparisons to known data. We do feel all our numbers; results, and conclusions are true and accurate and reflect the true potentials of each climate zone.

As in most research projects you observe and learn things you were not always looking for and we did as well. A big surprise to us was the measured effects of tilting our radiator off of the horizontal when averaged over longer periods of time (weekly averages). We drop in efficiency only 15% is we raise the collector angle from 0 to 45 degrees. Setting the radiators at 90 degrees to the horizon (e.g. on a vertical wall) resulted in a measured drop in cooling rate of only 25%. This latter result is about half of what we expected based on the “view factor” formula that governs this situation. This is an important finding since it reminds us that long term weather effects are not governed by a single formula, and it gives these systems more flexibility in design and operation since tilting the radiators does not disable their cooling function

Multiplier	Tilt above horizon
1	0
0.865	45
0.76	90

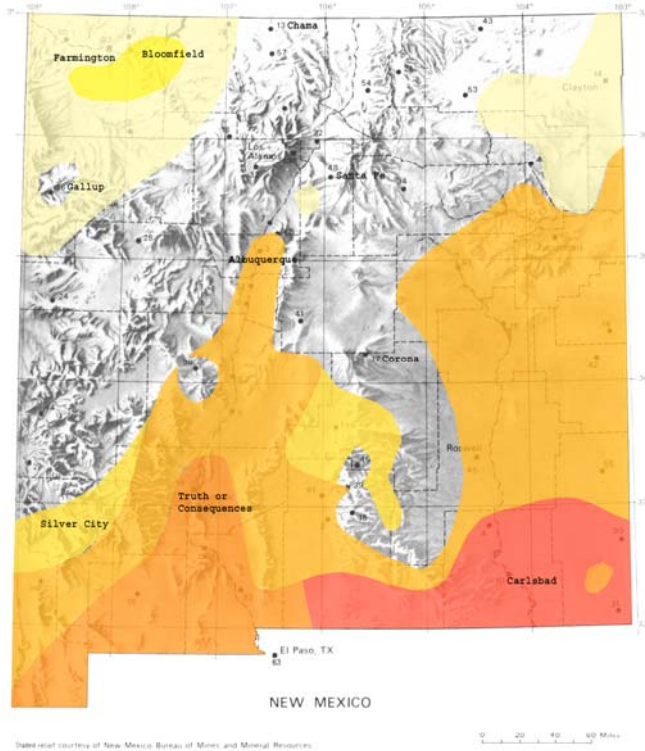
We have found that the economics of these radiant cooling systems improve greatly if they are also utilized for heating during the daytime. These radiators can absorb 3 times more BTU's then it can radiate in the same amount of time at night making them more effective as heaters than coolers. This heat could be utilized all year long for domestic hot water, pool or hot tub heating or subsidize space heating in the cooler months. This heat should not be ignored but integrated in the system design and economic scenarios. This concept has been well documented by Steve Baer of Zomeworks and others in this field. The “Dawn” (trademark) system we have tested does this. In the day time heat is extracted for hot water or space heating during winter. This works well in the swing months and mild climates, but will not work during severe winter weather. In the summer evenings the system is used for cooling. At today's cost of energy, these combined systems should pay for themselves in 5-8 years of use where just a cooling system could take up to 20 years to pay back.

**Conclusions:**

1. NSRC is an effective way to cool a well constructed home. We have shown through our testing and correlations, the NSRC works very effectively in the high desert climates in New Mexico. The hotter the climate the more need for cooling and the more NSRC can save. We have also shown that it makes sense to start with an energy conserving home. A poorly insulated and constructed home would need many more collectors to cool the structure and energy conservation strategies are a more effective investment.
2. NSRC can save substantial amounts of water and energy over air conditioning and evaporative cooling. See the summary sheets of each climatic zone. We can achieve as much cooling with NSRC as a swamp cooler or air conditioner for a fraction of the water and power usage. The hotter the climate, the more the need for cooling and the radiator area should increase from 22% to 33% of the floor area coming from Albuquerque to Carlsbad. The radiant cooling calculator can help optimize the area of radiator needed for a specific climate zone or you can interpolate our charts between 400 and 600 Sq Ft.
3. NSRC, swamp cooling or air conditioners is not needed for the colder climate zones of Red River, Chama, Gallup, Santa Fe, and Corona. In a well designed home such as we have proposed, the need for cooling is so minimal that an active mechanical system such as the NSRC

system is probably overkill and not needed for these sections of the state. In these zones the evening temperatures are low enough that nighttime ventilation through open windows should be enough. In these climates we suggest the collectors be glazed and set at a steep angle and maximized for winter heating. Large commercial buildings that need cooling year round are the exception. Following the guidelines as we have, with some interior thermal mass, these climate zones can easily draw on evening cool temperatures to night cool the building sufficiently.

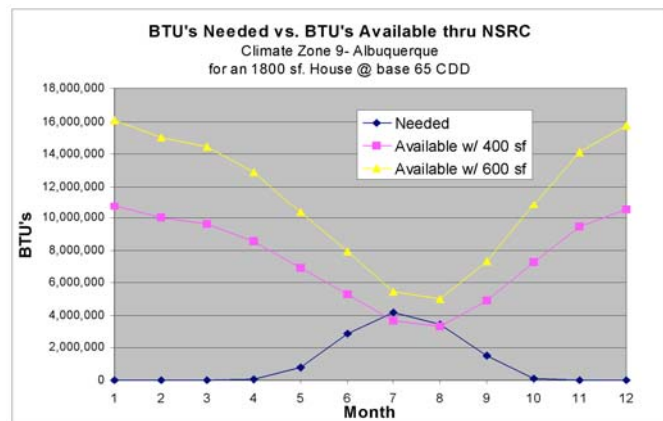
In zones Albuquerque and warmer, the evening air is not cold enough for long enough to be effective for simple night ventilation. These zones could benefit from NSRC. The hotter the zone, The better the savings potential. See map.



4. The economic payback will improve as the cost of water and Energy increase. As with any alternative energy system the payback is directly related to the cost of conventional energy and water. The higher the cost of fuel, the faster the payback. We have seen the cost of propane increase 16% on average each year for the past 4 years.

5. Design strategies that utilize these radiators during the day for hot water heating will improve the economic payback. As mentioned before, heating is a much greater need than cooling even in the hottest regions of New Mexico. These radiators, as designed, are used for heating low temperature hot water. The heating capacity is 3 times the cooling capacity in BTU's/hour. Given these facts and the concept of designing a system as an add on to an existing radiant heating system allows for the dual usage of both heating and cooling. Based on experience with solar hot water systems, the combination payback rate makes these systems very practical and cost effective. The tilt test data shows us that a 45 degree angle for these radiators help optimize these units for winter heating with only a small penalty in cooling performance. The integration behind sloped metal roofing also can be done with little effect on performance in cooling. The "Dawn" system we have tested proves this.

6. System integration with existing radiant floor systems are simple to construct and cost effective. As we have mentioned above there are advantages to this combination. As the existing heating system already includes most of the operating parts, the additional needs for cooling are minimal. The heating system already has the distribution pump and coils in the floor, the thermal mass of the slab, the control thermostats and allocated space in the mechanical area. The addition of the unglazed collector/radiators on the roof, one check valve, an expansion tank, a 60-watt pump and 2 ball valves and the piping between, would add the cooling part of the

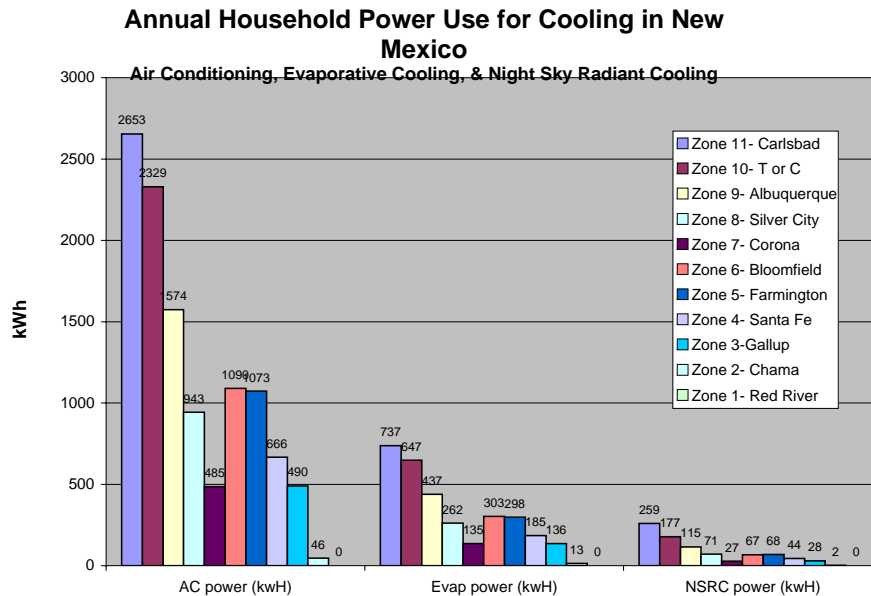


integrated system. This addition will not add much more to the cost of the total heating/cooling system.

7. NSRC for commercial buildings or process cooling has great potential for use all year long, and can provide the best payback. As shown on the yearly cooling available vs. needed charts for year round cooling the effectiveness of these radiators increase as the outdoor ambient temperature drops. Convection and conduction add to the total heat loss from the radiators. Skies may also be clearer in winter possibly adding to the radiant effect as well. Many commercial buildings utilize cooling systems all year long as internal heat gains are more than the building skin loses. Some manufacturing processes also utilize cooling on a yearly basis. Radiant cooling utilized for both commercial and manufacturing processes can add to the total potential savings of water and power in the state of New Mexico.

8. Air conditioner and swamp coolers utilize fans to move the energy through a home. Evaporative coolers typically utilize all outdoor air brought in and conditioned, while some AC systems bring in a percentage of outdoor air. NSRC utilizes a pump that is much more efficient in moving thermal energy and does not require outside air intake. This minimizes the dust, pollens and pollutants brought into a home through fans.

9. As more and more New Mexicans look to Solar PV for their electrical source of power, each watt of power needed is directly related to the size and cost of the power system. Cooling loads on an electrical system will increase the amount of power needed. This relates to the extra expense in panels and batteries which could be substantial. NSRC uses 90-95 % less power than air conditioners and 65-80 % power than evaporative coolers to provide the same amount of cooling BTU's. Most off grid homes utilize their PV to also pump the water from their well adding again to power and water usage. In these situations NSRC would be the rational choice for cooling.



Power Usage for each Climate Zone.

As one continues through this report, the information and process we followed to reach our conclusions will be explained more in depth.

Because of its clear skies, high altitudes, and cool weather, New Mexico has some of the best potential in the country for NSRC. It is just another renewable clean energy source New Mexico is blessed with and should be harvested. New Mexico should look at NSRC as Green Economic Development. Further study and testing of NSRC systems should be encouraged in New Mexico. Research and developing of quality equipment and creative solutions and installations will help lead to another sustainable industry for our state.

# 2

## History of Night Sky Radiant Cooling

Night Sky Radiant Cooling is not a new technology. This phenomenon has been utilized by many indigenous cultures throughout the world. The Iranians used ice making walls that incorporated Night Sky Radiant Cooling and adobe storage buildings for ice over 1,000 years ago. In the 17<sup>th</sup> Century Count von Rumford, of the fireplace fame, described and tried to harvest this energy as well.

New Mexico and Arizona scientists and free thinkers of the 20<sup>th</sup> century have built and developed many creative systems and have documented successful results. As power and water become more scarce and costly, we will see many more installations and equipment developed for this technology and integrated with solar heating.

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## A Brief History of Night Sky Radiant Cooling

Because of the relatively constant temperature of the surface of the earth, the amount of energy lost in the form of heat from the surface of the earth at night must be comparable to the amount of energy gained by the sun. In his 1978 "Sunpapers" Benjamin T. "Buck" Rogers (a New Mexico solar innovator and Los Alamos engineer) points out that "the Earth radiates to the outer space (during) both day and night,' but the heat loss from the earth at the night is much more palpable. Radiation is actually the only mechanism by which the earth can lose heat, thus keeping the planet in thermal equilibrium. Jeffery Cook explains in his book *Passive Cooling*:

Considering that the sun pours its energy on the earth at a rate of about  $1.5 \times 10^{19}$  kJ per day, and that the average surface temperature is approximately constant over a number of years, it is obvious that a similar amount of energy per day must escape. Some of this abundant energy is, of course, reflected back into space as visible light, and a small fraction is converted to chemical energy by photosynthesis. But the largest part heats up the earth's surface, atmosphere, and oceans, and is ultimately emitted into space in the form of thermal infrared radiation.



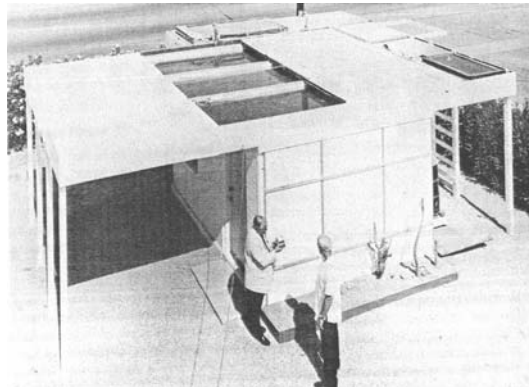
Above and Left: Iranian Yakhchals with Ice ditch wall

Night sky radiant cooling has in modern times all but been forgotten due to widespread use of modern mechanical cooling systems and refrigerants. However, this type of cooling has roots in many ancient civilizations across the globe. By constructing large ditches filled with water and surrounded by tall mud walls to the south east and west that blocked the sun when it was low on the horizon, the ancient Iranians used night sky radiation to create ice when ambient temperatures were well above freezing. This ice was then moved to a large domed structure called a Yakhchal where the ice was stored through summer months. Geoff McDonell describes a different type of radiant cooling in Turkey where cold stream water was run through channels in floors and walls to cool their palaces during the warm summers. Buck Rogers cites yet another example of ice making in the East Indies. He describes archeological evidence that radiant cooling was used in England to condense and collect water in what he called a 'dew pond'.

Jeffery Cook maintains that radiant cooling was observed and understood centuries ago by diplomat and physicist Count von Rumford. Von Rumford concluded that "frigorific rays" that arrive continually on the surface of the earth from "the heavens" to cool the planet. He also wisely noted that "the inhabitants of certain hot countries who sleep at night on the tops of their houses in order to be more cool and comfortable, do wisely in choosing that situation to pass their hours of rest." (p138)

Nearly 200 years later Count von Rumford's insightful conclusions were confirmed by the testing of a new combined radiant cooling and heating technology developed by Harold R. Hay and John I. Yellott. The two developed a system that consisted of bags full of water positioned on the roof of a building and covered with a moveable layer of insulation. Hay, a chemist and building material specialist, conceived of the idea of moveable insulation when he observed the discomfort of extreme heat and cold endured by the poor of India when their native thatch roofs were replaced by metal roofs- and their natural layer of insulation was eliminated. Hay's first experiment involved a water-filled styrofoam box with a movable lid. In the summer sun the lid

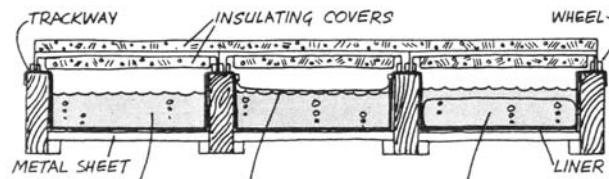
covered the water to keep it cool, and during the winter the lid removed allowed the water to be heated by the rays of the sun. Hay's experiment evolved after a meeting with John Yellot- an engineer and solar energy advocate. Yellot immediately realized the potentials of Hay's simple experiment as a passive heating and cooling system for buildings, and the two collaborated to build a 120 square ft test facility. The prototype was the precursor to the well-known Skytherm Southwest House in Atascadero, CA. In The Solar Home Book Bruce Anderson discusses the Atascadero House:



Yellot and Hays' Skytherm Test building. **Source:** Bruce Anderson, *The Solar Home Book*

In 1967, they built a one-room, single-story building with an adjoining carport. On the roof of this tiny building was a series of ponds with a total area of 170 square feet and two movable insulating covers above them... In the final version, the water was contained in plastic bags supported on corrugated steel decking lined with black polyethylene sheets... During the summer, they removed the covers at night and replaced them by day, just as with the insulated box. They reversed this cycle during the winter, with the roof ponds exposed on sunny days and covered at night or on cloudy days.

With *no* auxiliary sources of heating or cooling, the building remained comfortable throughout that year... While outside air temperatures ranged from 30 degrees F to 115 degrees F in a normal year of Phoenix weather, the roof ponds kept room temperatures between 66 degrees F and 82 degrees Fahrenheit.

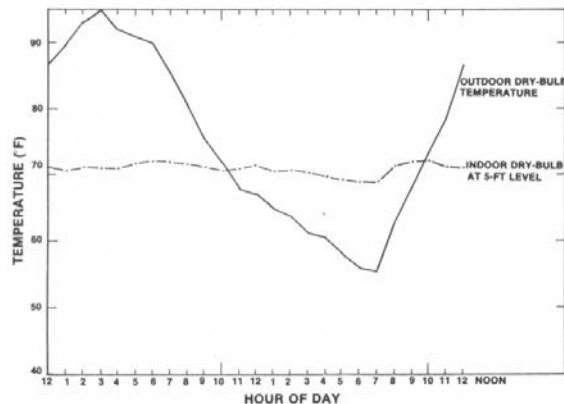
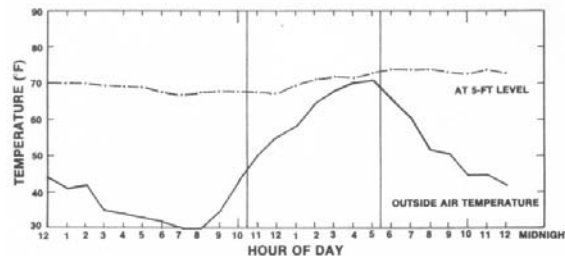


Water containment study cross section of roof ponds at Phoenix test building.

**Source:** Bruce Anderson, *The Solar Home Book*

Hay and Yellot's new system used evaporative as well as night sky radiant cooling at night when the insulating panels were removed. The cooled water on the roof kept the ceiling and room cool during the extreme heat of the Phoenix summers.

Six years later in 1973, in collaboration with architects Ken Haggard and John Edmisten, Hay built a full sized house in Atascadero, California based on the principals tested in the Phoenix prototype. The house had a heated floor area of about 1100 Sq. Ft. and an approximately equal amount of roof pond area. Water contained in large waterbed-like plastic bags were placed on the roof. The radiant temperature gain and loss of the ponds was regulated by an elaborate construction of moveable insulating panels controlled by interior thermostats. The system also had no need for pumps, compressors, piping, or ducts, and could be easily operated by the average homeowner. According to William Shurcliff in his analysis of the performance of the building, the tenants were extremely pleased with the cooling system, which they rated as "far superior" to conventional air conditioning. "Lack of blowing



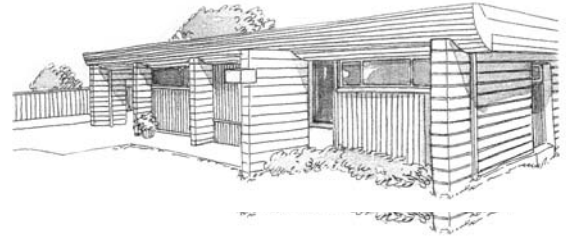
Heating and cooling temperature profiles, Atascadero, CA  
**Source:** Edward Mazria, *Passive Solar Energy Book*

air and noise, and the uniformity of temperatures throughout the house made it ‘one of the most comfortable houses’ they’d ever experienced.” (Anderson p136) In fact, no auxiliary heating or cooling was used. Edward Mazria points out that the roof pond system in the Atascadero house kept indoor temperatures between 68 and 72 degrees while outdoor ambient temperature fluctuated between 32 and 68.

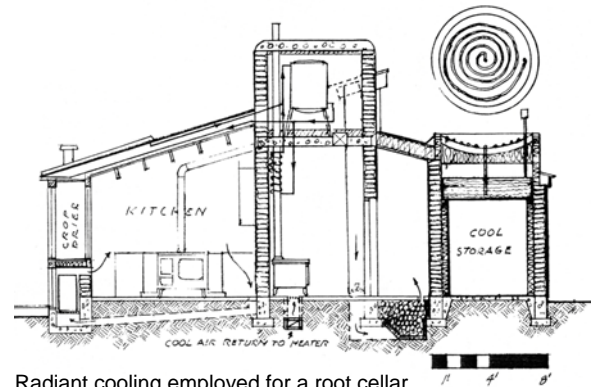
Another example that John Yellot sites as a successful example of the roof pond experiment is a residence that was built and tested in Las Cruces, New Mexico. The DOE funded project was similar to the Atascadero house with one important difference. The water-filled bags were supported on a ceiling of concrete rather than corrugated steel panels. The Las Cruces house purportedly functioned quite well and maintained comfortable indoor conditions throughout the entire year (Cook, p94) despite the fact that the response of the building was much slower because of the thermal resistance inherent in the concrete ceilings of the structure.

In 1975 Peter Van Dresser was experimenting with experimental technology of roof ponds as well. In his publication *Homegrown Sundwellings*, Van Dresser discusses an auxiliary cool storage chamber or root cellar for keeping food cool by means of this “experimental feature”. He describes a space “kept cool by massive walls, good insulation and a night sky radiating panel which maintains a reservoir of chilled brine to hold temperatures down within the chamber.” This variant on the roof pond pumps brine (salt water) during the night up to the skyward facing radiator. In the morning, the near freezing brine is drained down to a metal holding tank that forms the ceiling of the cool storage room.

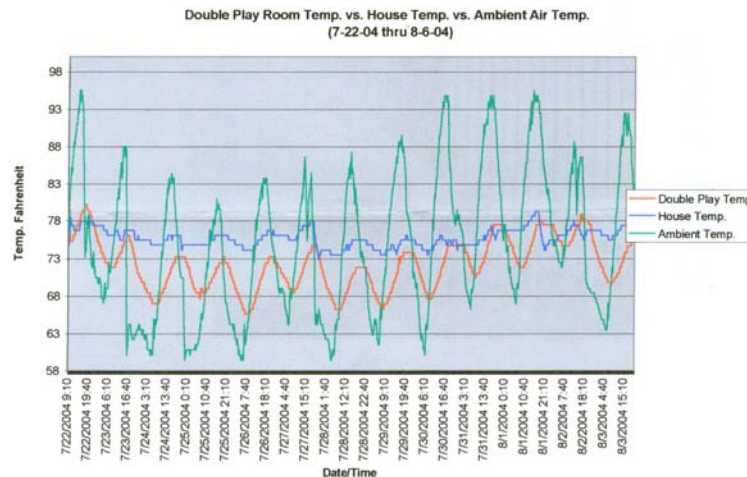
Steve Baer of Zomeworks, inspired by Harold Hay’s Skytherm Designs, has been working with the principal of night sky radiation for over three decades and has developed such technologies as the Cool Cell as well as the Double Play Solar Heating and Cooling System. Both of which function dually as a passive solar heating and radiant cooling systems for buildings (see performance chart below). Baer has also been working with pool heaters as radiators for cooling and regards using pool heaters “an ideal way to interest the public” in radiant cooling. In



An Exterior view of the Atascadero House  
**Source:** Bruce Anderson, *The Solar Home Book*



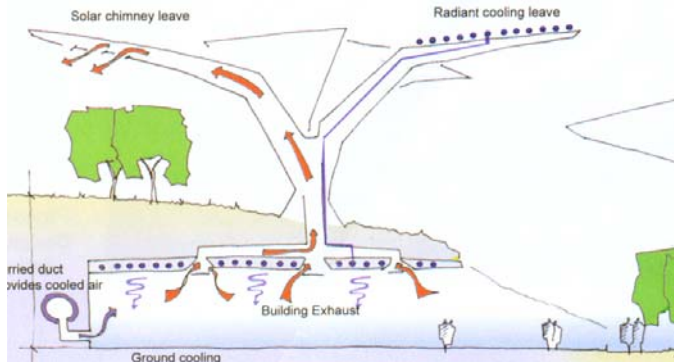
Radiant cooling employed for a root cellar  
**Source:** Peter Van Dresser, *Homegrown Sundwellings*



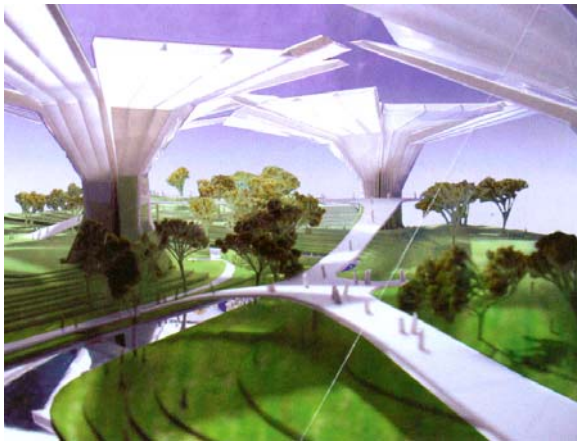
Thermal performance of Baer’s Double Play System  
**Source:** Zomeworks, *Double Play Progress Report*

2002 Baer held a conference in Albuquerque discussing the promise of heating and cooling using unglazed collectors and related systems.

Dick Bourne of the Davis Energy Group, Inc. has also done a fair amount of research into the possibilities of radiant cooling as integrated into a hydronic floor system. Bourne's paper, "Indirect Natural Cooling Using Building Slabs," discusses the findings from a test done on a 70,000 square foot building in Vacaville, California. The system uses water sprayed on the roof that is cooled by radiation and evaporation then pumped through the concrete slab to cool the building. Bourne predicts a quick two-year payback for projects of 30,000 square feet or



larger. Various technical papers experimental data addressing the possibilities of night sky radiant cooling and have surfaced from a team at the National Renewable Energy Labs headed by Jay Burch, Jim Salasovich, Craig Christensen, and Jeff Thornton of Thermal Energy Simulation Specialists, Inc. One of the team's simulations concluded that a multi-use unglazed collector system in Albuquerque could supply up to 92% of the total heating, cooling and domestic hot water loads.



A design incorporating radiant cooling.  
Source: Fabric Architecture

Presently, in Germany, a company called Karo Systems is manufacturing an architecturally integratable radiant ceiling panel. The panels are made of a mesh of thin polypropylene tubing through which water flows. The panels can be installed into ceilings, walls, and floors making the buildings thermally capable of storing and exchanging heat. Images from another German firm, Behnisch, Behnisch & Partner Inc., show an interesting use of radiant cooling for a Las Vegas theme park. The firm proposes huge tree like structures that create an internal downdraft flow of cool air while providing shade for the park inhabitants. The huge structures also produce electricity through the use of photovoltaics and wind turbines.

# 3

## Explanation of Night Sky Radiant Cooling

This section explains simply how the physical process of NSRC works. The diagram shows graphically how this process works and the formulas we used to project our savings.

Estimating NSRC potential from temperature records explains the “White Plate Temperature” and how we correlated this from the dew point and ambient temperatures. These are the major numbers utilized in these calculations.

The Radiator “U” Value is explained as well as the “Tilt Effect” and the wind effect and how to integrate them into the final results.

The next set of graphs shows the full year potential for cooling for each zone. We have included the potentials of both 200, 400, and 600 SQ. FT radiator panels where applicable. This would be of interest for large commercial buildings or low temperature process cooling.

**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

Mark Chalom Architect  
Bristol Stickney Consulting



## What is Night Sky Radiant Cooling?

In the same way that thermal radiation travels from the sun to the surface of the earth, across the vacuum of space, the heat from the earth also radiates back into space. Night sky radiant cooling is a natural process that helps the earth maintain thermal equilibrium. The effect of this radiant heat leaving the surface of the earth can easily be seen on some mornings after a clear night. A layer of frost will form on rooftops and on automobiles even though the outdoor air temperature is well above freezing. This frozen condensation is proof that the rooftops were losing heat by radiation to the night sky faster than the surrounding warmer air could replace that heat by natural convection. The roof surfaces become so cold that moisture condenses out of the air, freezing solid. The radiant cooling occurs at a slower rate on partly cloudy nights, but can still provide reliable cooling. Only when the night sky is completely cloudy, does the radiant cooling effect stop completely. In New Mexico, clear skies and partly clear skies are available most of the time, so radiant night sky cooling can be counted upon most of the time.

The same natural mechanism that causes ice to form on car roofs can be used to cool our buildings. By capturing this radiant energy at night and storing it in the thermal mass of a building, the need for evaporative cooling and air conditioning can be seriously reduced or eliminated. The same equipment used for daytime active solar heating, a typical heating method in the New Mexico, can be employed at night for “collecting” and storing the “coolth” obtained by NSRC by implementing relatively simple modifications. The heat storage mass of hydronic radiant heated floors can be used not only for heating in winter, but can be used for “cool storage” in summer.

While the glazed solar thermal panels that are typically used for solar heating can be used to cool as well, accompanying these collectors with an inexpensive unglazed pool collector mounted horizontally on the roof of a building drastically increases the cooling potential of the system. This paper compares the tested efficiency of a number of different unglazed pool collectors or radiators currently on the market as well as four different types of radiant cooling systems suitable for new construction and retrofitted homes.

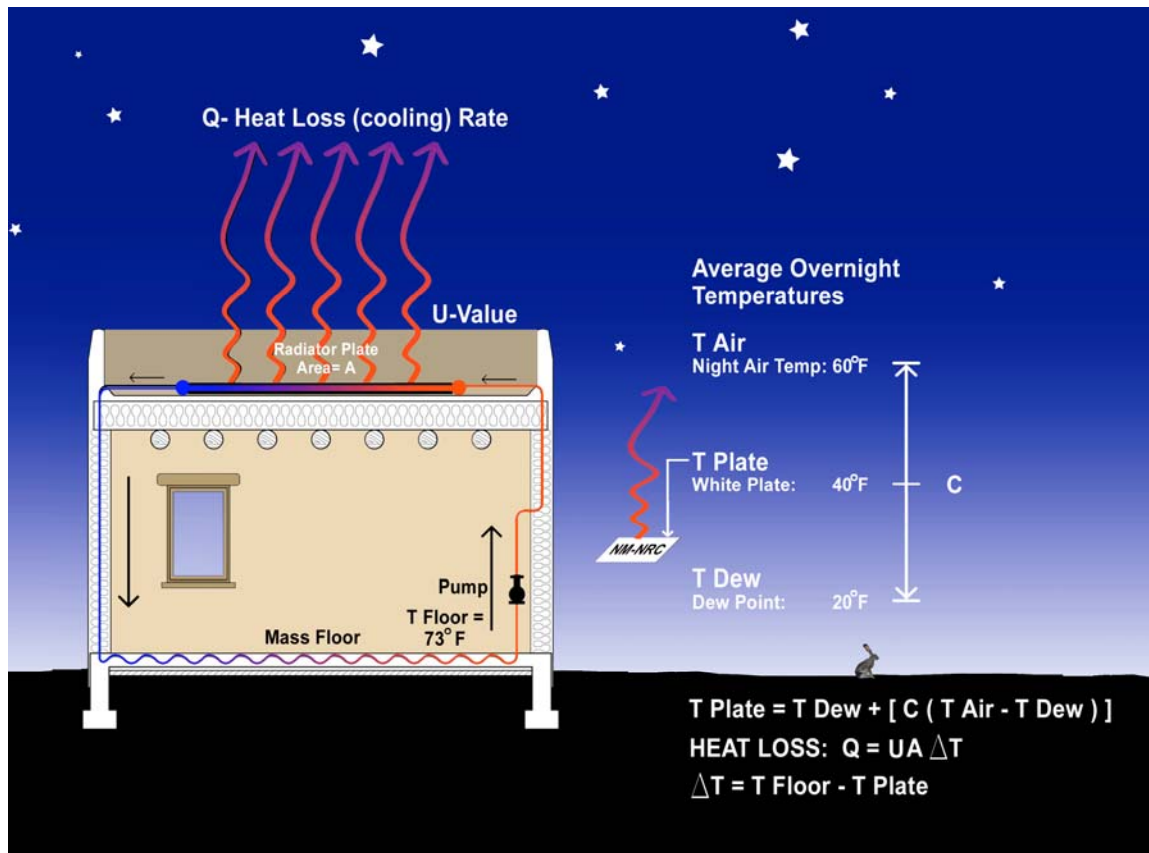


Figure 1

## **Estimating Night Sky Cooling Potential from Temperature Records.**

### **Overview**

Night Sky Cooling is similar to Solar Energy in that it is governed by an assortment of weather variables. The indoor and outdoor temperatures, cloudiness, humidity, altitude, wind, and rain all play a part in regulating the radiant cooling performance. The complex relationship between all these variables has been thoroughly analyzed and documented over the years to the point where mathematical models and computer simulations can be used to study the phenomenon with a high level of accuracy. (e.g. Theoretical Evaluation of the NightCool Nocturnal Radiation Cooling Concept, by Danny Parker, FSEC web site)

Our challenge has been to take what we know about radiant cooling, and begin to make it more accessible to home builders and mechanical installers so that it can be put to use in the same way that Solar Collectors and Radiant Floor Heating is today. Towards that end, we have developed a means of evaluating the radiant cooling potential using existing average monthly weather data, without resorting to complex computer simulations. The purpose of this simplified method is to allow the end users to make a decision quickly, about the radiant cooling potential in their location by looking primarily at average temperature records and using only the simplest mathematics.

In Figure 1 on the proceeding page, we show a graphical representation the principals of Night Sky Radiant Cooling which illustrates the relationships between monthly average overnight temperatures and the Cooling Rate available from night sky radiation.

### **Metal Plate Temperature (White Plate)**

A thin metal plate exposed to the clear night sky will typically drop in temperature below that of the surrounding air. This is direct evidence of the radiant cooling effect, since the warmer air cannot be cooling the metal. The plate becomes a “sensor” that reacts to the multiple weather variables surrounding it, like wind and cloudiness, producing a cold temperature that represents the coldest useful temperature available at that moment. Using this sensor, instead of trying to correlate all of the individual weather variables, simplifies the quest for the Night Sky Radiant Cooling Rate. (Steve Baer of the Zomeworks Corporation deserves honorable mention for pointing this out.)

In Figure 1, “T Plate” denotes the temperature of the metal plate.

### **Dew Point & Air Temperature Correlation**

When measured at night, “T Plate” will almost always be found between the Dew Point temperature and the night Air Temperature. During the testing phase of this project, we measured these temperatures every five minutes with data loggers and produced nightly averages time, and time again. The goal was to find a long-term average correlation for our climate, shown as “C” in Figure 1. In Figure 1, “C” is shown at the midpoint between the Dew Point and the Air. This is not a bad assumption, since our test results show an average of 0.441 when all our bench test data is combined, and an average of 0.488 when all the field test data is included from the summer season of 2005. On very clear nights the value is lower and during unfavorable conditions, the value is higher. But it seems that on the average in New Mexico a value of ½ will yield reasonable results when used as a rule of thumb.

### **Source Temperature (Mass Core or Reservoir)**

Heat loss to the night sky is driven by the difference in temperature between the warm radiator and the cold sky. It is not a simple linear relationship, so increasing the radiator temperature will dramatically increase the heat loss to the sky. For purposes of comparison, we chose a radiator temperature that matched the typical performance of our field tests. In these tests, we monitored the heat loss from concrete floors that were cooled with liquid, pumped through tubing embedded in the floor. The “T Floor” temperature of 73 F, shown in Figure 1, corresponds to the typical conditions seen in our field tests. This type of cooling system can be engineered to operate at

higher or lower temperatures if needed. They can also be designed to use water tanks for heat/cool storage instead of, or in addition to mass floors.

**Radiator Performance Expressed as “U Value” (Heat loss from the radiator plate)**

There are a number of different types of panels readily available for use as night sky radiators. Most are manufactured by the solar heating industry, and intended to be used for the solar heating of liquid during the day. But, they can also be operated “in reverse” for cooling at night. They are available in plastic, metal and various liquid flow path configurations. Some work better than others when used for radiant cooling. Since there is no widely accepted testing and rating system for night sky cooling panels, we created methods of testing and comparing to suit the goals of this project. See Section 5 for more details about our testing methods.

The results of our radiator panel tests were reduced down to a single number for comparison. This number was intentionally derived to have the same units as “U value”, which is widely used in the building industry as a Heat Loss rating for common building materials. “U value” is commonly expressed in BTU’s per Hour per Square Foot per Degree Fahrenheit. The “U value” of our radiators uses the same units, and represents the number of BTU’s the radiator can emit to the Night Sky, per Square Foot of surface area, per Hour, per Degree (F) of temperature difference between the radiator surface and the White Plate. See section 5 for a list of Night Sky U Values for various radiator panels.

**Radiant Cooling - Hourly, Nightly, Monthly Average**

A Heat Loss Rate “Q” can be calculated using the formula shown in Figure 1 based on the average temperatures, the “U value” and the Area of the radiator also indicated on the Figure. This yields an Hourly value, which represents the average cooling to be expected with this radiator under these temperature conditions, in BTU’s per Hour. To obtain the total cooling to be delivered overnight, multiply by the number of hours the cooling pump will be run. A maximum of 10 hours per night is consistently available in this climate during the warm season. So, to estimate the maximum cooling delivered overnight, multiply by 10 Hours. Then to estimate the Monthly cooling total, multiply by the number of days that month (e.g. 31 days).

**Tilt Effect (View Factor)**

Tilting the radiator plate has a small mitigating effect on the cooling rate. This is because a tilted plate has a partial view of the ground as well as the sky. The ground is warmer than the sky, so the radiant cooling rate slows down. This effect can be calculated using the cosine of the tilt angle, and is known as the View Factor. To measure this effect in our climate, we set up white metal plates at 90, 45 and 0 degrees and measured the temperature differences between them over several months in several different locations. The results are shown in the following Table.



VIEW FACTOR MULTIPLIERS FOR DIFFERENT TILTS

	Horizontal	45 Degree	90 Degrees
Predicted	1	0.85	0.50
Measured	1	0.86	0.76

To adjust the Cooling Rate to account for a tilted radiator, multiply it’s “U value” by the value interpolated from this table.

**Wind Effect**

When the wind picks up, it causes heat to be transferred to the radiator plate faster by forced convection. A cold plate is therefore warmed by the wind, and its cooling performance drops. The “U values” listed in this report were calculated and averaged over time to include the wind,

rain and cloudiness that occurred over the test period. So, the wind and other intermittent weather effects for this climate are built into the results.

However, if a local climate is especially windy during the cooling season, and the average wind speed is constant and relentless for weeks or months, rather than intermittent. Then an additional wind adjustment can be made as suggested in the following table.

**WIND MULTIPLIERS FOR CONSTANT AVERAGE WIND SPEEDS**

Wind Speed MPH	0	5	10	15	20
Multiplier	1	0.87	0.74	0.62	0.49

To adjust the Cooling Rate to account for a constant wind, multiply "Q" by the value interpolated from this table.

# 4

## Cooling Alternatives For New Mexico

Evaporative coolers and air conditioners (the most common cooling devices in New Mexico) cool in different ways. The mechanics of these systems are explained. The various new efficient systems and directions this new equipment is going, will improve savings over the quantities we have suggested and used in this report. In cooler climate zones simple passive and night ventilation techniques are explained and encouraged.

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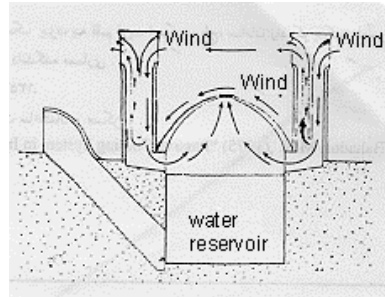


## Cooling Alternatives

Dating back to Ancient Egyptian civilizations, evaporative cooling is the oldest known method of cooling in arid desert climates. In fact, some 3000 years before the birth of Christ, buildings were designed with integral evaporative cooling mechanisms to keep perishable food cold. The buildings used towers open on one side oriented to the prevailing wind to suck air into the building. The temperature of the moving air drops as it passes over a large subterranean water reservoir before it blows into the space to cool it. (image "Windcatchers")



Ancient Iranian evaporative cooling techniques.  
**Source:** CAIS, *Wind Catchers*



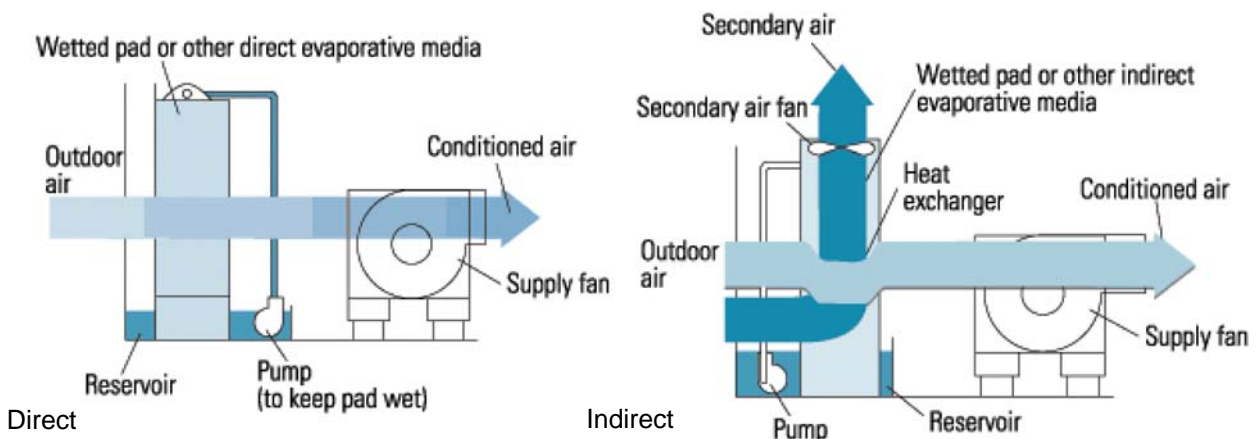
The evaporative cooler of today use the same ancient principals. When air blows through a wet medium- a tee-shirt, aspen fibers, or treated cellulose, fiberglass, or plastic- some of the water is transferred to the air and its dry bulb temperature is lowered. The cooling effect depends on the

temperature difference between dry and wet bulb temperatures, the pathway and velocity of the

air, and the quality and condition of the medium. (SWEEP, p1) Today evaporative cooling is a primary method of cooling in New Mexico and other similarly arid regions of the country because it provides an effective way to cool hot dry air. A modern example of the evaporative cooling tower can be found in Zion National Park Visitor's Center, a holistically designed energy efficient building. In fact, design of the structure was inspired by the canyons' of Zion's own natural cooling effect.

Tall, wet canyon walls and hanging gardens cause a natural cooling effect in the canyon...Architects incorporated similar tall elements in their design to give the building perspective within the canyon environment. These elements were integrated with the energy goals to create downdraft cool towers as the primary cooling system... Water is pumped onto a honeycomb media at the top of the tower. The evaporatively cooled air, which is denser than the ambient air, falls through the tower under its own weight where it then enters the building. No fans are required to cool the building.

There are multiple types of evaporative coolers. Direct evaporative coolers use a fan to pull outside air through a media that is kept completely wet. Water is pumped from a reservoir and is either sprayed or dripped on the media. The wetness of the media both filters and cools



Direct evaporative cooler, and Indirect evaporative cooler diagram:  
**Source:** SWEEP, *New Evaporative Cooling Systems*

the air as it moves through it. The resulting fresh, cool, humidified air is blown into a space. (SWEET, p2) Indirect evaporative coolers unlike direct evaporative coolers do not add humidity to the indoor air, instead they use an air-to-air heat exchanger to cool the air. One fan pulls inside air, fresh air, or a combination, through wetted passages, thus cooling the air that passes through the heat exchanger and leaves the building. The main fan simultaneously pulls outside air through the heat exchanger into the dwelling, this air is cooled down by the thermal contact with wetted passages in the heat exchanger.

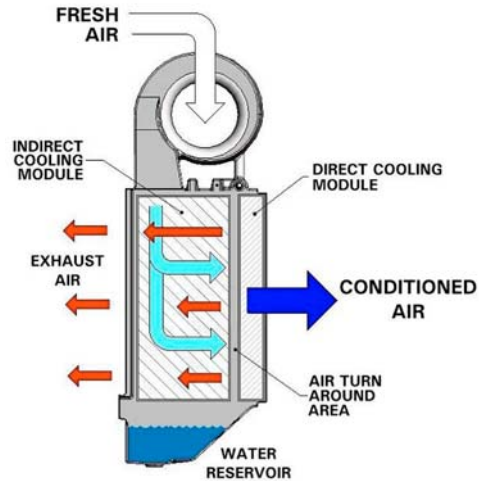
A third type of evaporative cooler is the indirect/ direct systems which, as the name suggests, uses both indirect and direct evaporative cooling techniques. The system uses a single blower that pulls in outside air and directs most of it through the dry side of a heat exchanger that uses thick media to efficiently indirectly cool the air stream without adding moisture. This partially cooled air then passes through a direct cooling module before being directed into the home. (SWEET, p12) Indirect, Direct systems can achieve comfort in a wider range of areas because they can lower air temperatures well below the wet bulb, and the cool air supplied to the space is much drier than that of direct units.

Determining the exact amount of water consumed by an evaporative cooler use in the homes of New Mexico is a difficult task. Factors such as: the type of evaporative cooler being used, outdoor air temperatures, the number of hours the device is turned on, and the size and character of the space being cooled, all come into play and create widely varying water consumption.

Evaporative coolers that use the “bleed off” method of self-cleaning are quite inefficient with their water use. In these units, water that is not evaporated has to be continuously diluted and drained away in order to flush the residue of air pollutants and scale in the water. The more efficient units use a batch process to deal with the impure wastewater. These units use a sloped sump allowing the heavy impurities and pollutants fall to the bottom where they be drained and easily flushed periodically, rather than requiring a constant bleed off of water. Some suggest that the waste water drained from the more efficient units can be directed to use in garden and lawn applications, while the slow trickle from the other method is less useful for such applications.

It takes approximately 1061 Btu to evaporate a pound of water. Therefore a gallon of water will theoretically produce 8700 BTUs of evaporative cooling. (SWEET, p.7) According to an analysis done by SWEET, net water use of an evaporative cooler averages 3491 gallons of water per year in the Southwest, with a range of 1692 in Cheyenne to 5884 in Phoenix. This number takes into account the water associated with making electricity which can range from .67 to .33 gal/kWh depending on the type of power plant producing the electricity.

PNM and the city of Albuquerque suggest typical water usage and operating costs for swamp cooling is 960 gallons per month, which translates to approximately 32 gallons per day in the cooling season. The Water Use and Conservation Bureau at the New Mexico Office of the State Engineer estimates that in an average weather year, a 1500 square-foot home in Santa Fe might use 2,980 to 4,470 gallons of water depending on the type of cooler, while a



Indirect/Direct evaporative cooler  
**Source:** SWEET, *New Evaporative Cooling Systems*

**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, SWEET, 2003; SWEET estimates

home of the same size in Las Cruces might use 12,457 to 18,686 gallons during the same year.

Another common cooling option is refrigeration or air conditioning. While this option uses no water to cool a space, it uses significantly more electricity, thus translating into water use at the power plant. The chart above describes the relative water and energy use of DX (Direct Exchange air conditioner) coolers versus evaporative coolers in various cities in the Southwest.

Although evaporative cooling and refrigeration are both effective ways to cool a space the water and energy requirements of the technology coupled with the growing populations and the limited water resources of the southwest suggest its growing impracticality. An effective natural cooling method that uses almost no water and only a small amount of electricity might quickly become a more attractive option.

We have found that the cost savings for an off the grid, photovoltaic powered home that uses Night Sky Radiation for cooling can be quite substantial. The largest electrical load is often the cooling load. An air conditioner consumes too much electricity, so evaporative cooling has been the cooling method of choice for off the grid homes. Given the fact that a pump is 10 times more energy efficient than a fan to move energy, the savings for a PV powered home can be translated directly to the cost of expensive PV panels. By using a pump to cool rather than a fan, we can reduce electrical needs, and therefore the number of photovoltaic panels needed for the function of a home. This point will become more important as more people choose solar energy for their electrical needs.

# 5

## Radiator Test Data

This section gives an explanation of the radiator testing phase, and discusses how we developed the White Plate Data and the testing of various radiators to find cooling “U” Values for the radiators. The testing lab (Skylab) was integrated with a complete on-site weather station where weather data as well as test data was collected at 5-minute intervals.

The results of the collector tests are summarized and a detailed summary sheet for each radiator is given compiling its specific test data, materials, working pressures and temperatures, as well as our observed pros and cons of each unit. Photos and diagrams of each unit help to distinguish between the various properties for each radiator.

All climate zones in New Mexico are susceptible to freeze. With propylene glycol, all collectors are freeze tolerant.

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## Description of radiator testing phase

The summers of 2005 and 2004 we set up to test various radiator types to understand the following:

- What materials make a good radiator.
- What characteristics of a radiator cross-section makes a good night time radiator.
- Develop average “U” Value for each radiator type.
- Document how much energy we can radiate from each type of radiator.
- Project BTU’s radiated per dollar invested.
- Understand the effect of wind, clouds and humidity on the radiative process
- Look for a correlation between White plate temps, ambient temps, dew points and other indicators to develop simple prediction methods to calculate potentials around the state.



The answers to these questions are in the radiator summary sheets following this narrative.

Our test facility, nicknamed Skylab was built in Tesuque, NM at an elevation of 6800 ft above sea level. We built 4, 4' x 10' insulated tabletops mounted on saw horses set horizontal facing the sky. No effort was utilized to block existing wind. Up to 2 radiators at a time were set up and tested for one or two weeks depending on how well we thought the data was representative of average conditions. At first we would test 2 of the same radiators at the same time to validate the data accuracy. Then we utilized 2 different radiators at the same time, essentially racing them against each other.

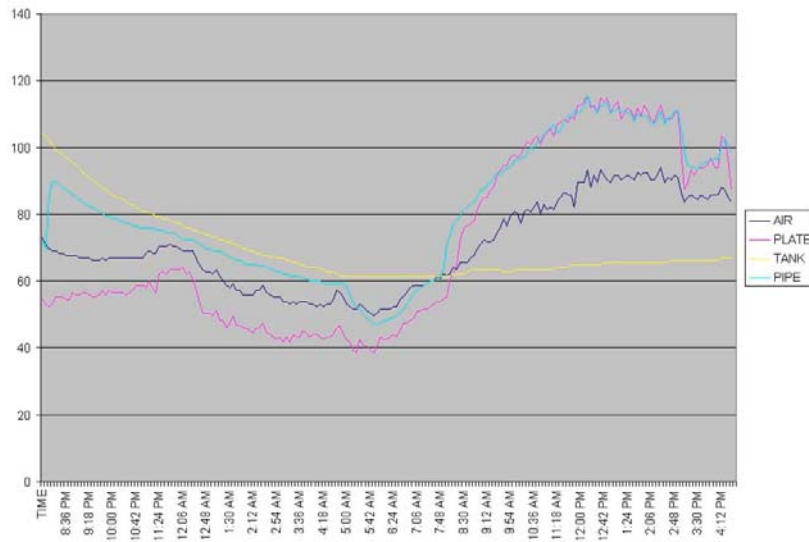
The set up consisted of the following elements:

- The radiating radiator on the table with inlet and outlets on opposite sides.
- An insulated 40 gallon water tank to serve as a measured thermal mass of water. This tank was insulated to minimize effect from ambient conditions.
- A 10 watt DC “Sid” water pump to circulate the fluids at a rate of ½ gal/ min set on a timer.
- A white metal plate facing horizontal giving us a constant radiative potential.



The monitoring system consisted of 2 Hobo data loggers set to take measurements at 5 minute intervals. Each Hobo logged 4 temperature points. The first probe monitored the white plate temperature, showing the radiant potential. The second measured the inlet temperature to the radiator, allowing us to monitor the water coming from the mass storage tank and temp going into the radiator. The third monitors the temperature coming out of the radiator – at night showing a drop in temperature, and thus, energy being radiated.

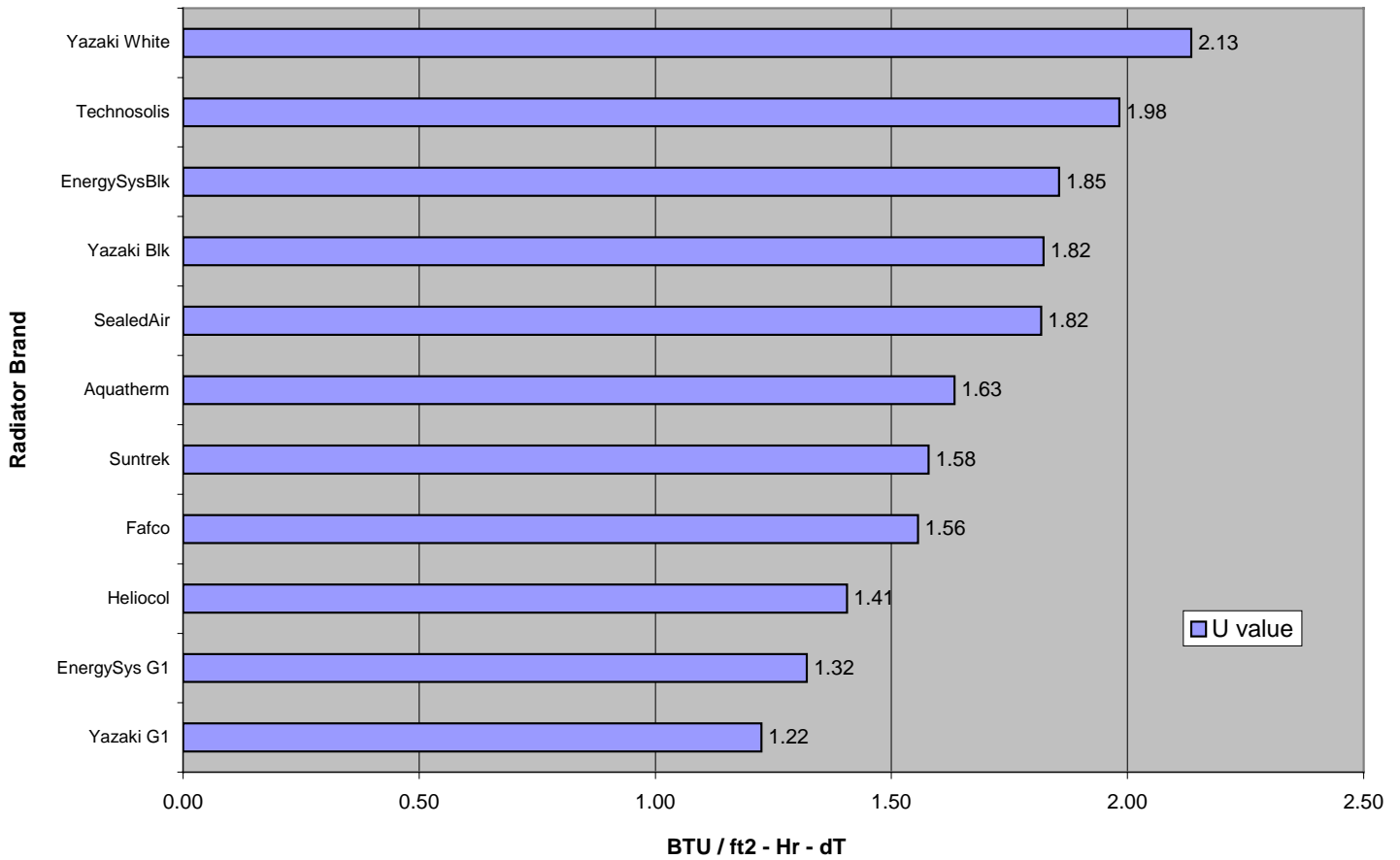




The fourth probe measures the temperature at the middle of the thermal mass tank. With a given amount of water at a set temperature, we can measure the temp drop over time and calculate the total number of BTU's radiated as a function of time. The timer turns on the pump in the late afternoon, picking up BTU's and raising the temp in the tank to about 85 degrees, this brings the mass into the range of temperatures we are trying to lower. Pumping during the night we documented the temp drop in 40 gallons of water and calculated the BTU's radiated for a 10-hour night.

This data was correlated to actual weather data taken on site with the "Davis Vantage Pro Weather Station." Data was taken at 5 minute interval so we could match up to the data from the Hobos. We monitored ambient temperature, Wet bulb, Dry Bulb, Relative humidity, Dew Point, Wind speed and direction and rain. Solar intensity was also recorded. This gave us a good picture of actual weather conditions on site and how the radiative effect was influenced by weather.

### Cooling 'U' value test results



### Collector Cooling Performance

Collector Number	Collector Name	Average Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-dT]	Collector Type	Area	Cair-dew
	Panel	U value			
4.2	Yazaki G1	1.22	Blk-SS-G1	20.30	0.310
2.1	EnergySys G1	1.32	Metal Blk FintubeG1	16.80	0.439
8	Heliocol	1.41	Blk Plastic	40.68	0.439
3	Fafco	1.56	Black Plastic	47.68	0.590
6	Suntrek	1.58	Black Plastic	40.84	0.590
1	Aquatherm	1.63	Black Plastic	31.33	0.471
5	SealedAir	1.82	Black Plastic	31.33	0.471
4.1	Yazaki Blk	1.82	Blk-SS	20.30	0.347
2	EnergySysBlk	1.85	Metal Blk Fintube	16.80	0.425
7	Technosolis	1.98	Blk Plastic	31.25	0.347
4	Yazaki White	2.13	Stainless Steel Pillow	20.30	0.425
	AVERAGE	1.667			0.441

## Collector Cooling Performance

Collector Number	Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-dT]	Average Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-dT]	Collector Type	Collector Name	Area	Cair-dew	Start Date
1.0	1.66		Black Plastic	AQUATHERM 94	31.33	0.616	6/12/2005
1.0	1.61	1.63	Black Plastic	AQUATHERM 94	31.33	0.471	6/19/2005
2.0	1.72		Metal Blk Fintube	EnergySysBlk 85	16.80	0.498	6/26/2005
2.0	1.95		Metal Blk Fintube	EnergySysBlk 85	16.80	0.650	7/2/2005
2.0	1.89	1.85	Metal Blk Fintube	EnergySysBlk 85	16.80	0.425	7/10/2005
2.1	1.42		Metal Blk FintubeG1	EnergySys080105	16.80	0.532	7/31/2005
2.1	1.44		Metal Blk FintubeG1	EnergySys	16.80	0.455	8/7/2005
2.1	1.24		Metal Blk FintubeG1	EnergySys	16.80	0.356	8/14/2005
2.1	1.27		Metal Blk FintubeG1	EnergySys	16.80	0.310	8/21/2005
2.1	1.31		Metal Blk FintubeG1	EnergySys	16.80	0.744	8/28/2005
2.1	1.24	1.32	Metal Blk FintubeG1	EnergySys	16.80	0.439	9/11/2005
3.0	1.52		Black Plastic	FAFCO 94	47.68	0.543	5/30/2005
3.0	1.59	1.56	Black Plastic	FAFCO 94	47.68	0.590	6/5/2005
4.0	2.06		Stainless Steel Pillow	Yazaki White 94	20.30	0.498	6/26/2005
4.0	2.16		Stainless Steel Pillow	Yazaki White 94	20.30	0.650	7/2/2005
4.0	2.18	2.13	Stainless Steel Pillow	Yazaki White 94	20.30	0.425	7/10/2005
4.1	1.96		Blk-SS	Yazaki071805	20.30	0.492	7/17/2005
4.1	1.69	1.82	Blk-SS	Yazaki072405	20.30	0.347	7/24/2005
4.2	1.44		Blk-SS-G1	Yazaki080105	20.30	0.532	7/31/2005
4.2	1.42		Blk-SS-G1	Yazaki	20.30	0.455	8/7/2005
4.2	1.00		Blk-SS-G1	Yazaki	20.30	0.356	8/14/2005
4.2	1.04	1.22	Blk-SS-G1	Yazaki	20.30	0.310	8/21/2005
5.0	1.75		Black Plastic	SEALED AIR 85	31.33	0.616	6/12/2005
5.0	1.88	1.82	Black Plastic	SEALED AIR 85	31.33	0.471	6/19/2005
6.0	1.54		Black Plastic	SUNTREK 85	40.84	0.543	5/30/2005
6.0	1.62	1.58	Black Plastic	SUNTREK 85	40.84	0.590	6/5/2005
7.0	2.11		Blk Plastic	Technosolis071805	31.25	0.492	7/17/2005
7.0	1.85	1.98	Blk Plastic	Technosolis072405	31.25	0.347	7/24/2005
8.0	1.28		Blk Plastic	Heliocol	40.68	0.744	8/28/2005
8.0	1.53	1.41	Blk Plastic	Heliocol	40.68	0.439	9/11/2005
104.2	1.34		Blk-SS-G1-75.0	Yazaki x5 S.F.	101.6	0.430	8/8/2005
104.2	1.24		Blk-SS-G1-75.0	Yazaki x5 S.F.	101.6	0.437	8/15/2005
104.2	0.98	1.18	Blk-SS-G1-75.0	Yazaki x5 S.F.	101.6	0.541	8/22/2005
105.0	1.41		Blk Plastic	SEALED AIRx2 S.F.	62.66	0.569	7/17/2005
105.0	1.19		Blk Plastic	SEALED AIRx2 S.F.	62.66	0.411	7/25/2005
105.0	1.71	1.44	Blk Plastic	SEALED AIRx2 S.F.	62.66	0.503	8/1/2005
109.0	0.40		Metal-UnG-22.5	Dawn Solar Albq.	286.00	0.481	9/12/2005
	1.407	1.519		AVERAGES		0.488	

### Radiant Cooling Plate Tilt Correction

Night Air Temp [°F]	Correction 90	Correction 45	End Date	Location
57.9	0.686	0.846	08/06/05	Tesuque
55.5	0.693	0.852	07/30/05	Tesuque
61.1	0.578	0.766	07/23/05	Tesuque
56.1	0.849	0.903	08/13/05	Santa Fe
54.7	0.850	0.914	08/20/05	Santa Fe
53.6	0.823	0.892	08/27/05	Santa Fe
51.0	0.841	0.881	9/24/05	Albuquerque
	0.760	0.865	Average	

Multiplier	Tilt above horizon
1	0
0.865	45
0.76	90

# Aquatherm

contact:  
www.warmwater.com, 1-800-535-6307

material : UV stabilized polypropylene

manifold dimension : 1.9"

standard sizes : 4'x6', 4'x8', 4'x10', 4'x12' = 24, 32, 40, 48 sf

\*\*\*approx. retail cost : 4'x8' = \$313, 4'x10' = \$338, 4'x12' = \$350

working pressure : 35 PSI @ 140°F, 85 PSI @ 80°F

maximum temperature : 140 °F

freeze tolerant : yes- when using propylene glycol

recommended flow rate : 3.25 - 5.0 GPM (size dependant)

\*heating potential : 1010 BTU's/ ft<sup>2</sup>/day



photos courtesy of Aquatherm/ Solar Industries

**\*\*cooling U value : 1.63**

pros : perforation in panels discourages ponding, many sizes to choose from, higher than average cooling U value

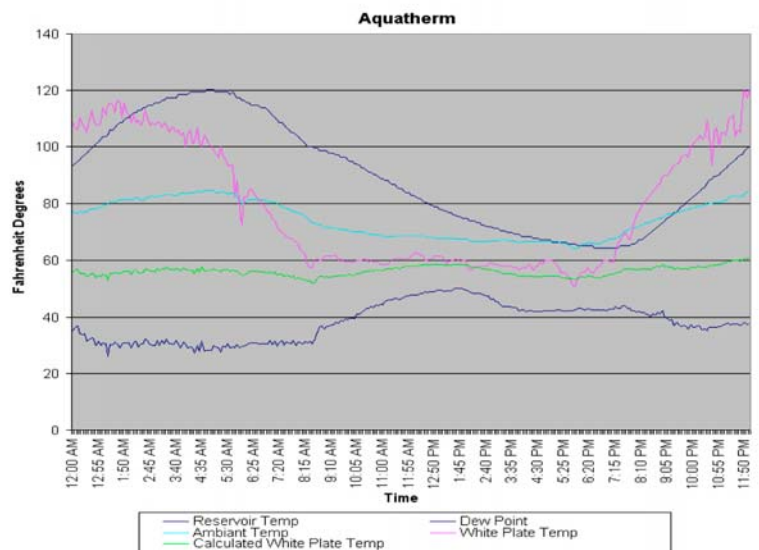
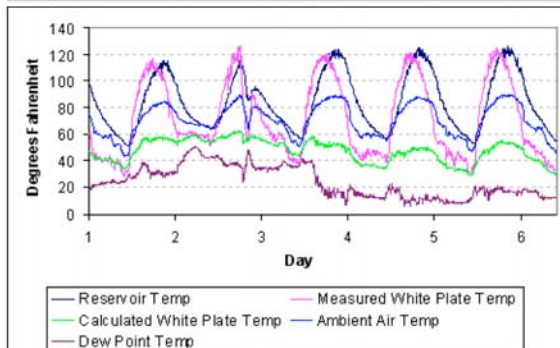
cons : low stagnation temperature



- \* As measured by the Florida Solar Energy Center  
cooling U value= Btu/ sq. ft. - hr. - dT
- \*\* As tested by Mark Chalom and Bristol Stickney
- \*\*\* Price shown is for the price of one purchased collector.  
Prices may vary between dealers and when buying multiple collectors.

## Cooling performance: one week in June near Santa Fe

Week beginning :	June 12, 2005			
Ten-hour averages - 8:00 P.M. to 6:00 A.M.				
Day	Ambient Temp [°F]	Dew Point [°F]	Measured White Plate Temp [°F]	Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-ΔT]
1	57.0	22.7	40.4	1.402
2	56.8	43.5	59.3	2.097
3	56.5	35.3	54.5	1.674
4	56.3	14.3	46.2	1.610
5	56.0	9.7	45.0	1.714
6	55.8	14.7	45.1	1.678
Avg	56.4	23.4	48.4	<b>1.696</b>



## Night Sky Radiant Cooling Potentials For the State of New Mexico

Mark Chalom Architect  
Bristol Stickney Consulting



# Energy Systems Inc.

collector no longer available

equivalent collector: Productos de Sol, S.A. model: CSP-20-B

material : metal black fin tube

manifold dimension : 3/4" diameter

standard sizes : 3' x 7' = 21 sq. ft.

cost : N/A

working pressure : N/A

maximum temperature: N/A

recommended flow rate: N/A

\*heating potential (equivalent): 719 BTU's / ft<sup>2</sup>/ day

**\*\*cooling U value : 1.32 (w/ glazing) - 1.85 (unglazed)**

pros : easy to find used, more durable than plastic, higher than average cooling U value

cons : not as efficient at heating, one size only, smaller- more field connections and possibilities for leaks

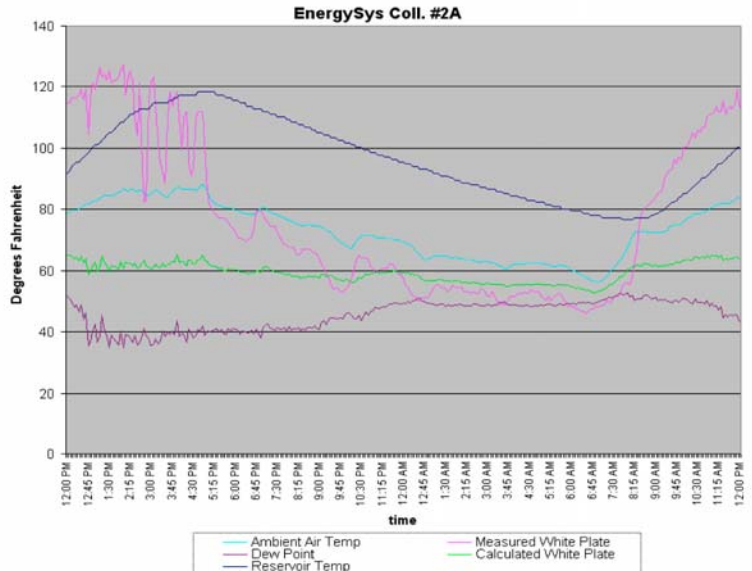
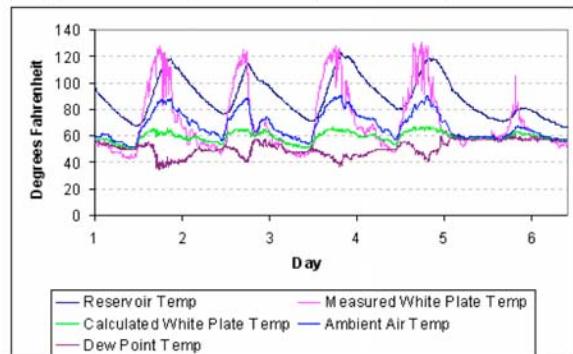
\* As measured by the Florida Solar Energy Center  
cooling U value= Btu/ sq. ft. - hr. - dT  
\*\* As tested by Mark Chalom and Bristol Stickney  
\*\*\* Price shown is for the price of one purchased collector.  
Prices may vary between dealers and when buying multiple collectors.

**2** 2 = no glazing  
2.1 = single glazed



## Cooling performance: one week in August near Santa Fe for collector 2.1

Week beginning :	08/08/05			
Ten-hour averages - 8:00 P.M. to 6:00 A.M.				
Day	Ambient Temp [°F]	Dew Point [°F]	Measured White Plate Temp [°F]	Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-ΔT]
1	49.0	52.2	49.4	1.448140953
2	70.2	47.3	56.0	1.418578561
3	68.4	49.4	50.4	1.27343097
4	72.4	47.9	59.5	1.389333872
5	58.1	56.9	57.3	1.704859396
6	55.4	56.7	55.9	1.458828555
Avg	62.3	51.8	54.7	<b>1.449</b>



**Night Sky Radiant Cooling Potentials For the State of New Mexico**  
Mark Chalom Architect  
Bristol Stickney Consulting



# Fafco Sun saver™

contact:  
www.fafco.com

material : UV stabilized plastic polymer, polyolefin

manifold dimension : 50.87 in long

standard sizes : 4'x8', 4'x10', 4'x12' = 32, 40, 48 sq. ft.

\*\*\*approx. retail cost: 4'x8'= \$270, 4'x10'= \$212, 4'x12'= \$242

working pressure : @ 80° F: 0-30 psi, @ 212° F: 0-5 psi

maximum temperature: 212 F

freeze tolerant: drain during freezing months unless using propylene glycol

\*heating potential : 1,014 BTU/ ft<sup>2</sup>/ day



photo courtesy of Fafco

**\*\*cooling U value: 1.56**

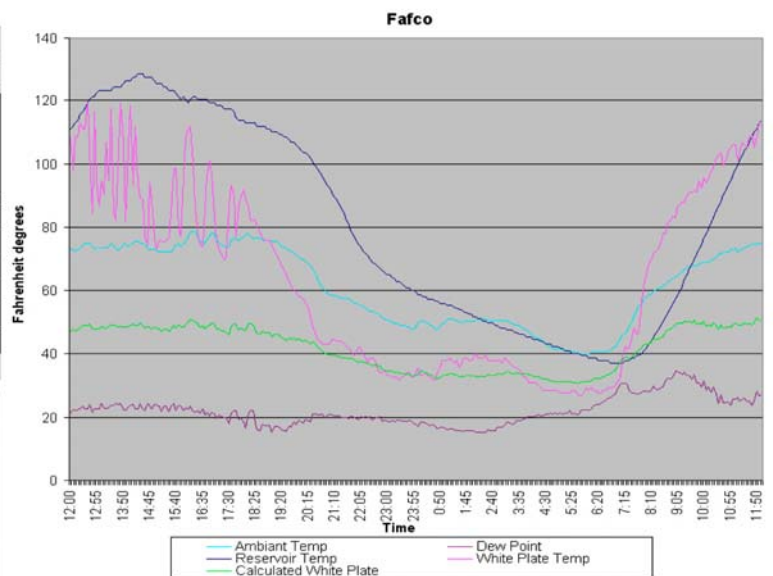
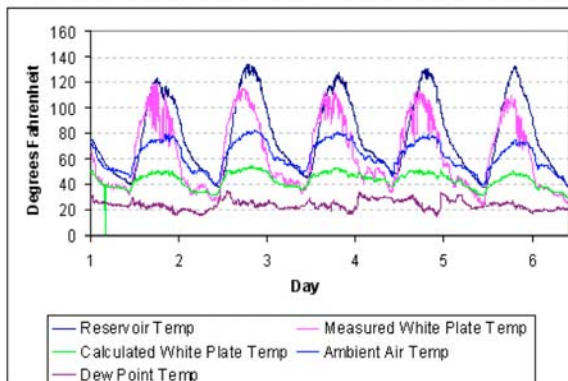
pros: high stagnation temperature, good cooling U value, various sizes

cons: prone to puddling

- \* As measured by the Florida Solar Energy Center  
cooling U value= Btu/ sq. ft. - hr. - dT
- \*\* As tested by Mark Chalom and Bristol Stickney
- \*\*\* Price shown is for the price of one purchased collector.  
Prices may vary between dealers and when buying multiple collectors.

## Cooling performance: one week in June near Santa Fe

Week beginning :	May 30, 2005			
	Ten-hour averages - 8:00 P.M. to 6:00 A.M.			
Day	Ambient Temp [°F]	Dew Point [°F]	Measured White Plate Temp [°F]	Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-ΔT]
1	54.6	24.8	41.9	1.609
2	50.8	18.9	36.6	1.517
3	57.4	22.3	43.6	1.525
4	58.3	28.7	46.7	1.504
5	52.6	25.7	40.5	1.612
6	49.1	19.7	34.1	1.399
Avg	53.8	23.3	40.6	<b>1.528</b>



## Night Sky Radiant Cooling Potentials For the State of New Mexico

Mark Chalom Architect  
Bristol Stickney Consulting



**4**

4 = painted white  
 4.1 = painted black  
 4.2 = single glazed

**Yazaki**

(tested collector no longer available)

equivalent collector: Solahart Industries Pty. Ltd. model: Kf  
 contact: [http://www.solahart.com.au/default.asp?V\\_DOC\\_ID=748](http://www.solahart.com.au/default.asp?V_DOC_ID=748)

material : fully wetted steel plate w/ selective surface

Yazaki collector shown below

manifold dimension : 1/4"

standard sizes (equiv.): 76.3" x 40.3"

\*\*\*approx. retail cost (equiv.): \$380 - \$400

working pressure (equiv.): 12 psi, max- 20-25 psi

maximum temperature (equiv.): 284°F

freeze tolerant : yes- propylene glycol

recommended flow rate (equiv.): .59 gpm

\*heating potential (equiv.): 895 BTU/ft<sup>2</sup>/day



**\*\*cooling U value : 1.22 (glazed), 1.82 (black), 2.13 (white)**

pros : most efficient for cooling, durable, fewer connections

cons : more expensive, low working pressure, small size

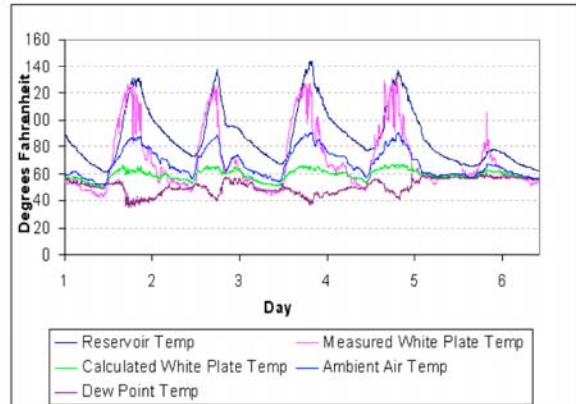
\* As measured by the Florida Solar Energy Center  
 cooling U value= Btu/ sq. ft. - hr. - dT

\*\* As tested by Mark Chalom and Bristol Stickney

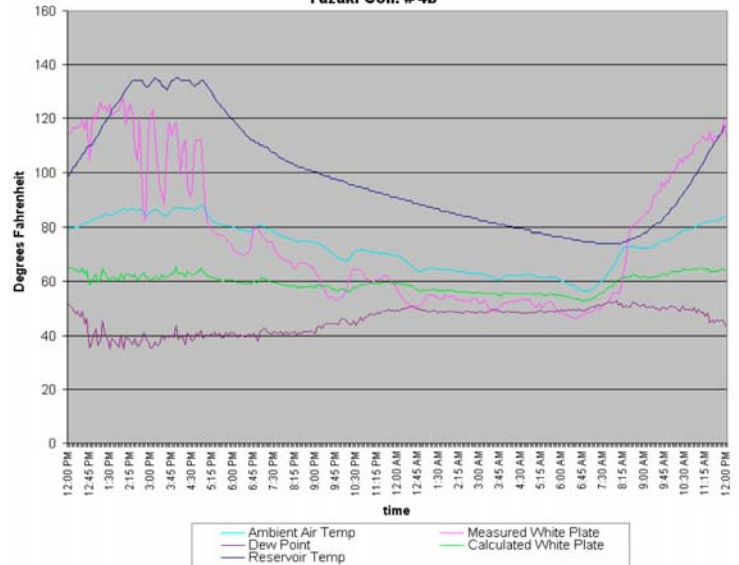
\*\*\* Price shown is for the price of one purchased collector.  
 Prices may vary between dealers and when buying multiple collectors.

**Cooling performance: one week in August near Santa Fe for collector 4.2**

Week beginning :	08/08/05			
Ten-hour averages - 8:00 P.M. to 6:00 A.M.				
Day	Ambient Temp [°F]	Dew Point [°F]	Measured White Plate Temp [°F]	Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-ΔT]
1	49.0	52.2	49.4	1.556773337
2	70.2	47.3	56.0	1.254108315
3	68.4	49.4	50.4	1.136919879
4	72.4	47.9	59.5	1.186648619
5	58.1	56.9	57.3	2.032313009
6	55.4	56.7	55.9	1.605387696
Avg	62.3	51.8	54.7	<b>1.462</b>



Yazaki Coll. # 4b



**Night Sky Radiant Cooling Potentials For the State of New Mexico**

Mark Chalom Architect  
 Bristol Stickney Consulting



## Sealed Air FP

contact:  
www.sealedair.com

material : UV stabilized plastic polymer

manifold dimension : approx. 3" diameter

standard sizes : 4'x8', 4'x10', 4'x12' = 32, 40, 48 sq.ft.

\*\*\*approx. retail cost : 4'x8' = \$300, 4'x10' = \$310, 4'x12' = \$320

working pressure : 25-30 psi, max static= 100psi

maximum temperature:

freeze tolerant: yes- when using propylene glycol

recommended flow rate: 3-5 GPM

\*heating potential : 948 BTU/ ft<sup>2</sup>/ day

**\*\*cooling U value : 1.82**

pros : very high cooling U value

cons: lower heating potential, solid piece- prone to ponding, stiff to work with

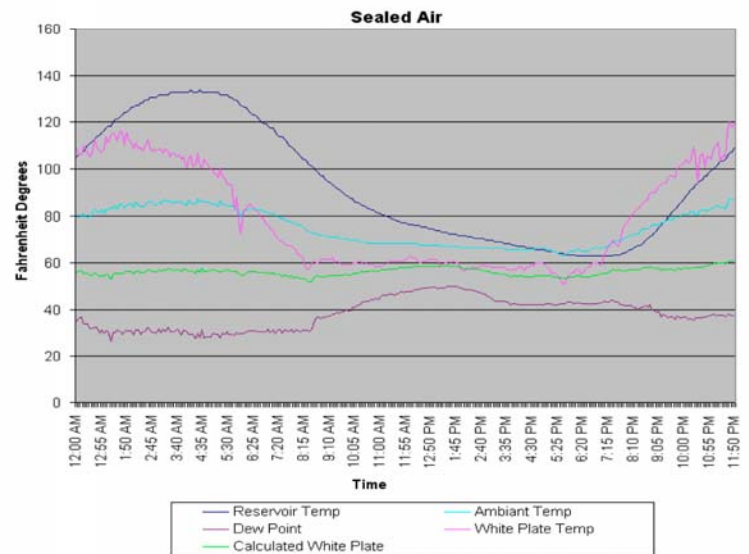
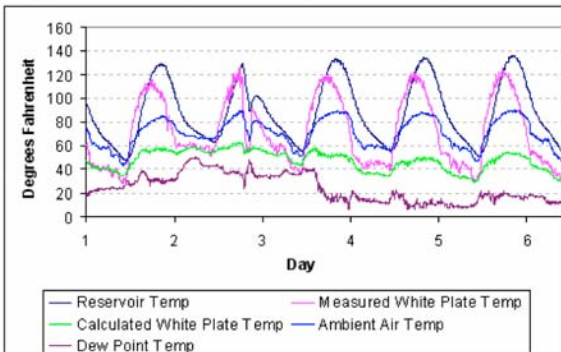
- \* As measured by the Florida Solar Energy Center  
cooling U value= Btu/ sq. ft. - hr. - dT
- \*\* As tested by Mark Chalom and Bristol Stickney
- \*\*\* Price shown is for the price of one purchased collector.  
Prices may vary between dealers and when buying multiple collectors.



images courtesy of Sealed Air

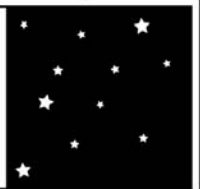
### Cooling performance: one week in June near Santa Fe

Week beginning :	June 12, 2005			
	Ten-hour averages - 8:00 P.M. to 6:00 A.M.			
Day	Ambient Temp [°F]	Dew Point [°F]	Measured White Plate Temp [°F]	Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-ΔT]
1	57.0	22.7	40.4	1.612
2	56.8	43.5	59.3	2.167
3	56.5	35.3	54.5	1.864
4	56.3	14.3	46.2	1.655
5	56.0	9.7	45.0	1.745
6	55.8	14.7	45.1	1.675
Avg	56.4	23.4	48.4	<b>1.786</b>



### Night Sky Radiant Cooling Potentials For the State of New Mexico

Mark Chalom Architect  
Bristol Stickney Consulting



# Suntrek

contact:  
www.suntrek.net, 1-800-292-7648

material : UV stabilized EPDM

manifold dimension : 28" x2" diameter

standard sizes : 6" width, variable length & configuration

\*\*\*approx. retail cost : \$3 per sq.ft for collectors,  
\$15 per manifold

working pressure : 40 psi max

maximum temperature: 160° F

freeze tolerant: drain during freezing mos.- unless propylene glycol is used

recommended flow rate: 15 gal./ min./ 10 sq. ft.

\*heating potential : 1,024 BTU/ ft<sup>2</sup>/ day

**\*\*cooling U value : 1.58**

pros : flexible, ordered to any length, shipped pre-assembled or not, easy to assemble, good cooling U value

cons: EPDM breaks down relatively quickly in NM sun

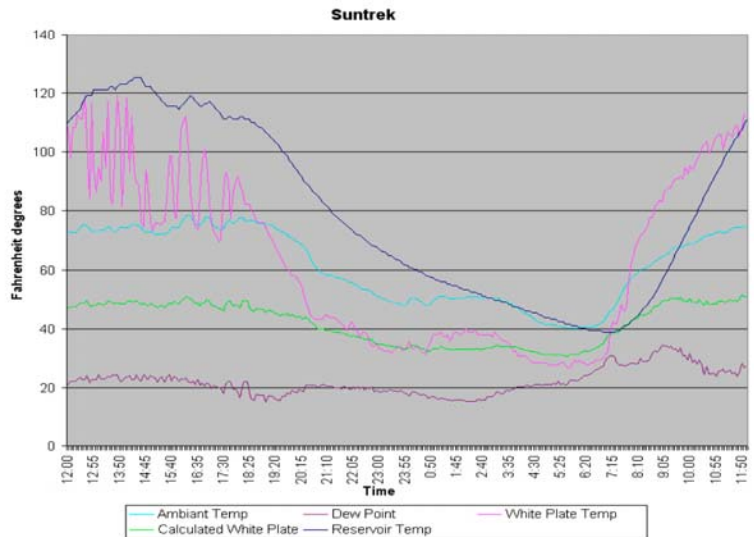
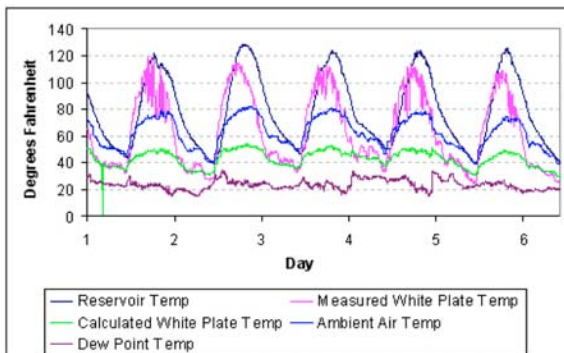
- \* As measured by the Florida Solar Energy Center  
cooling U value= Btu/ sq. ft. - hr. - dT
- \*\* As tested by Mark Chalom and Bristol Stickney
- \*\*\* Price shown is for the price of one purchased collector.  
Prices may vary between dealers and when buying multiple collectors.



photos courtesy of Suntrek

## Cooling performance: one week in June near Santa Fe

Week beginning :	May 30, 2005			
Ten-hour averages - 8:00 P.M. to 6:00 A.M.				
Day	Ambient Temp [°F]	Dew Point [°F]	Measured White Plate Temp [°F]	Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-ΔT]
1	54.6	24.8	41.9	1.61807295
2	54.4	18.9	36.6	1.533612434
3	54.2	22.3	43.6	1.578775004
4	54.0	28.7	46.7	1.536443722
5	53.8	25.7	40.5	1.623719999
6	53.6	19.7	34.1	1.394837495
Avg	54.1	23.3	40.6	<b>1.547</b>



## Night Sky Radiant Cooling Potentials For the State of New Mexico

Mark Chalom Architect  
Bristol Stickney Consulting



# Techno-Solis

contact:  
www.techno-solis.com, 1-800-99-SOLAR

material : UV stabilized plastic polymer

manifold dimension : 1.5" - 2" diameter

standard sizes : 4'x8', 4'x10', 4'x12' = 32, 40, 48 sq. ft.

\*\*\*approx. retail cost : 4'x8'= \$180, 4'x10'= \$190, 4'x12'= \$210

working pressure : max static= 80 psi, max op.= 35 psi

maximum temperature: 140°F

freeze tolerant: yes

recommended flow rate: 4.9 GPM

\*heating potential : 958 BTU/ ft<sup>2</sup>/ day

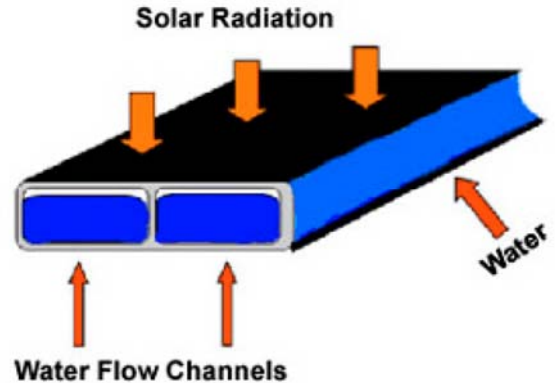


image courtesy of Technosolis

**\*\*cooling U value: 1.98**

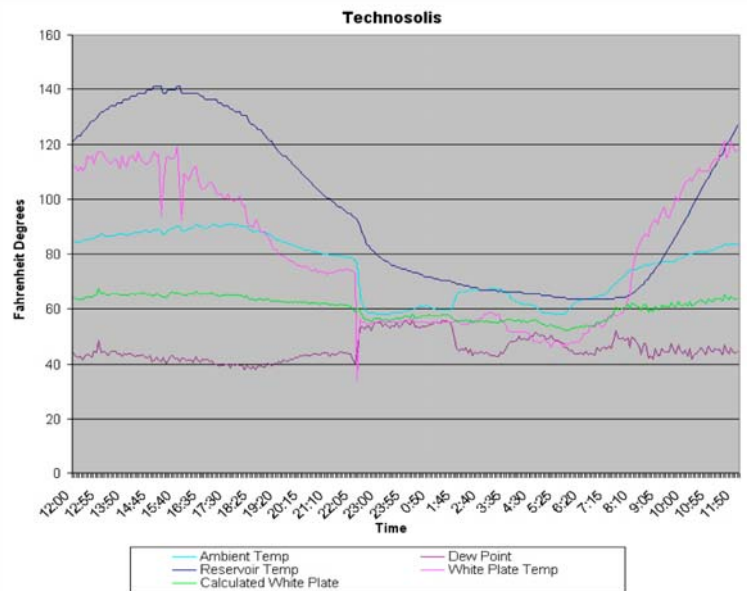
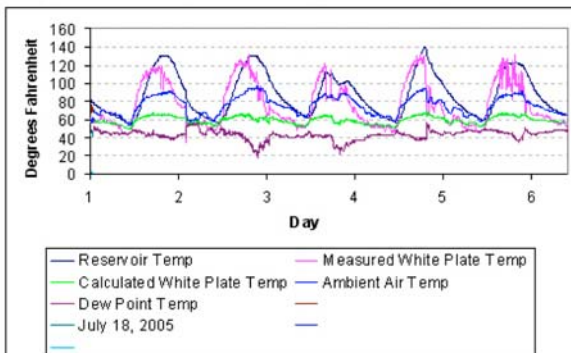
pros: comes in black or terra cotta, very good cooling U value, many sizes to work with

cons: prone to ponding, low stagnation temperature

- \* As measured by the Florida Solar Energy Center  
cooling U value= Btu/ sq. ft. - hr. - dT
- \*\* As tested by Mark Chalom and Bristol Stickney
- \*\*\* Price shown is for the price of one purchased collector.  
Prices may vary between dealers and when buying multiple collectors.

## Cooling performance: one week in July near Santa Fe

Week beginning :	July 18, 2005			
Ten-hour averages - 8:00 P.M. to 6:00 A.M.				
Day	Ambient Temp (°F)	Dew Point (°F)	Measured White Plate Temp (°F)	Heat Loss based on White Plate (BTU/ft <sup>2</sup> -hr-ΔT)
1	67.2	45.8	55.8	1.834
2	76.2	48.5	58.2	3.005
3	74.0	41.3	61.4	2.147
4	68.9	41.1	55.7	1.895
5	69.8	46.0	55.8	1.769
6	71.0	46.3	60.8	2.075
Avg	71.2	44.8	57.9	<b>2.121</b>



**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**  
Mark Chalom Architect  
Bristol Stickney Consulting



# Heliocol

contact:  
www.heliocol.com

material : UV stabilized polypropylene

manifold dimension : 2" diameter

standard sizes : 4'x12.5', 4'x10.5', 4'x8', 1'x12.5, 1'x 10.5'

\*\*\*approx. retail cost : 4'x12.5'= \$200, 4'x10.5'= \$160, 4'x8'= \$140

working pressure : 90 psi, 270 psi max

maximum temperature: 140°F

freeze tolerant : no- unless using propylene glycol

recommended flow rate: 1-5 GPM (depending on size)

\*heating potential : 1,024 BTU/ ft<sup>2</sup>/ day

\*\*cooling U value: 1.41

pros: flexible, no ponding

cons: low stagnation temperature,  
lower than average cooling U value

\* As measured by the Florida Solar Energy Center  
cooling U value= Btu/ sq. ft. - hr. - dT  
\*\* As tested by Mark Chalom and Bristol Stickney  
\*\*\* Price shown is for the price of one purchased collector.  
Prices may vary between dealers and when buying multiple collectors.

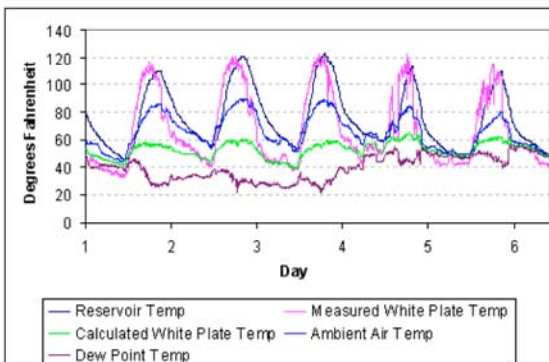


images courtesy of Heliocol

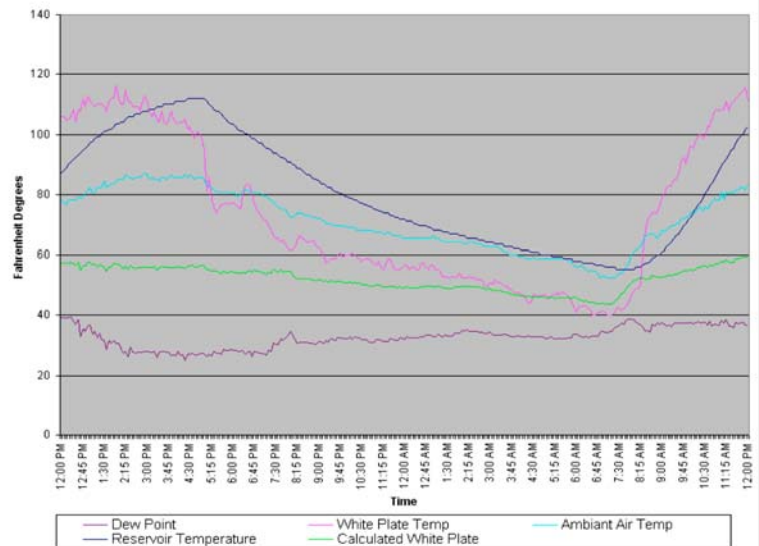


## Cooling performance: one week in August near Santa Fe

Week beginning :	08/29/05			
Ten-hour averages - 8:00 P.M. to 6:00 A.M.				
Day	Ambient Temp [°F]	Dew Point [°F]	Measured White Plate Temp [°F]	Heat Loss based on White Plate [BTU/ft <sup>2</sup> -hr-ΔT]
1	37.5	40.9	39.7	1.155
2	66.3	32.7	54.3	1.449
3	61.5	27.0	46.4	1.192
4	65.9	42.6	53.9	1.169
5	45.2	48.1	44.1	1.245
6	49.2	51.5	49.1	1.739
Avg	54.3	40.5	47.9	<b>1.325</b>



## Heliocol



## Night Sky Radiant Cooling Potentials For the State of New Mexico

Mark Chalom Architect  
Bristol Stickney Consulting



## Dawn

contact:  
www.dawnsolar.com, 1-800-803-1476

material : PEX tubing, copper piping below metal roof

manifold dimension : N/A

standard sizes : variable 300 ft<sup>2</sup> modules

\*\*\*approx. retail cost : \$7- \$10 per square ft

working pressure : 10-15 lbs.

maximum temperature: 200° F @ 80 PSI

freeze tolerant: yes (propylene glycol)

recommended flow rate: .5 gal/min per collector circuit

\*heating potential : 250-400 BTU/ ft<sup>2</sup>/ day

\*\*cooling U value : .4

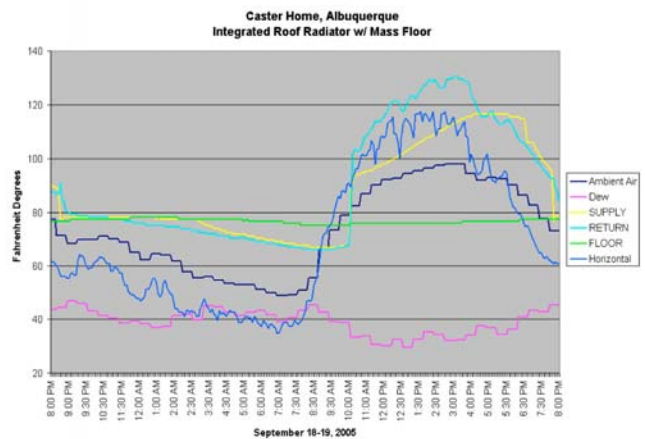
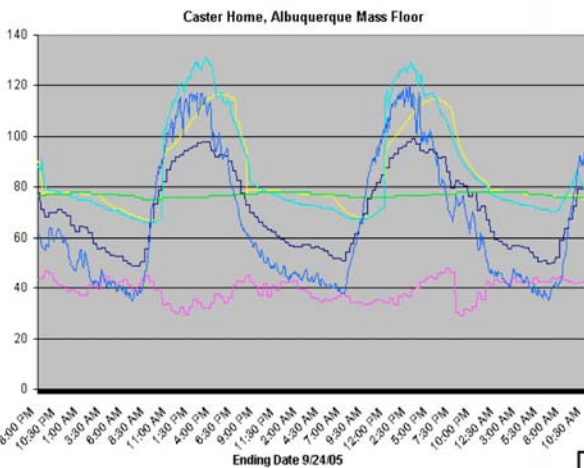
**pros:**

can work under a variety of roofing materials  
can be integrated with photovoltaics  
installed under entire roof- thus can make up for it's decreased efficiency  
through an increased area  
invisible

**cons:**

less efficient per square foot  
requires correct roof orientation  
new construction, or major roof renovation

\* As measured by the Florida Solar Energy Center  
cooling U value= Btu/ sq. ft. - hr. - dT  
\*\* Estimated based on field test monitoring.  
\*\*\* Price shown is for the price of one purchased collector.  
Prices may vary between dealers and when buying multiple collectors.



**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**  
Mark Chalom Architect  
Bristol Stickney Consulting



# 6

## Statewide Savings Potentials

This section looks at the savings potentials of NSRC as compared with air conditioning and evaporative cooling. One can easily compare the use of water and power to provide the same amount of cooling.

The comparison is based on the same designed home with 400 and 600 SQ. FT. of radiators. This was held as the constant and analyzed with the weather data from each of New Mexico's 11 climate zones. This allows direct comparisons. (See explanation of weather data and explanation of NSRC for the data and formulas we utilized)

This section showing the home and its thermal characteristics. These characteristics can easily be changed in the Data Input sheet on the Calculator for various types of buildings.

The first charts show the potential savings of this home comparatively in the various climate zones. The first chart shows the water savings in gallons over the cooling season. The next chart shows the savings in KWH.

The next set of graphs shows the comparative use of power and water during the cooling season for each climate zone. One can easily compare Zone to Zone.

The last set of graphs shows the full year potential for cooling for each zone. We have included both 400 SQ. FT. and 600 SQ. FT radiators. This would be of interest for large commercial buildings or low temperature process cooling.

**Night Sky Radiant Cooling Potentials  
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## HEAT LOSS FOR AN EFFICIENT NEW MEXICO HOME

floor area	1800				
AREA		Length or Area	R value	U value	HL/hr/degree
PERIMETER		180	8	0.125	22.5
WALLS		1653	21	0.047619	78.71429
WINDOWS		464	3.03	0.330033	153.1353
DOORS		42	2.5	0.4	16.8
ROOF		1800	38	0.026316	47.36842
VOLUME		cu'	.018 x V x AE x alt factor		
infiltration		15300	0.5		104.652
total HL BTU/DEGREE/HR					423.17
BTU/Day/SQ.FT./degree F					5.642267
BTU/DD					10156.08

This energy efficient home has been designed to the standards of the Passive Solar Guidelines. It is 20% more efficient than the requirements of the Model Energy Code and 25% better than the Base Case model in the Energy 10 model. These standards are simple to achieve and will recoup the extra expense in energy savings in just a few years and is well worth the cost. This efficient home makes the use of alternative energy systems simple and cost effective.

## HEAT LOSS FOR A INEFFICIENT NEW MEXICO HOME

floor area	1800				
		Length or Area	R value	U value	HL/hr/degree
AREA					ree
	PERIMETER	180	3	0.333333	60
	WALLS	1653	11	0.090909	150.2727
	WINDOWS	464	1.25	0.8	371.2
	DOORS	42	2.5	0.4	16.8
	ROOF	1800	19	0.052632	94.73684
VOLUME		cu'	.018 x V x AE x alt factor		
	infiltration	15300	0.75		156.978
			total HL BTU/DEGREE/HR		849.9876
			BTU/Day/SQ.FT./degree F		11.33317
		BTU/DD			20399.7

This home represents a typical home built in New Mexico 20- 30 years ago  
 It has 2x4 walls w/ R =11 insulation ,the roof has 6" of insulation the windows are single glazed and the building is not as air tight.

This home will require 2 times the energy needed to heat or cool then our base case efficient home. This would show twice the energy and water saved over Air conditioning or swamp cooler. The radiators needed for cooling would also be twice what would be needed for the efficient home.

The following listing shows major population areas reporting from each climatic region.

Climatic Region 1:

Red River  
Questa  
Eagle Nest

Climatic Region 2:

Cuba  
Tierra Amarilla  
Chama

Climatic Region 3:

Gallup  
Grants  
Luna Range  
Cloudcroft

Climatic Region 4:

Raton  
Cimarron  
Springer  
Las Vegas  
Mountainair  
Santa Fe  
Taos  
Los Alamos  
Sandia Ranger Station  
Ruidoso

Climatic Region 5:

Shiprock  
Farmington  
Aztec Ruins  
Chaco Canyon  
Clayton

Climatic Region 6:

Bloomfield

Climatic Region 7:

Magdalena  
Corona  
Mayhill

Climatic Region 8:

Carrizozo  
Silver City

Climatic Region 9:

Clovis  
Tucumcari  
Vaughn  
Roswell  
Tatum  
White Sands  
Alamogordo  
Albuquerque  
Socorro  
Lordsburg

Climatic Region 10:

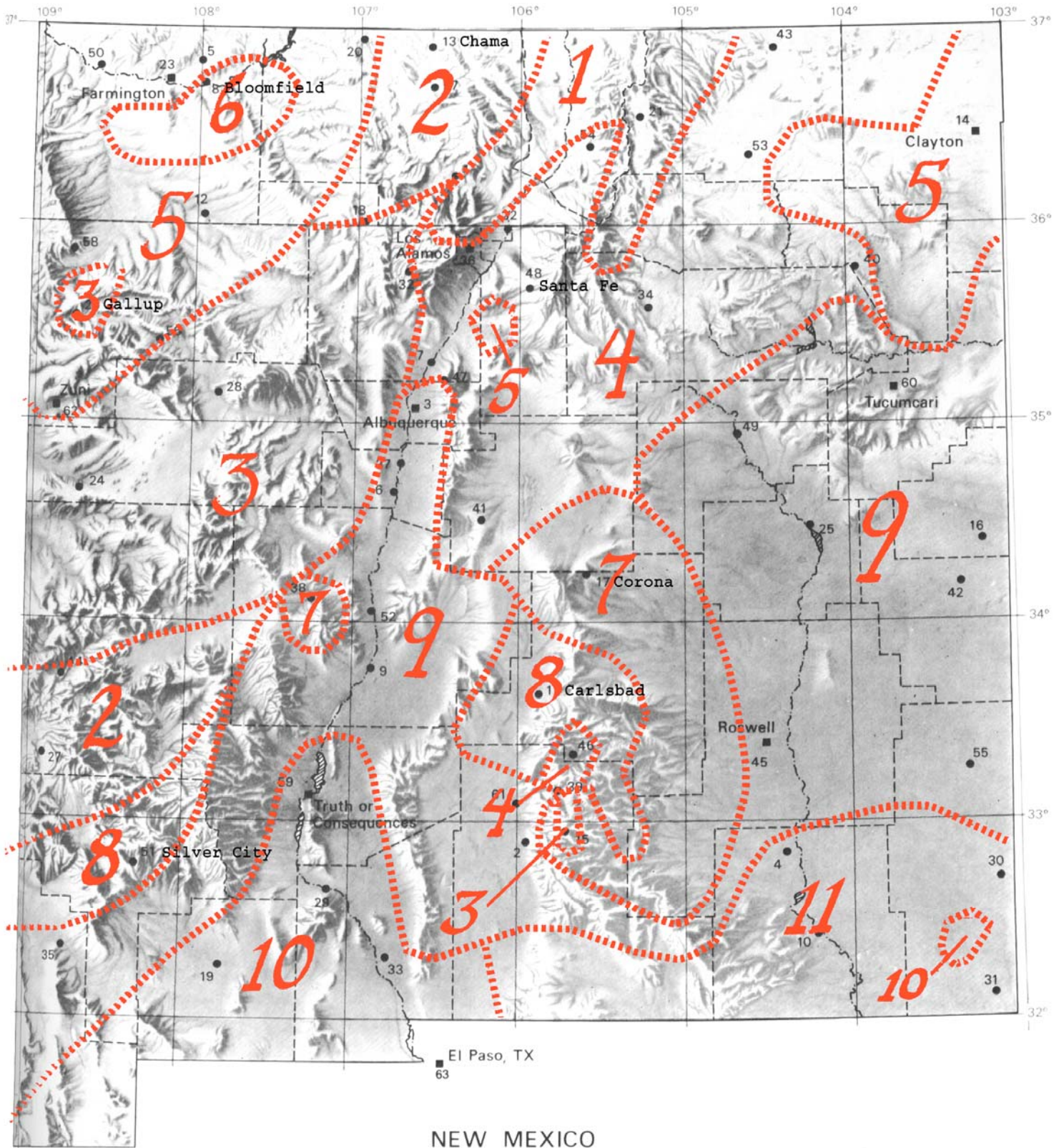
Las Cruces  
Deming  
Truth or Consequences

Climatic Region 11:

Hobbs  
Artesia  
Carlsbad  
Orogrande

**Source:**

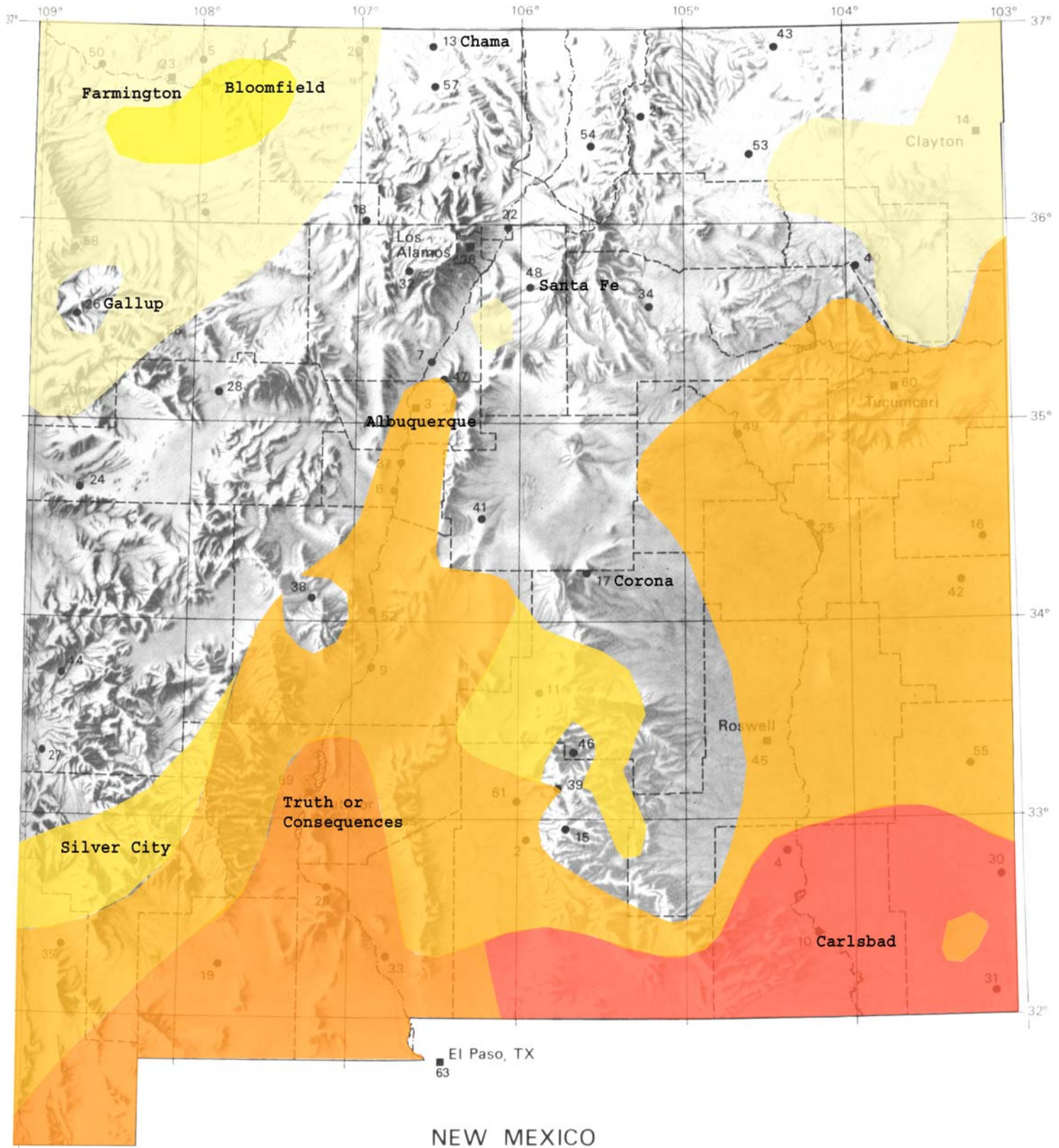
Energy Conservation Code Applications  
Manual, NMSU, Oct. 1977



Shaded relief courtesy of New Mexico Bureau of Mines and Mineral Resources



**Source:**  
Energy Conservation Code Applications Manual, NMSU, Oct. 1977

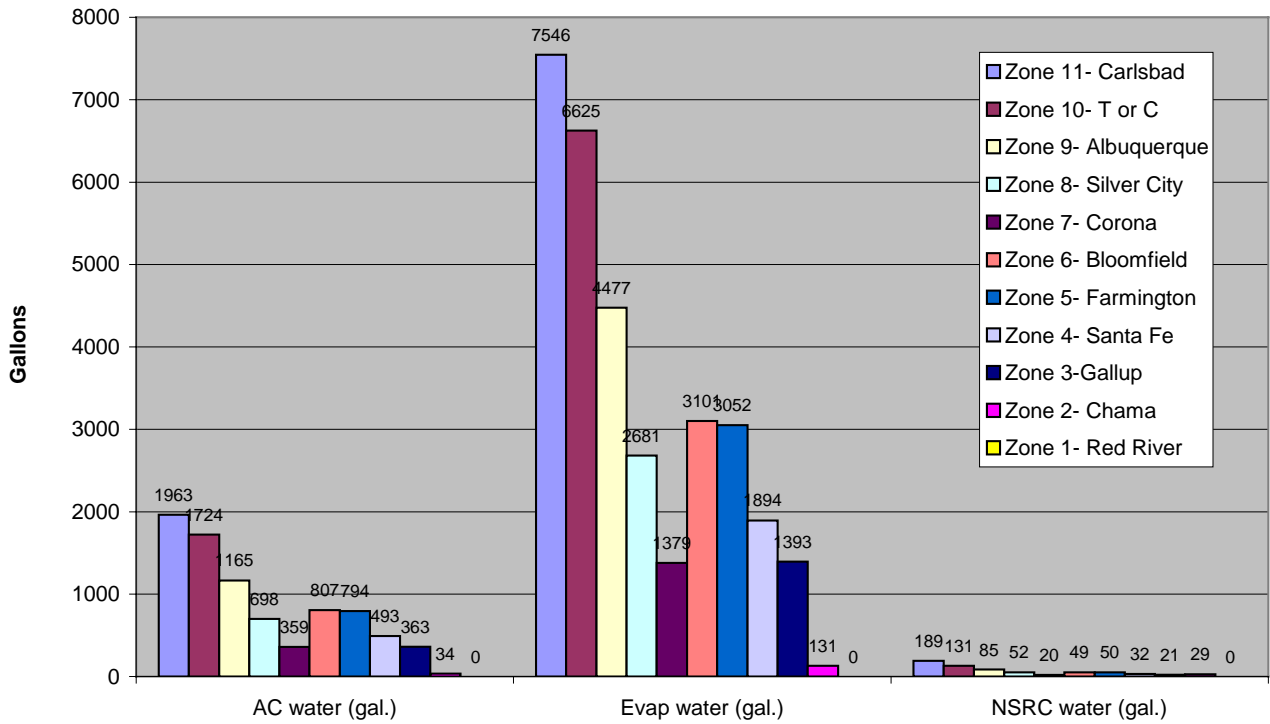


Shaded relief courtesy of New Mexico Bureau of Mines and Mineral Resources

# Annual Household Water Use for Cooling in New Mexico

Air Conditioning, Evaporative Cooling, & Night Sky Radiant Cooling

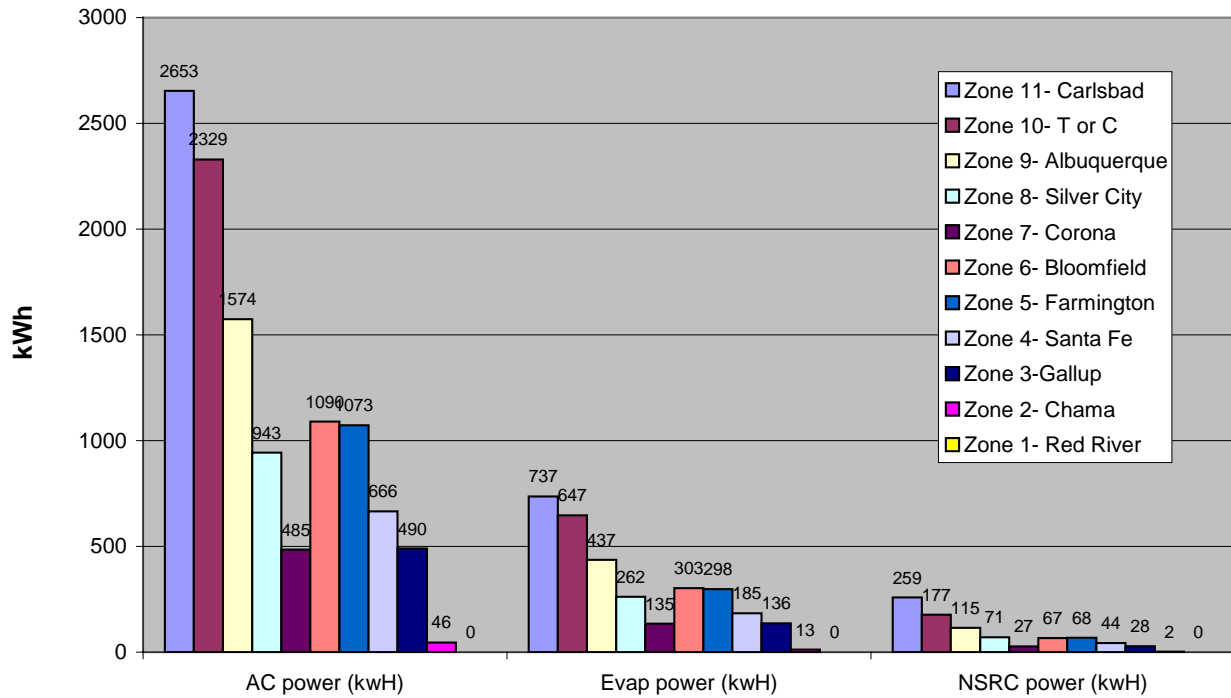
for an 1800 sf. Home @ base 65 CDD



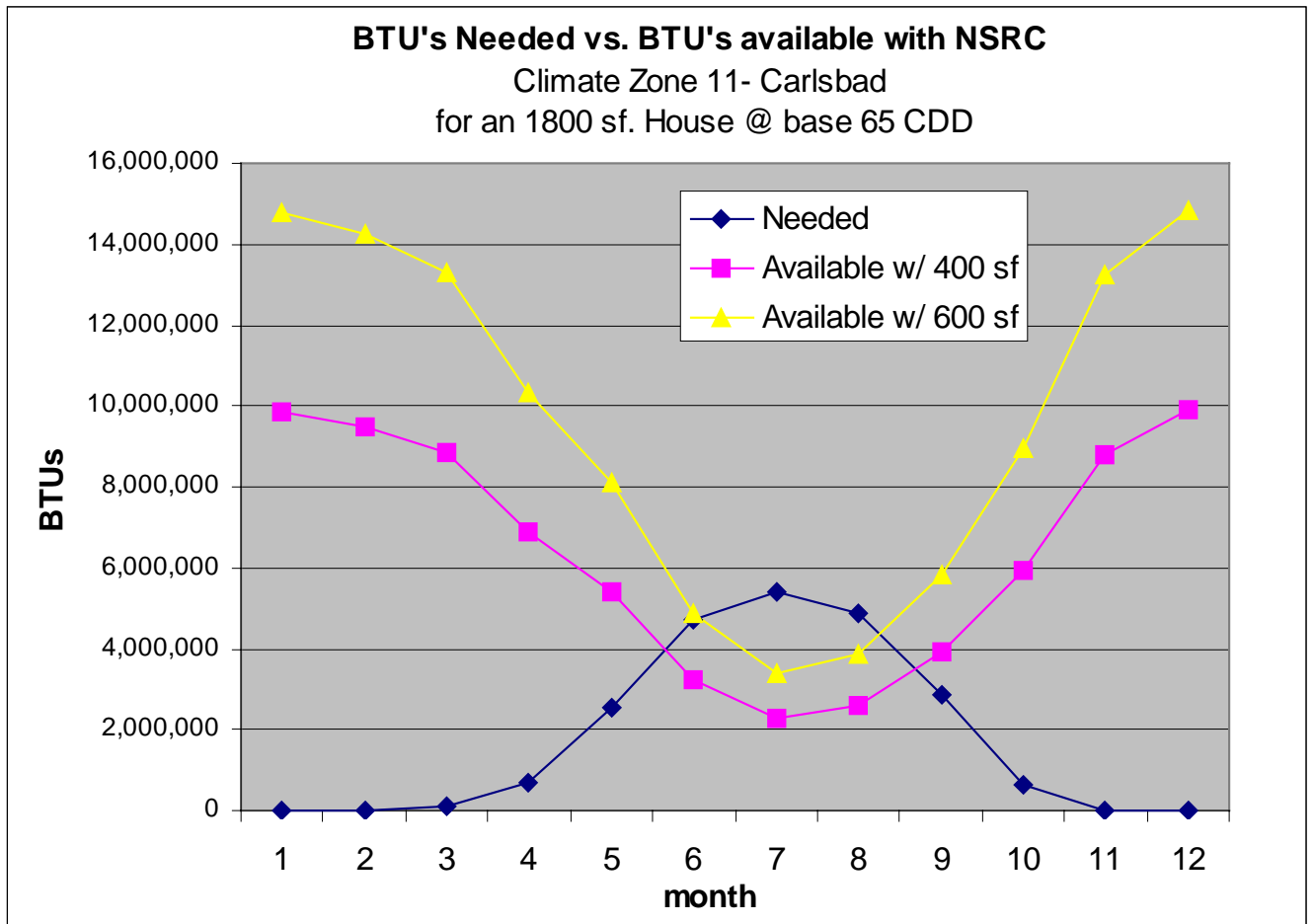
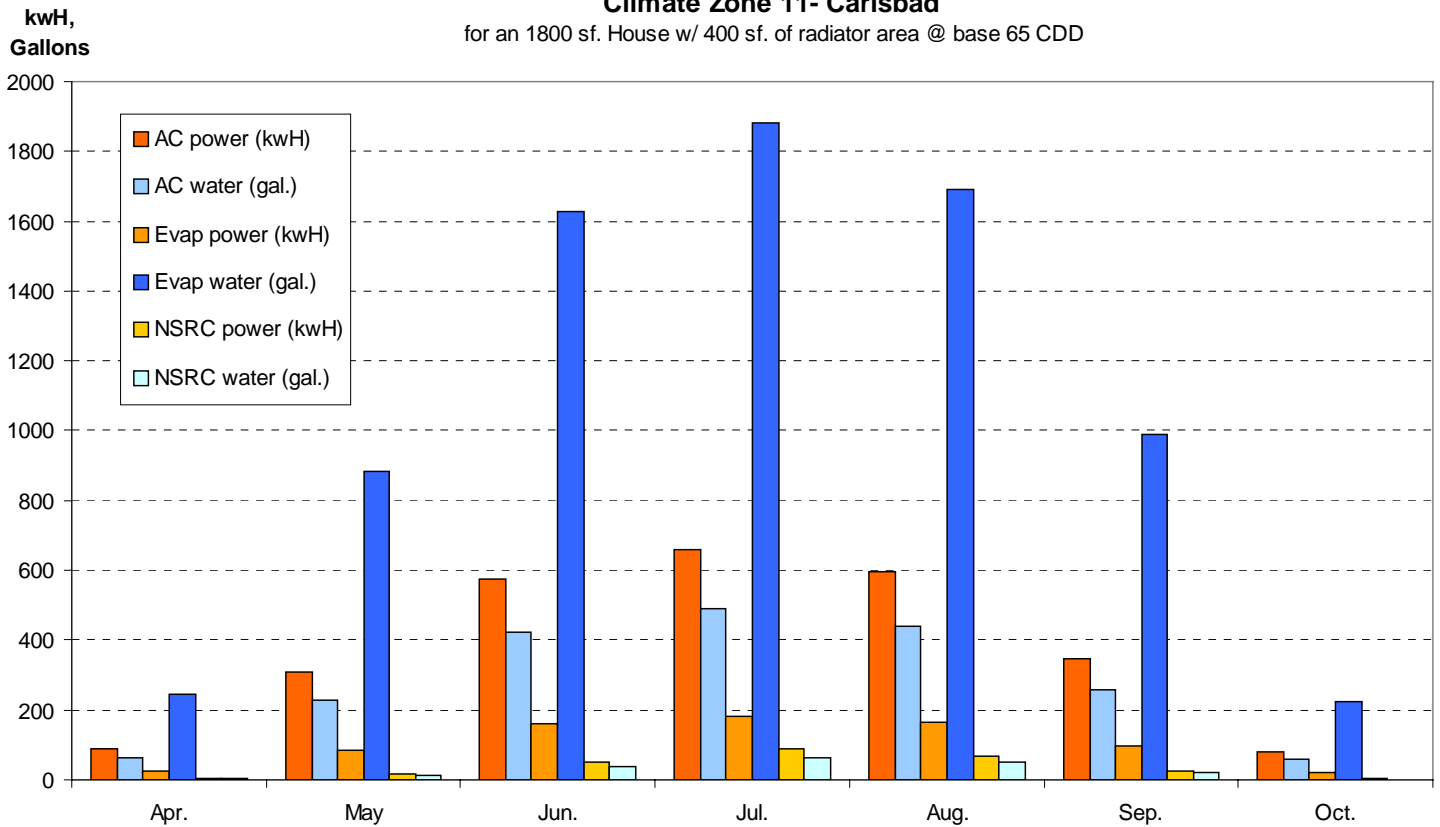
# Annual Household Power Use for Cooling in New Mexico

Air Conditioning, Evaporative Cooling, & Night Sky Radiant Cooling

for an 1800 sf. Home @ base 65 CDD



**Water & Power Use**  
 for Evaporative Cooling, Air Conditioning, & Night Sky Radiant Cooling  
**Climate Zone 11- Carlsbad**  
 for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD



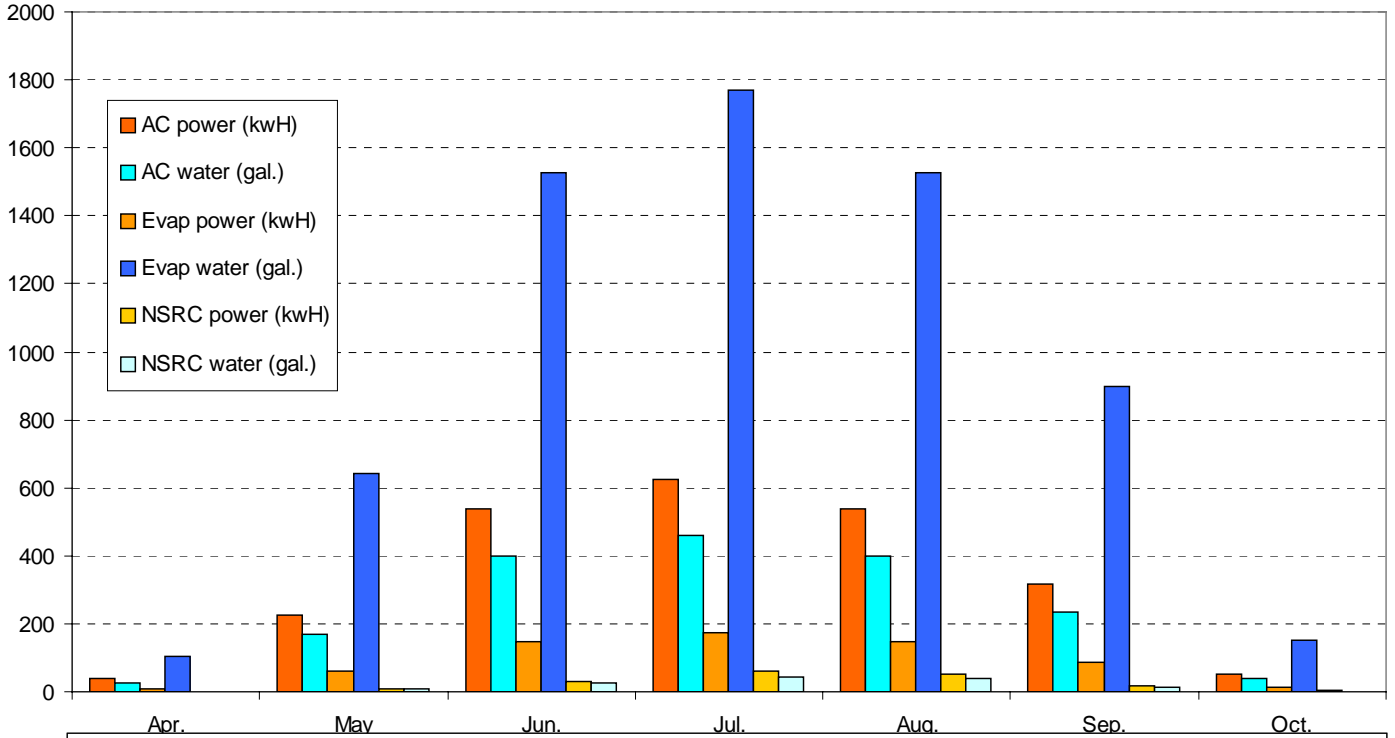
## Water & Power Use

for Evaporative Cooling, Air Conditioning, & Night Sky Radiant Cooling

### Climate Zone 10- Truth or Consequences

for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

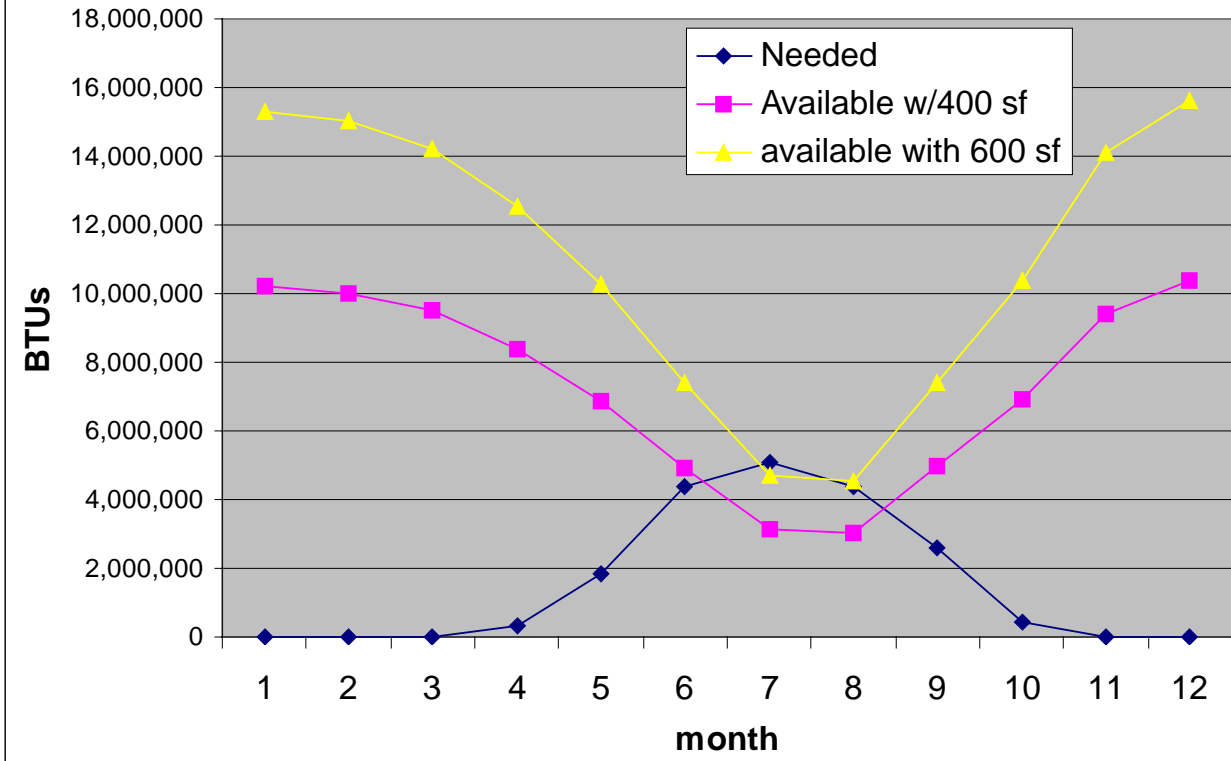
kWh,  
Gallons



### BTU's Needed vs. BTU's available with NSRC

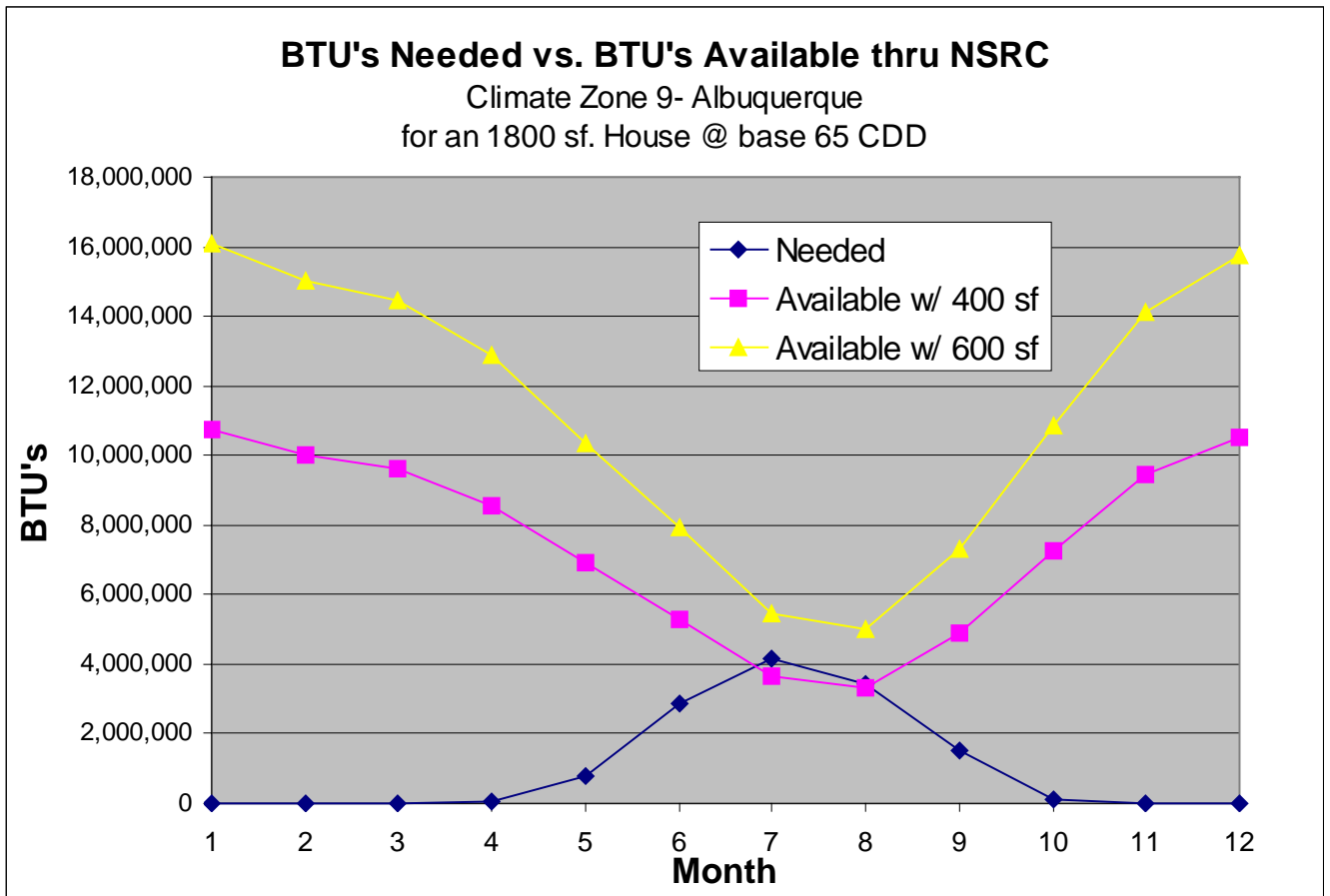
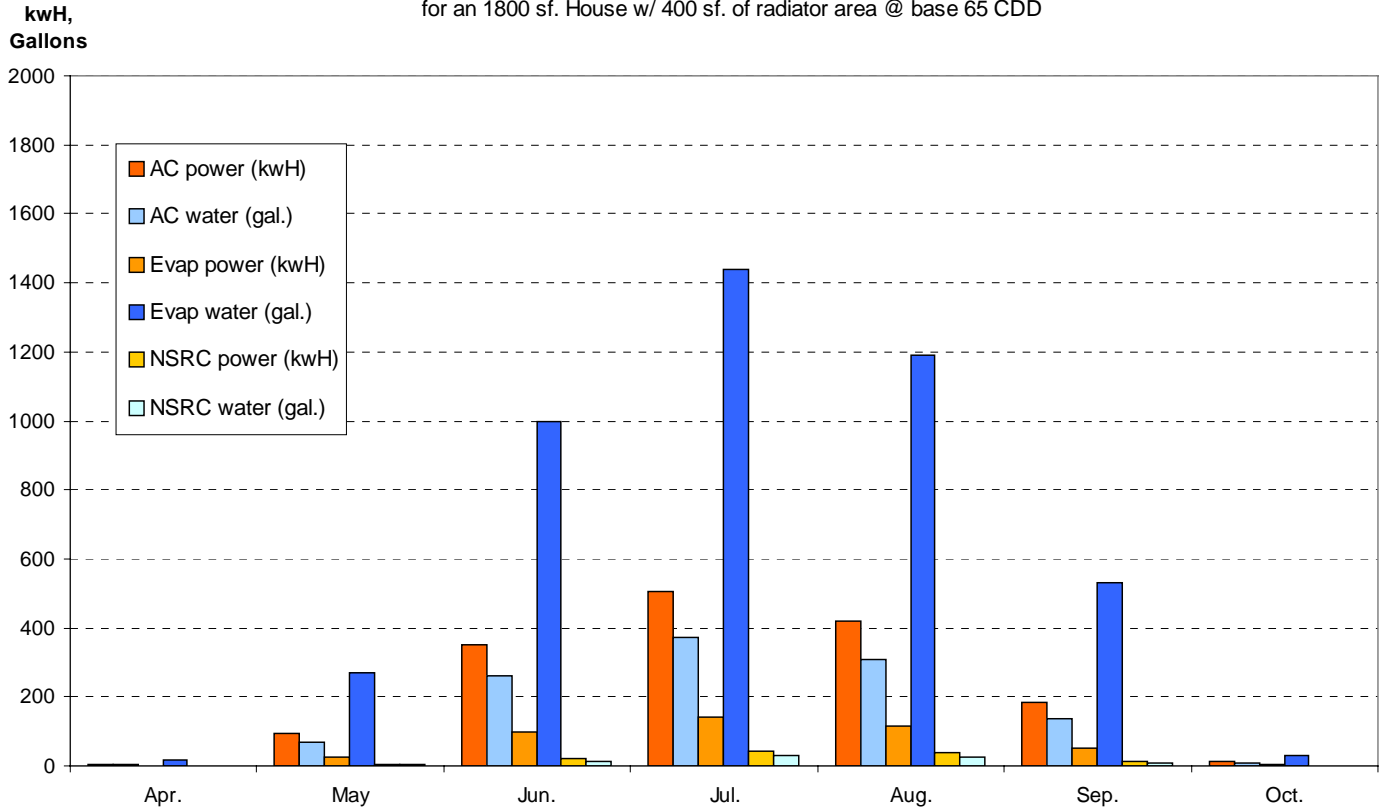
Climate Zone 10- Truth or Consequences

for an 1800 sf. House @ base 65 CDD



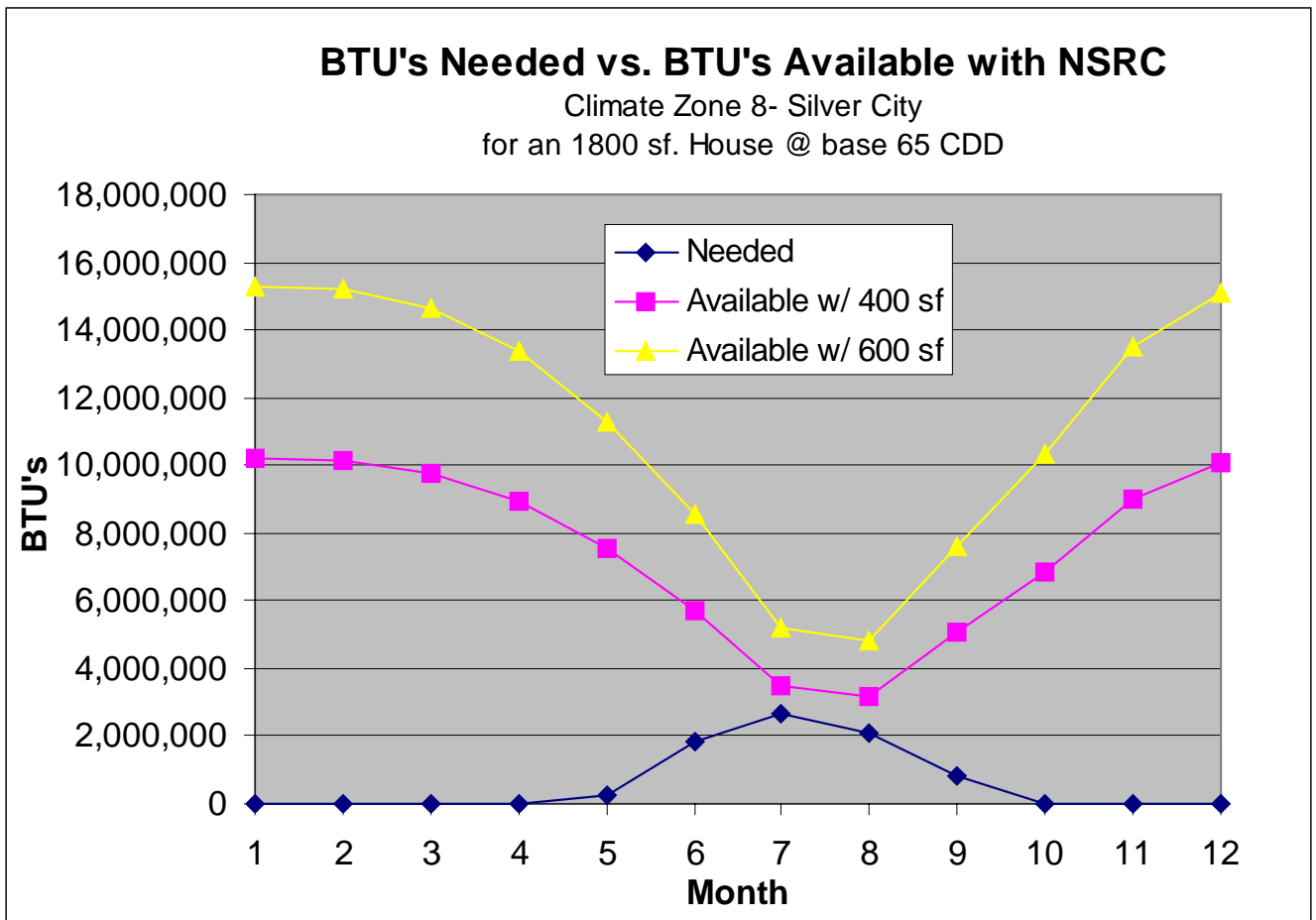
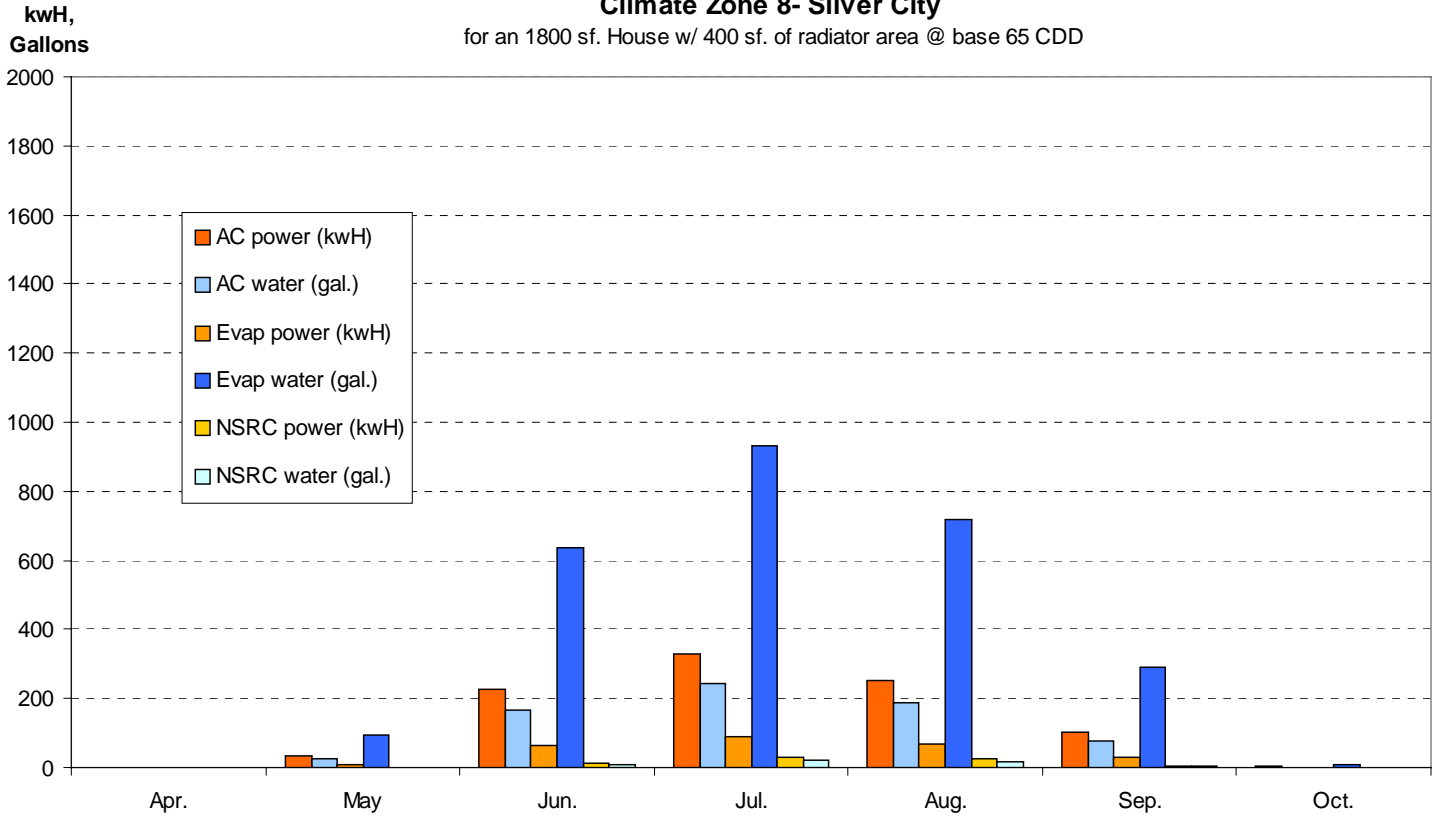
## Water & Power Use

for Evaporative Cooling, Air Conditioning, & Night Sky Radiant Cooling  
**Climate Zone 9- Albuquerque**  
 for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD



## Water & Power Use

for Evaporative Cooling, Air Conditioning, & Night Sky Radiant Cooling  
**Climate Zone 8- Silver City**  
 for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

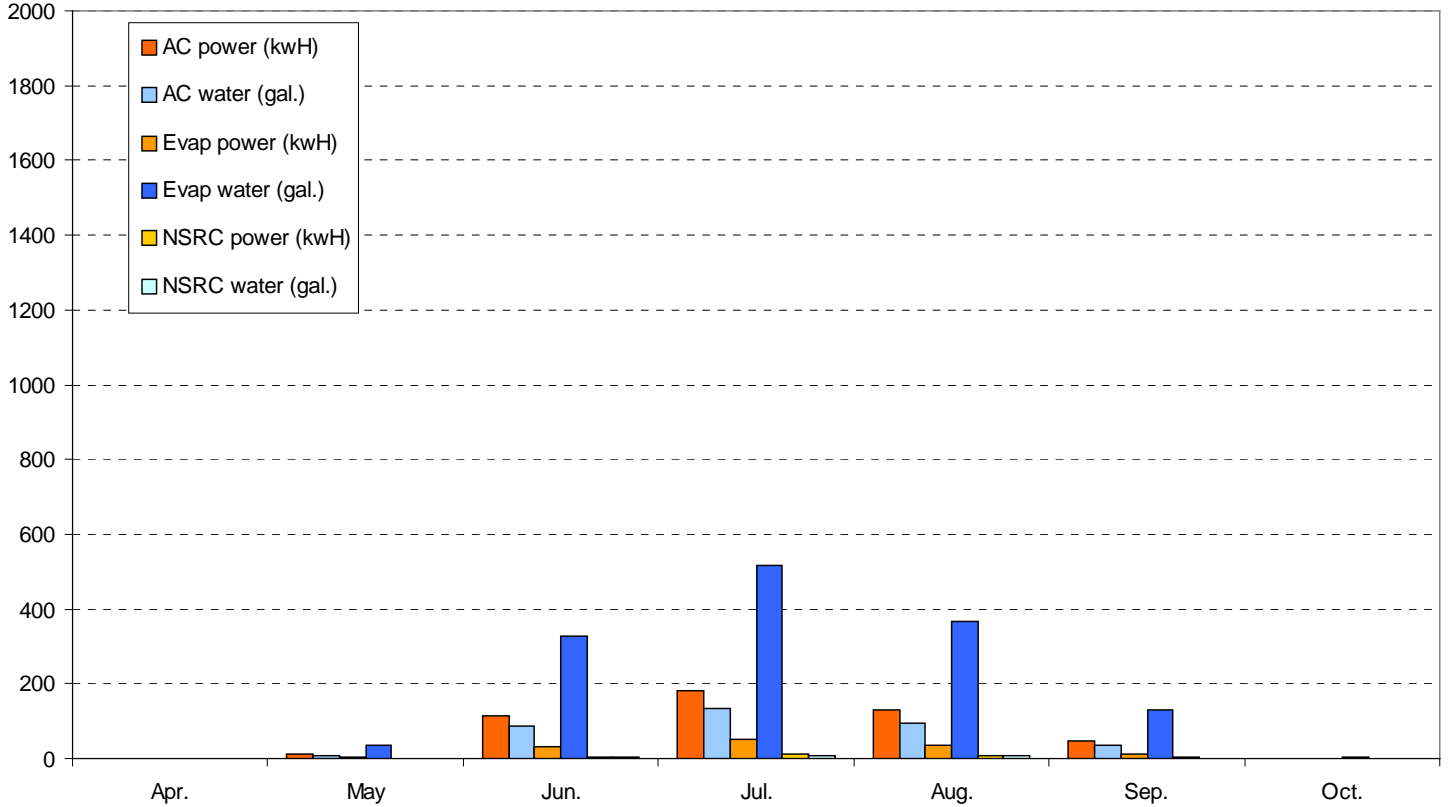


## Water & Power Use

for Evaporative Cooling, Air Conditioning, & Night Sky Radiant Cooling  
**Climate Zone 7- Corona**

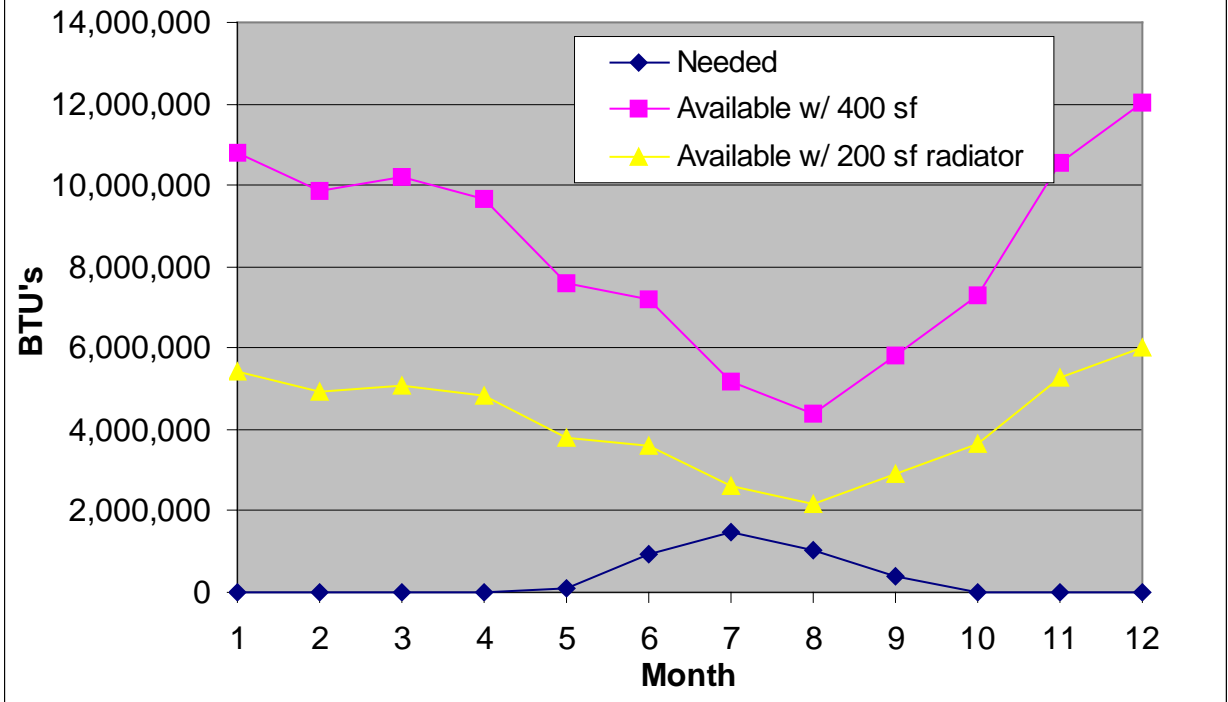
for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

**kWh,  
Gallons**



### BTU's Needed vs. BTU's Available with NSRC

Climate Zone 7- Corona  
for an 1800 sf. House @ base 65 CDD

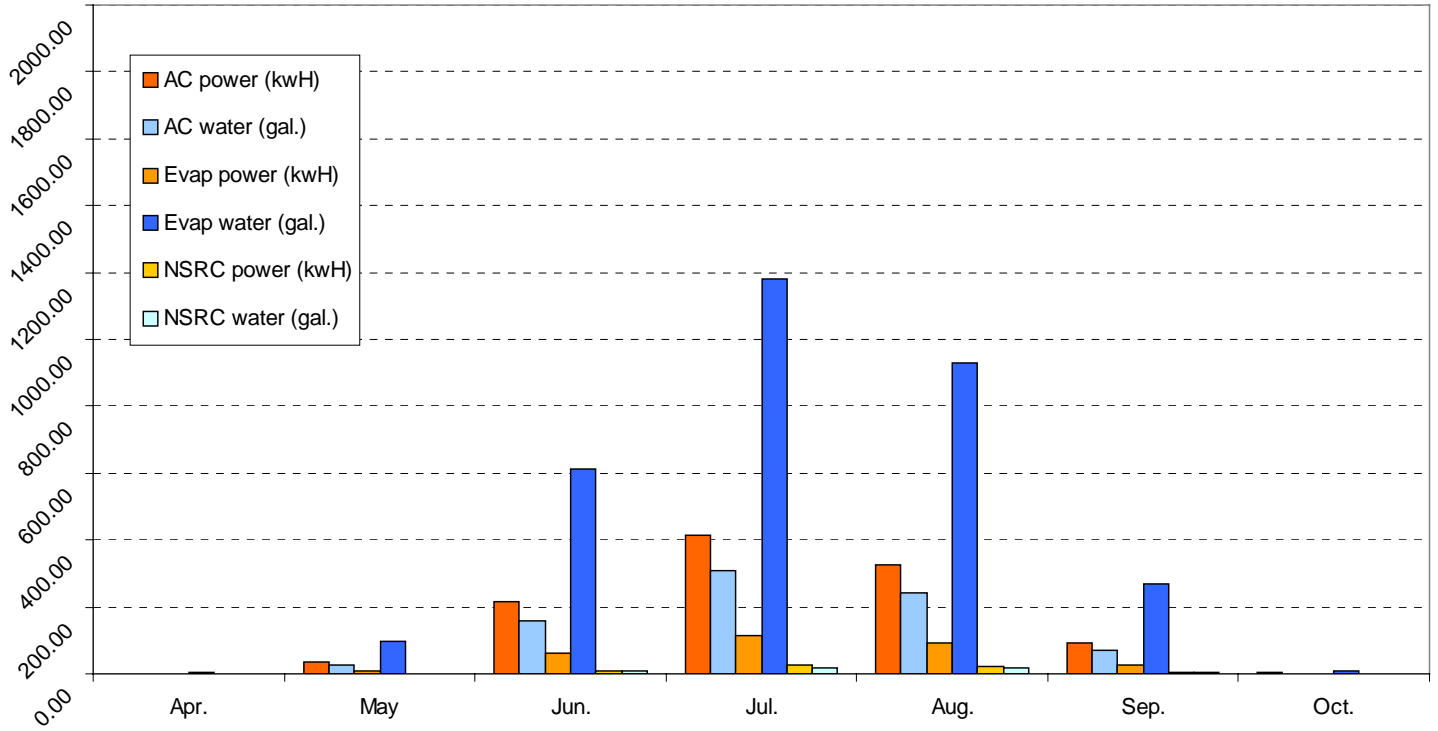


Water & Power use for Evaporative Cooling, Air Conditioning, &  
Night Sky Radiant Cooling

**Climate Zone 6- Bloomfield**

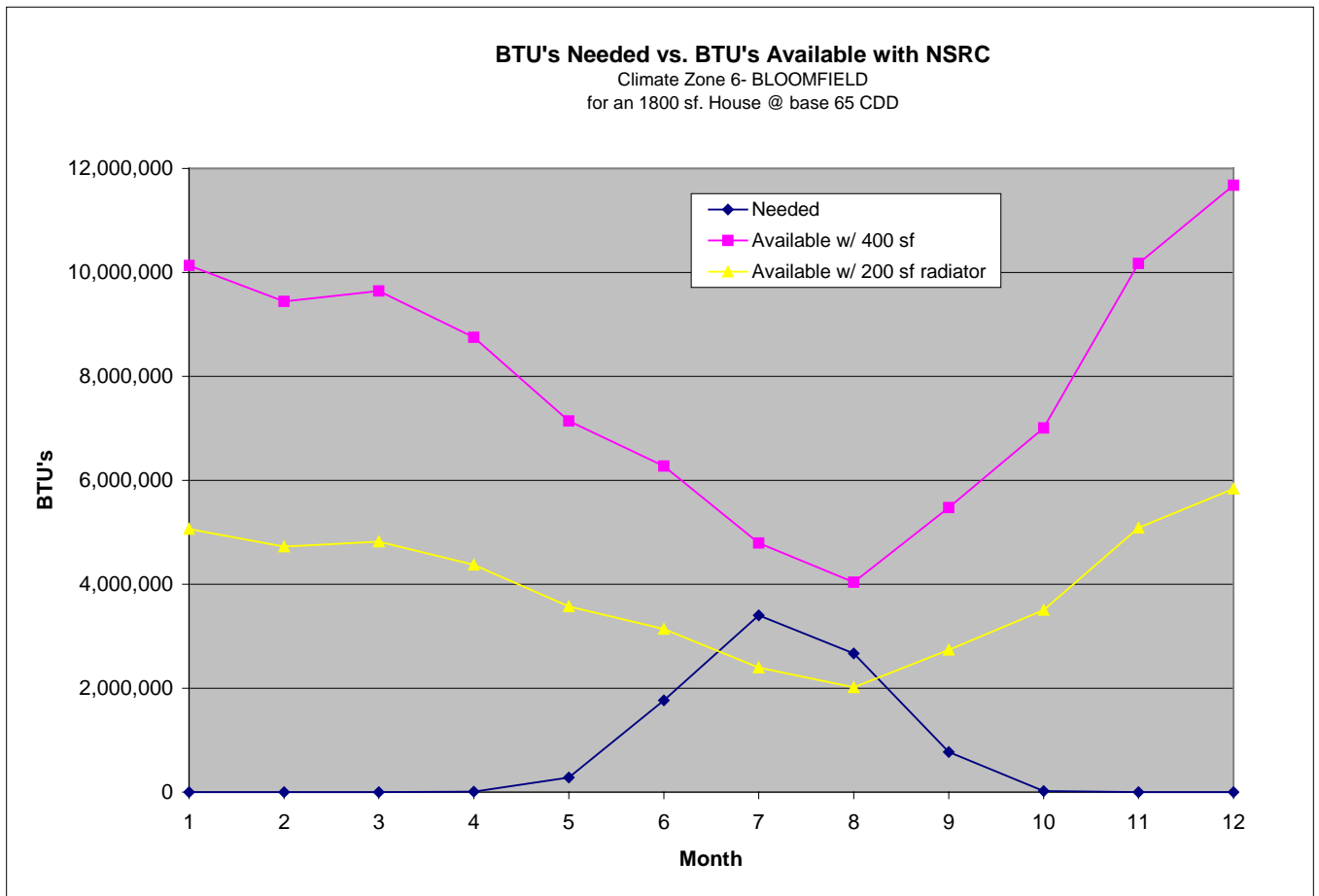
for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

kWh,  
Gallons



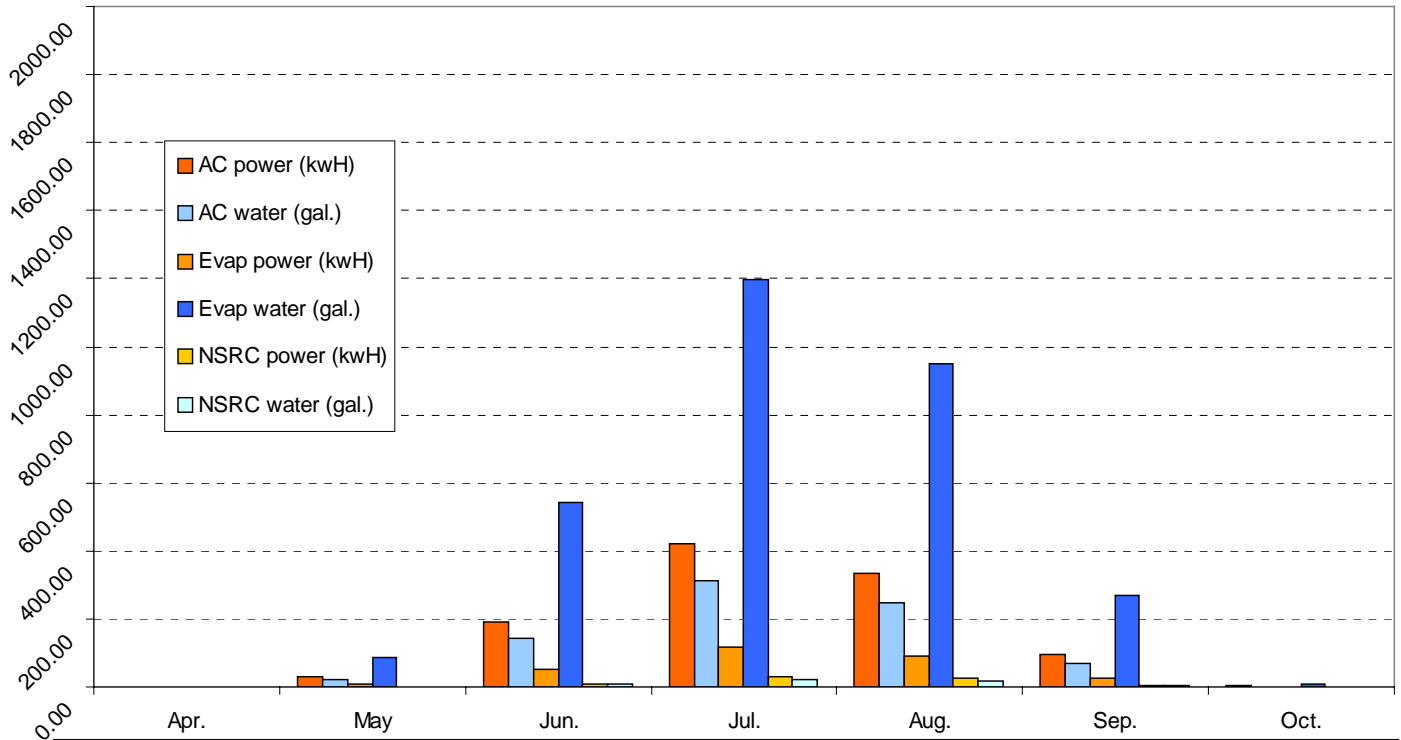
**BTU's Needed vs. BTU's Available with NSRC**

Climate Zone 6- BLOOMFIELD  
for an 1800 sf. House @ base 65 CDD

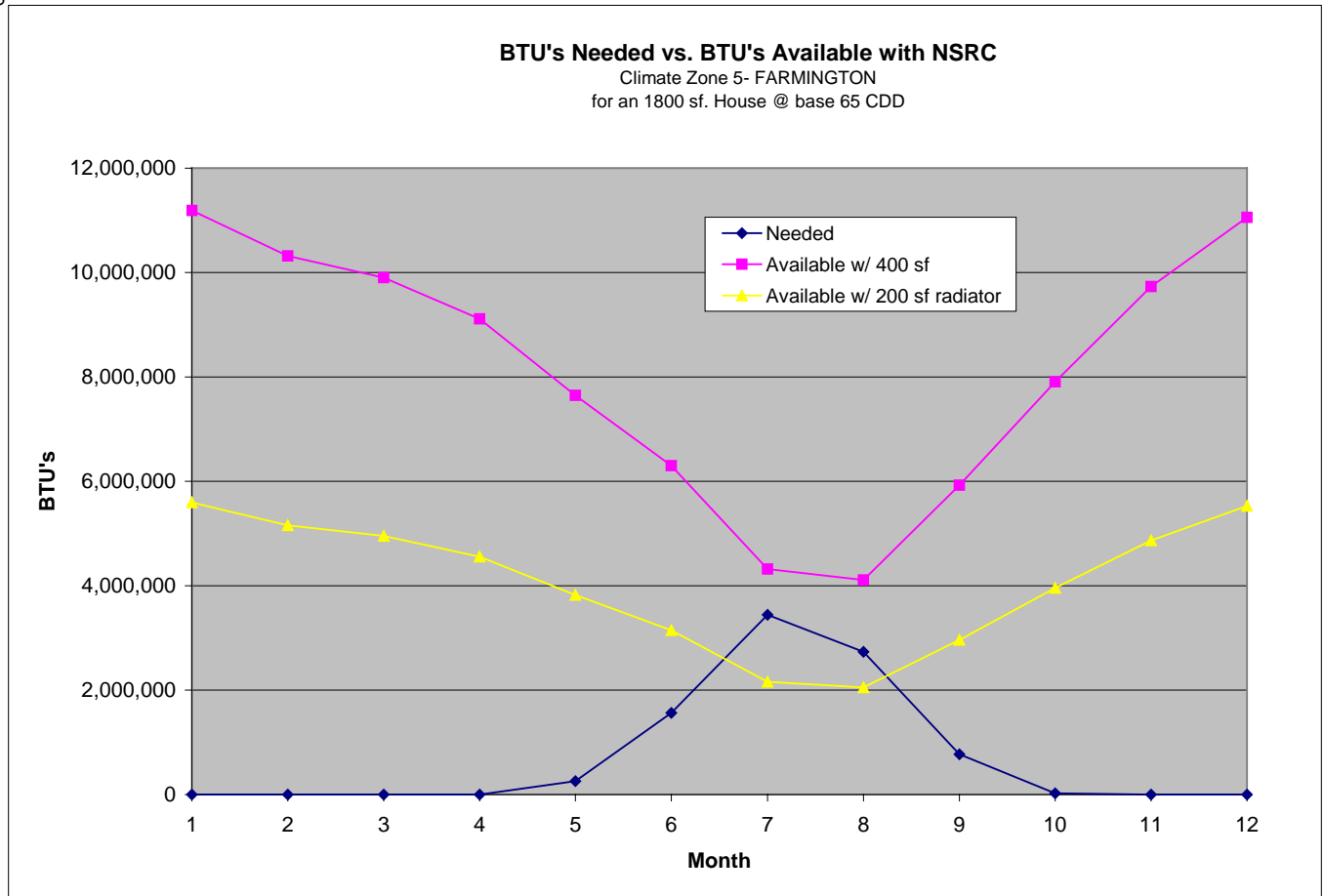


Water & Power use for Evaporative Cooling, Air Conditioning, &  
Night Sky Radiant Cooling  
**Climate Zone 5- Farmington**  
for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

kWh,  
Gallons



**BTU's Needed vs. BTU's Available with NSRC**  
Climate Zone 5- FARMINGTON  
for an 1800 sf. House @ base 65 CDD

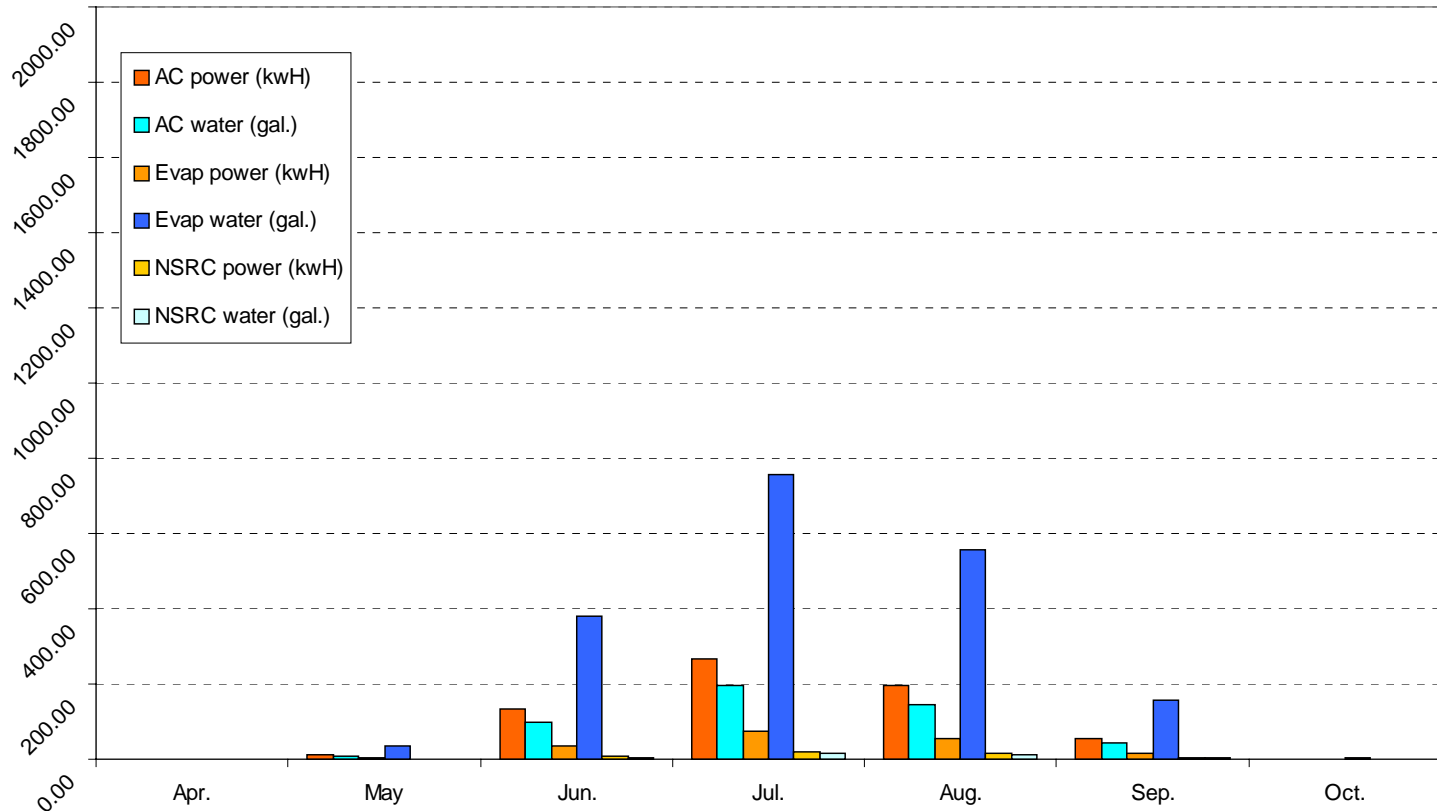


# Water & Power use for Evaporative Cooling, Air Conditioning, & Night Sky Radiant Cooling

## Climate Zone 4- Santa Fe

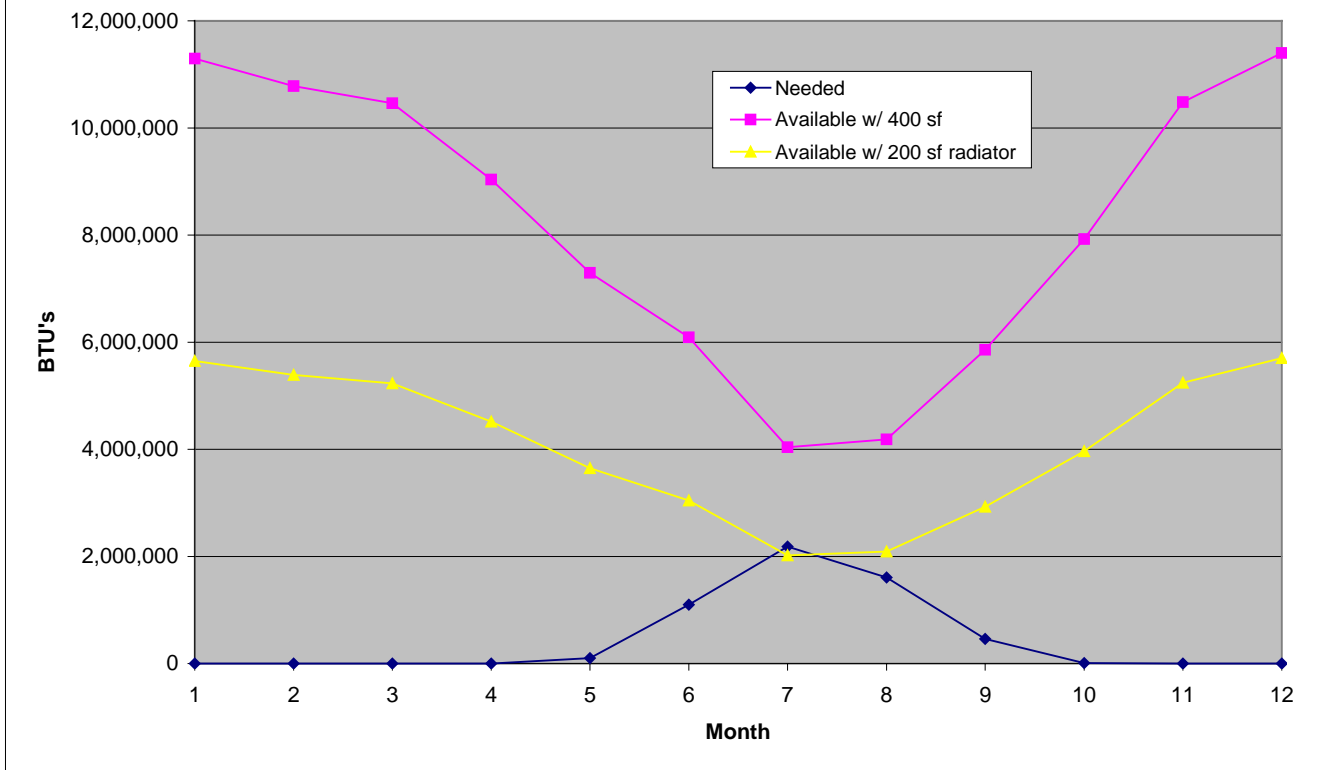
for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

**kWh,  
Gallons**



### BTU's Needed vs. BTU's Available with NSRC

Climate Zone 4- SANTA FE  
for an 1800 sf. House @ base 65 CDD

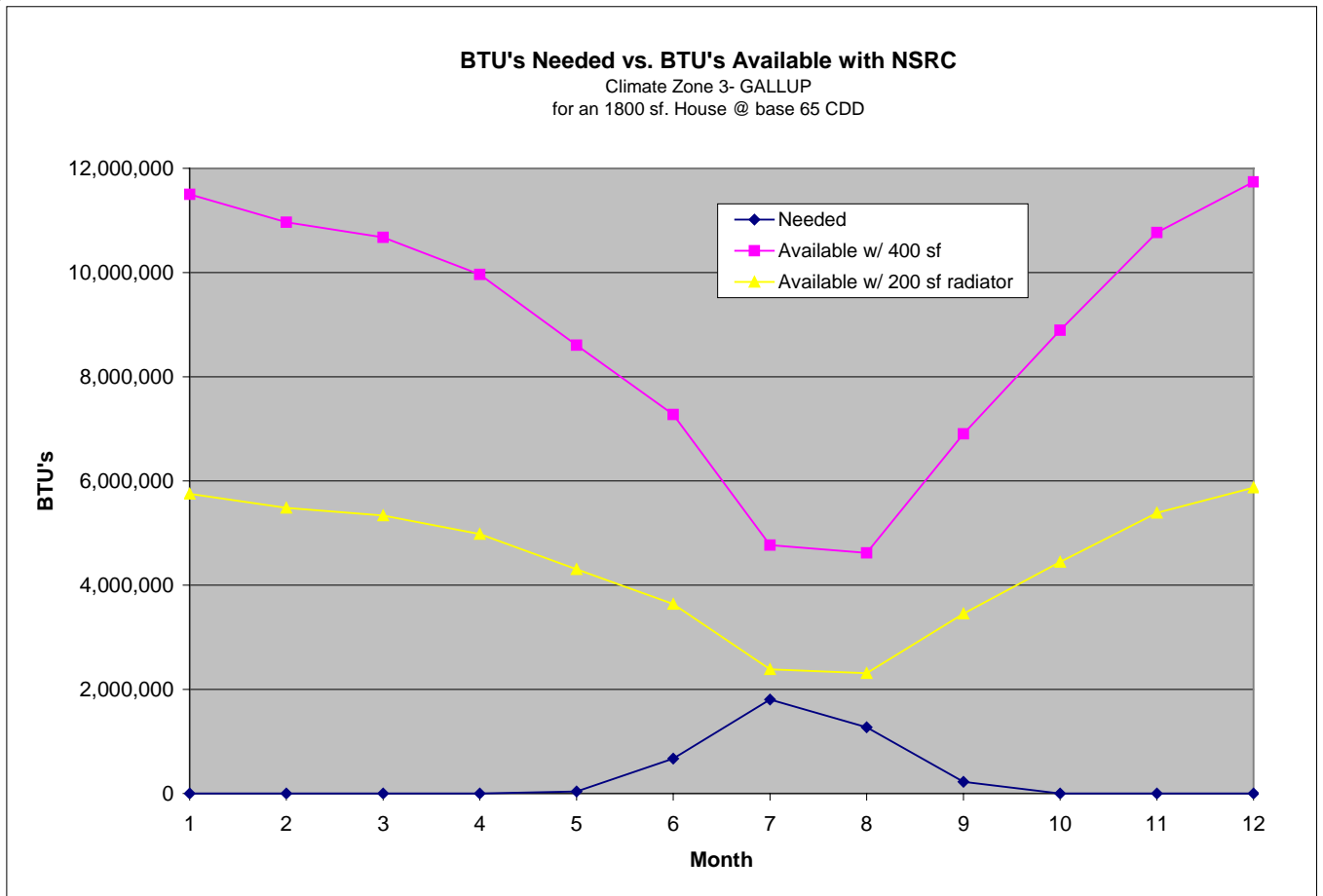
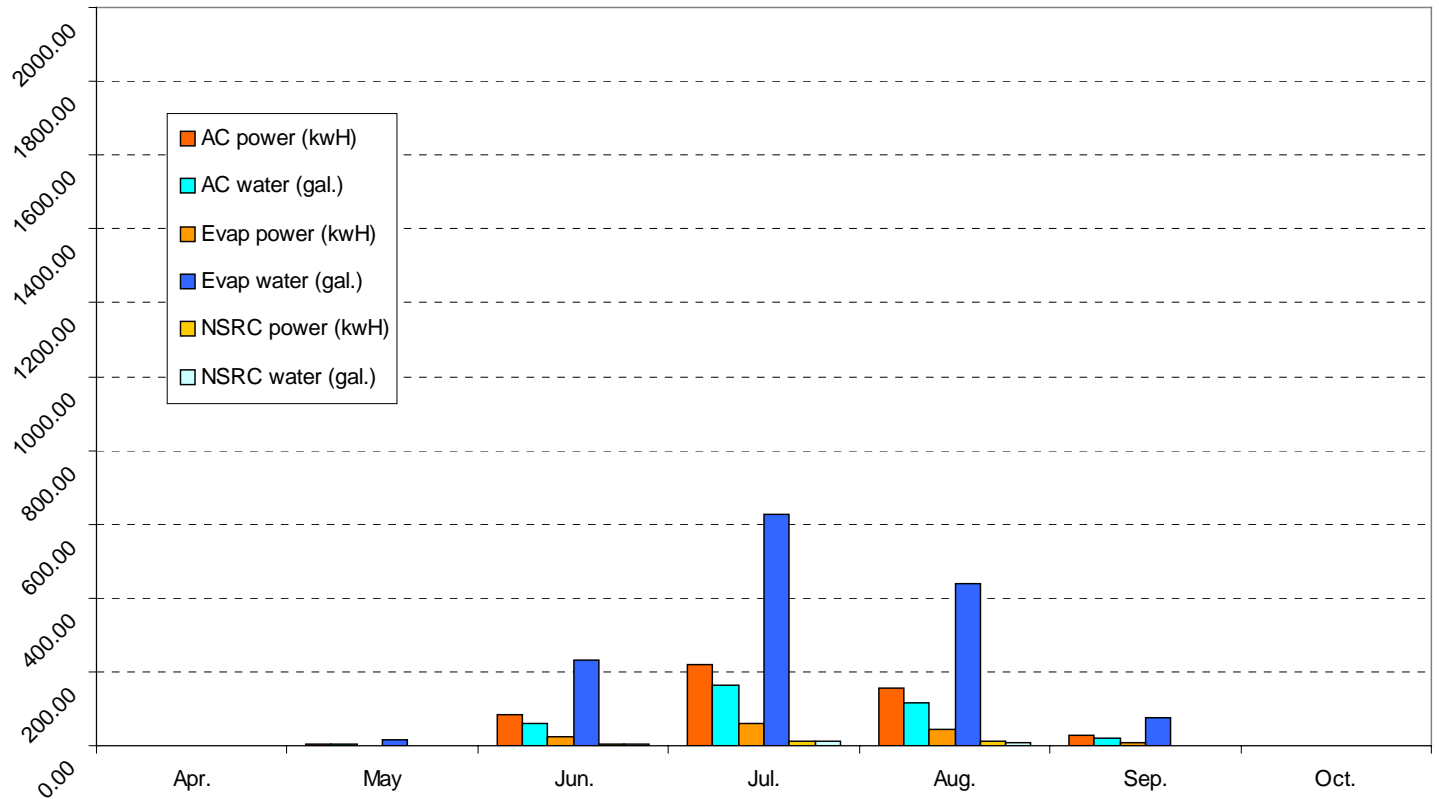


Water & Power use for Evaporative Cooling, Air Conditioning, &  
Night Sky Radiant Cooling

**Climate Zone 3- Gallup**

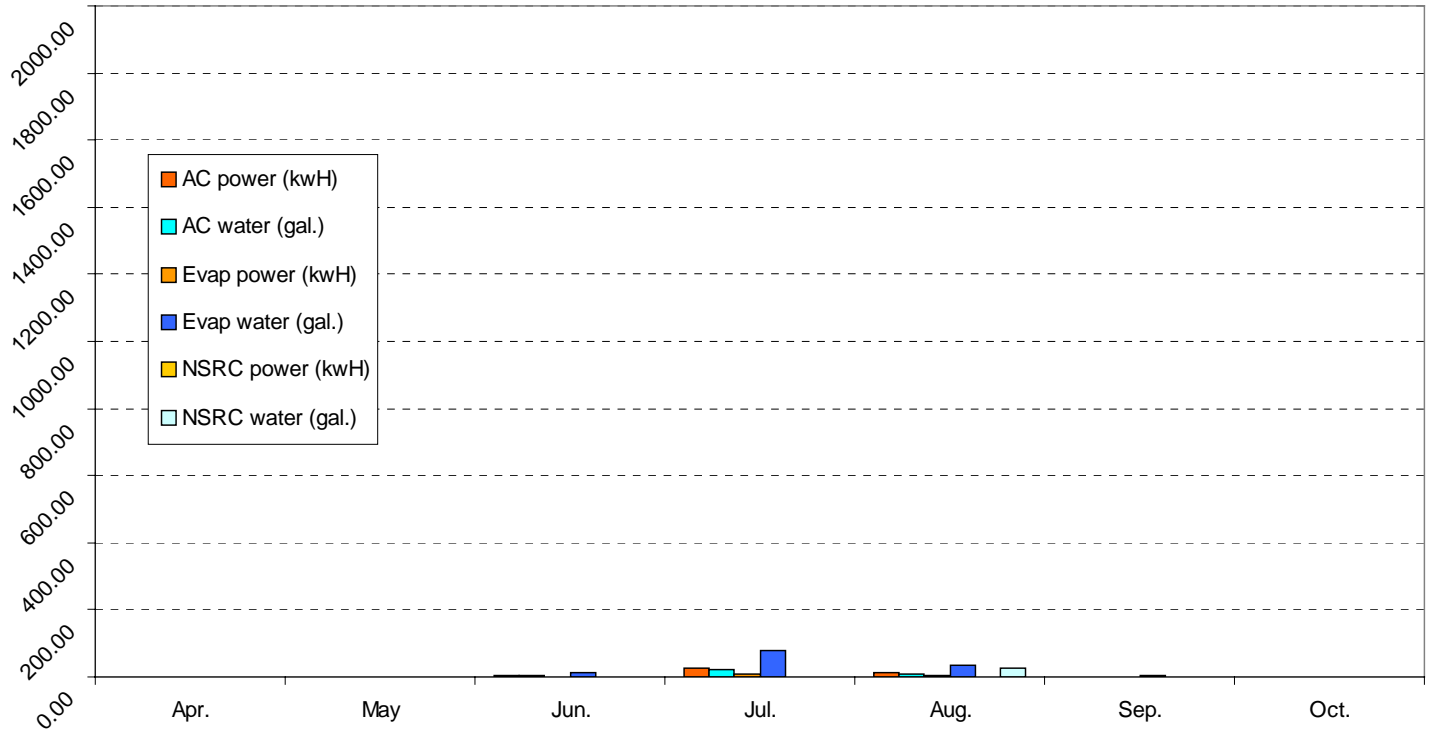
for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

kWh,  
Gallons



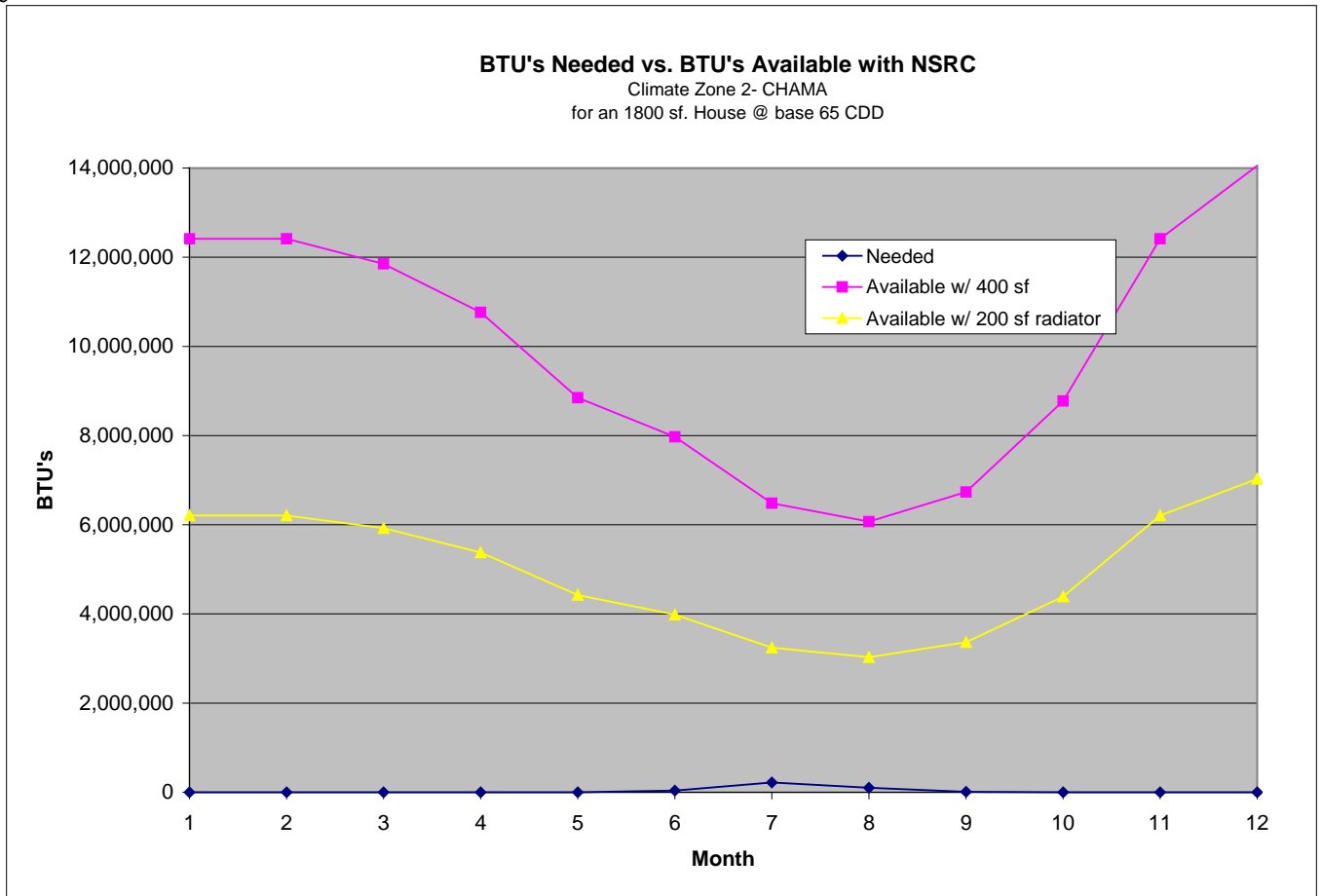
Water & Power use for Evaporative Cooling, Air Conditioning, &  
 Night Sky Radiant Cooling  
**Climate Zone 2- Chama**  
 for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

kWh,  
Gallons



**BTU's Needed vs. BTU's Available with NSRC**

Climate Zone 2- CHAMA  
 for an 1800 sf. House @ base 65 CDD

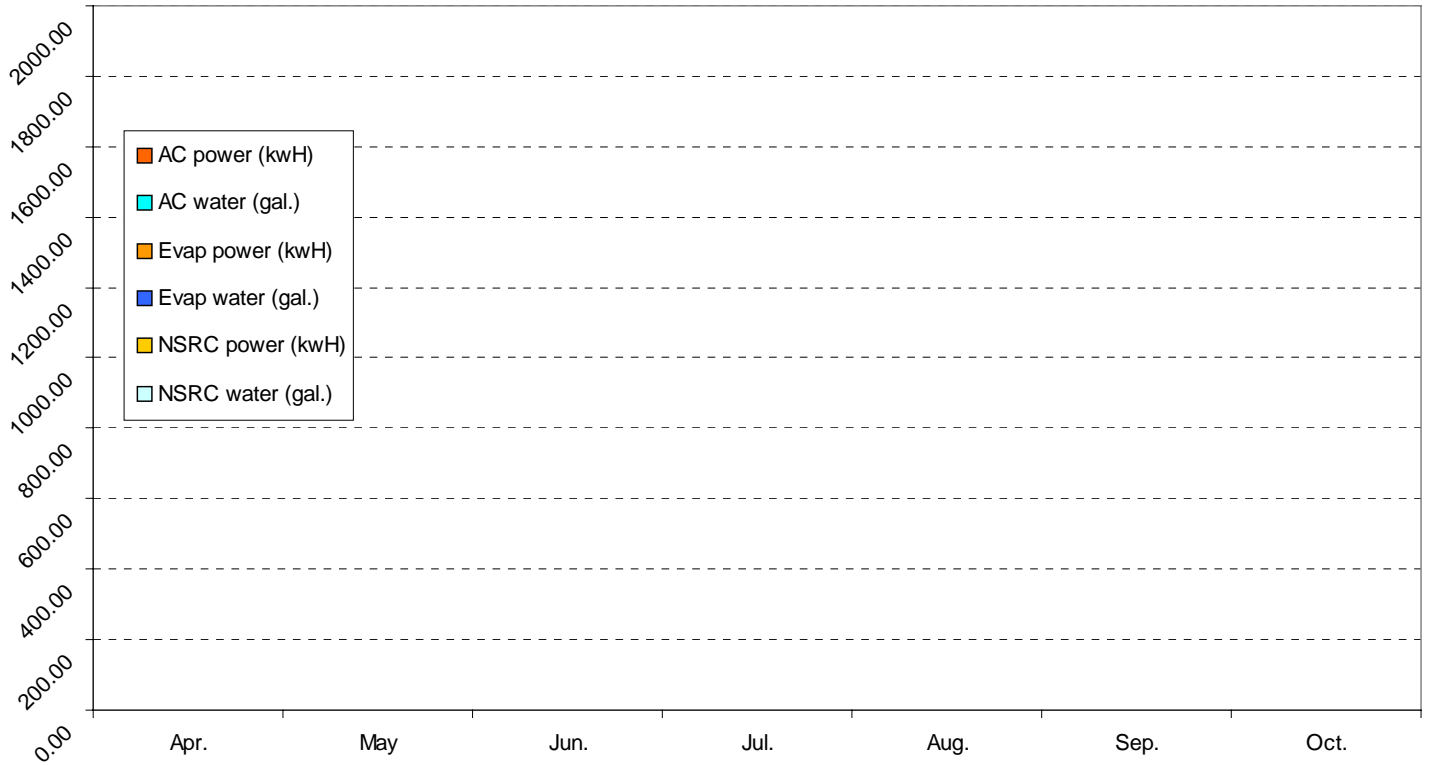


Water & Power use for Evaporative Cooling, Air Conditioning, &  
Night Sky Radiant Cooling

**Climate Zone 1- Red River**

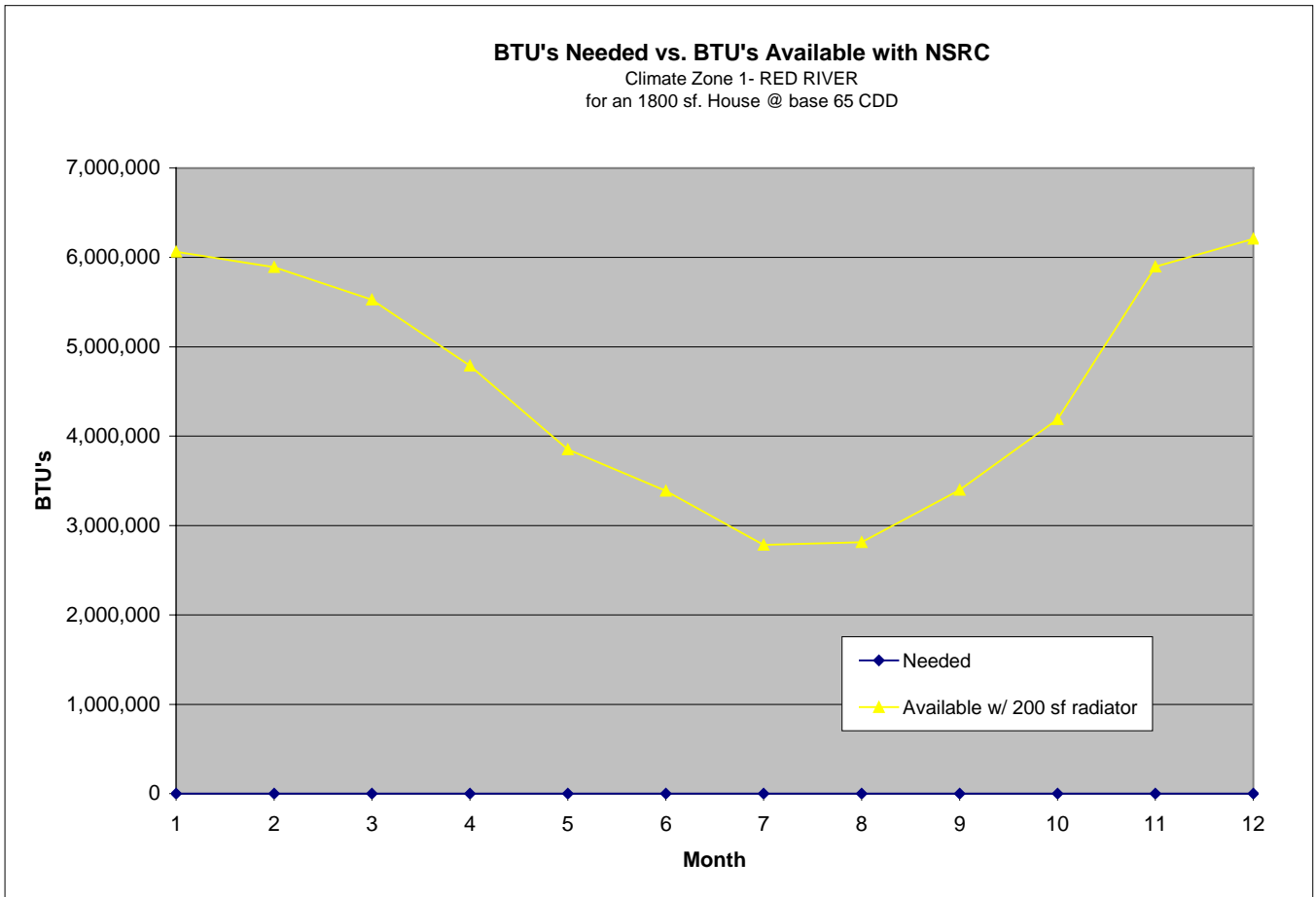
for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD

kWh,  
Gallons



**BTU's Needed vs. BTU's Available with NSRC**

Climate Zone 1- RED RIVER  
for an 1800 sf. House @ base 65 CDD

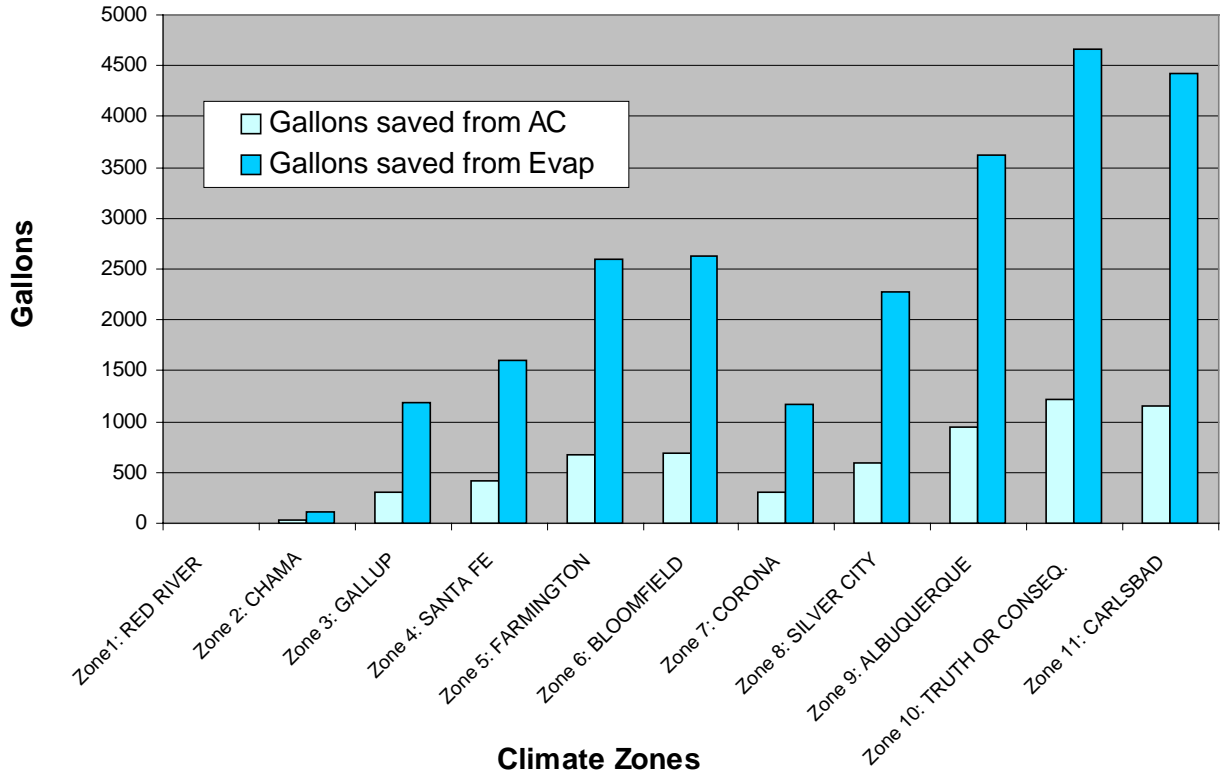


\* this chart represents savings for a well built efficient 1800 Sq. Ft. house with 400 Sq. Ft. of radiator panel.

Savings Summary per Climate Zone													
Climate Zone/ City	BASE	DD/Yr	BTUs Needed	AC ANNUAL SUMMARY				EVAP ANNUAL SUMMARY				Cooling Costs Saved using NSRC	
				Needed KwH	Saved using NSRC KwH	Saved using NSRC \$	Saved using NSRC Gallons	Needed KwH	Saved using NSRC KwH	Saved using NSRC \$	Saved using NSRC Gallons		
Zone 1: RED RIVER	65	0	0	0	0	\$0	0	0	0	0	\$0	0	100%
Zone 2: CHAMA	65	37	375775	46	39	\$3	29	13	11	\$1	111	111	85%
Zone 3: GALLUP	65	395	4011652	490	416	\$35	308	136	116	\$10	1184	1184	85%
Zone 4: SANTA FE	65	537	8785009	666	566	\$48	419	185	157	\$13	1610	1610	85%
Zone 5: FARMINGTON	65	884	8785009	1073	912	\$78	675	298	259	\$22	2594	2594	85%
Zone 6: BLOOMFIELD	65	878	8927194	1090	927	\$79	886	303	257	\$22	2636	2636	85%
Zone 7: CORONA	65	392	3971027	485	412	\$35	305	135	114	\$10	1172	1172	85%
Zone 8: SILVER CITY	65	760	7718621	943	801	\$68	593	262	223	\$19	2279	2279	85%
Zone 9: ALBUQUERQUE	65	1269	12888066	1574	1275	\$108	943	437	354	\$30	3626	3626	81%
Zone 10: TRUTH OR CONSEQ.	65	1878	19093430	2332	1637	\$139	1211	648	455	\$39	4656	4656	70%
Zone 11: CARLSBAD	65	2153	21855884	2669	1555	\$132	1150	741	432	\$37	4422	4422	58%

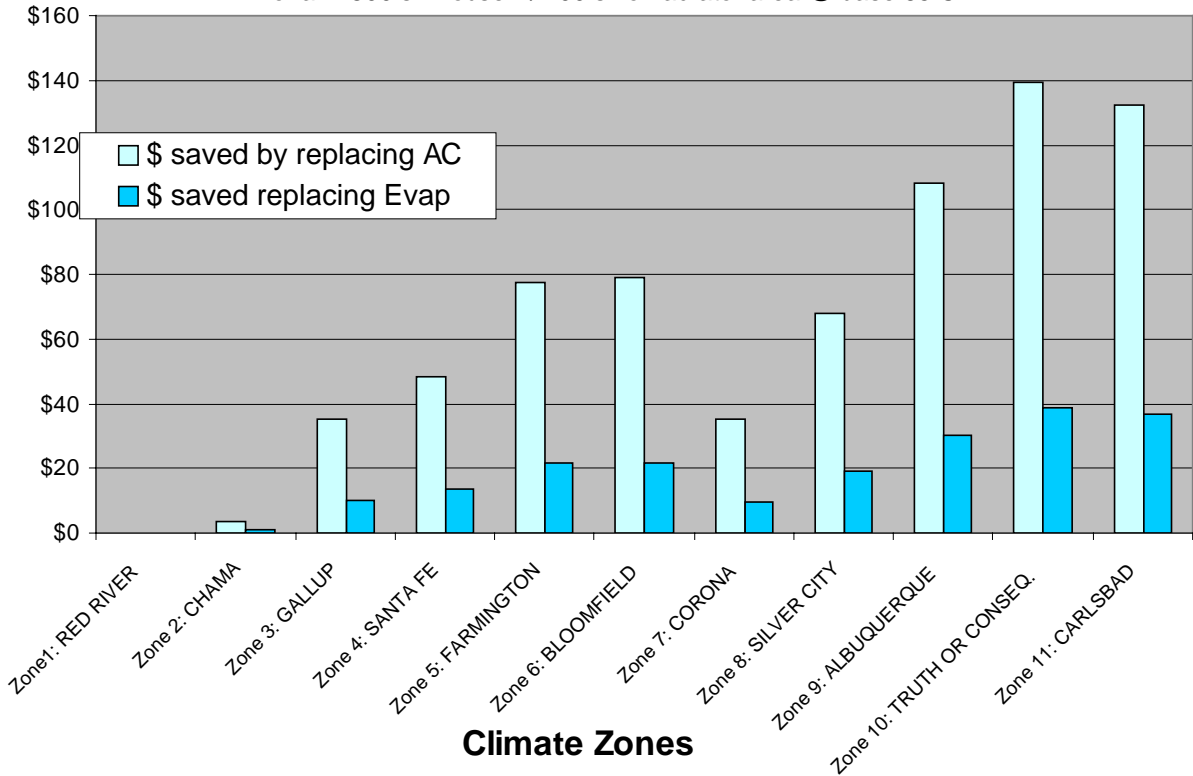
## Annual Water Savings using Night Sky Radiant Cooling vs. AC & Evap.

for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD



## Annual \$ Savings from Night Sky Radiant Cooling vs. AC & Evap.

for an 1800 sf. House w/ 400 sf. of radiator area @ base 65 CDD



# 7

## Field Tested Systems Summary

5 various NSRC systems were field inspected and explained in this section. Two were cooling only systems. One utilized unglazed pool collectors for the radiators. One utilized existing glazed collectors maximized for heating and one was a fin tube system under a metal roof (Dawn System, ™) with a low “U” value but a large area. This shows the varied directions the technology can be manifested. We were able to test 3 systems and establish “U” Values for the radiators and understand the advantages and disadvantages of each of the systems.

The testing procedures and results are explained.

**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

Mark Chalom Architect  
Bristol Stickney Consulting



## **Field Tests – Installed Night Sky Radiant Cooling Systems**

### **Brief Comparison of the Three Test Systems**

Three New Mexico houses were identified where direct solar heated mass floors were already installed. They are located in Tesuque, Santa Fe and Albuquerque. The owners of these houses allowed their warm floor heating systems to be operated in reverse for cooling in summer, and the results monitored with data loggers for several weeks each.

The installations were all similar in that the mass floors were all nominal 4” concrete. The concrete contained plastic “PEX” tubing, commonly used in radiant heated floors. The tubing allows the floor to be heated or cooled by pumping water or antifreeze solution through the core of the concrete. The floors were all insulated in some way. The Albuquerque mass floor was insulated with foam only around the perimeter, while the other houses had foam insulation under the concrete as well as the perimeter.

These three systems had some major differences as well. Each house was installed with a different kind of radiator panel set at various angles to the horizon. Unglazed plastic panels were used in Tesuque, at the Stickney home, and operated during the test periods only for cooling the mass floor at night. Existing solar collectors were employed in Santa Fe, at the Herman home, with single glass covers and selective surface black plates. These provided floor cooling at night and solar hot water during the day. In Albuquerque, at the Caster home, an existing metal roof was retrofitted with cooling fins below the metal roof to act as a radiator for the mass floor. This conventional metal roof was used to cool the floor at night and also heat the domestic hot water for the house on sunny days.

### **Field Test Goals**

The purpose of the field testing was simply to verify that useful cooling can be achieved by storing it in a mass floors when night radiators are installed on a house. The earlier bench testing of individual panels under controlled conditions yielded very encouraging results, as listed in the test results in Section 5 “Radiator Testing and Results”. But in the bench tests, the cool storage mass was a barrel of water, and not an actual living space. The field tests took this one step further by cooling the mass floor in each house, and recording the effect it has on the comfort temperature in the house. The field tests were therefore a proof of concept in practical application.

### **The Test Method**

At each house, the same test method was repeated. A weather station recorded the weather conditions, while “Hobo” data loggers recorded the temperatures in the house cooling system. A timer switch turned on the cooling pump for ten hours each night, from 8PM to 6AM. All night, liquid was pumped from the floor tubing, to the radiator panels on the roof and back to the floor. The data loggers were programmed to record the following temperatures at five-minute intervals:

- Mass floor surface temperature – This temperature provides the cooling effect in the living space by thermal radiation and convection to the room.
- Supply temperature feeding the radiator – This temperature corresponds to the core temperature inside the concrete floor.
- Return temperature coming back from the radiator – This temperature can be used to calculate the thermal energy (heating or cooling) provided by the radiator panels.
- Room air temperature near the ceiling – This is an indicator of the comfort level in the room and is driven by the floor surface temperature.

### **Tesuque Summary**

The size of the mass floor in Tesuque at the Stickney home is 257 square feet of “radiant heated” concrete. Two plastic radiator panels were placed on the roof and mounted near Horizontal. **See Figure 1.** The panels were the kind normally used for summertime swimming pool solar heating made by Sealed Air Corporation. The total radiator area of these panels was 62.7 square feet. This amounts to a radiator of about ¼ of the size of the mass floor surface area.



Figure 1

**Figure 2** shows the system response on a typical warm, clear day and night. The surface temperature of the floor is lowered by around 4 degrees over night. This cooler floor temperature then holds the room temperature a few degrees cooler throughout the next warm day. During this test period, the outdoor temperatures are peaking above 90F while the air in the closed test room rarely exceeds 80F.

### Tesuque Fan Effect

The Tesuque house was tested during separate weeks with and without a low speed floor fan running in the test room. The purpose was to observe the temperature stratification in the room, with and without air mixing. Some stratification was expected, since the hot air in the room is less dense, and will tend to rise to the ceiling, away from the cool floor. A low speed fan was used to force the hotter air to contact the cool floor, and increase the cooling effect by forced convection at the floor surface. This test room had a low ceiling of less than 8 feet. The stratification effect can be expected to be more of a problem in rooms with higher ceilings.

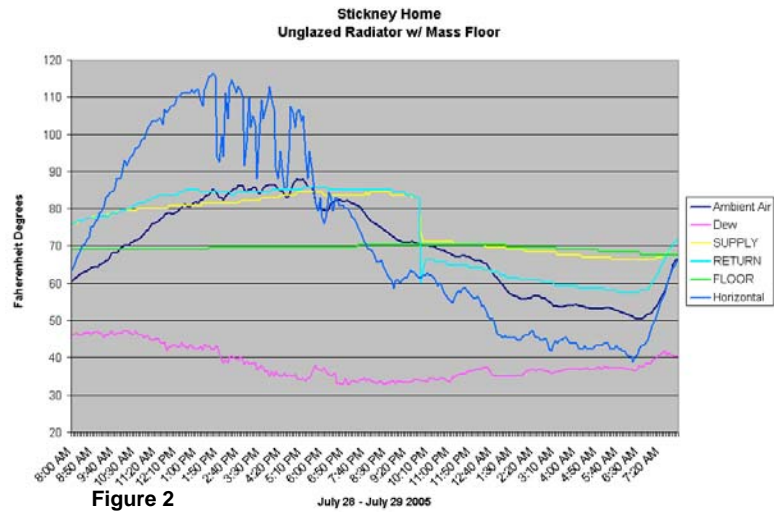


Figure 2

**Figures 3 - 4** show that without the fan, the air reached a temperature that was as much as 7 degrees warmer than the floor. But, with the fan running, the stratification was reduced by more than half, with the air staying less than 3 degrees warmer than the floor.

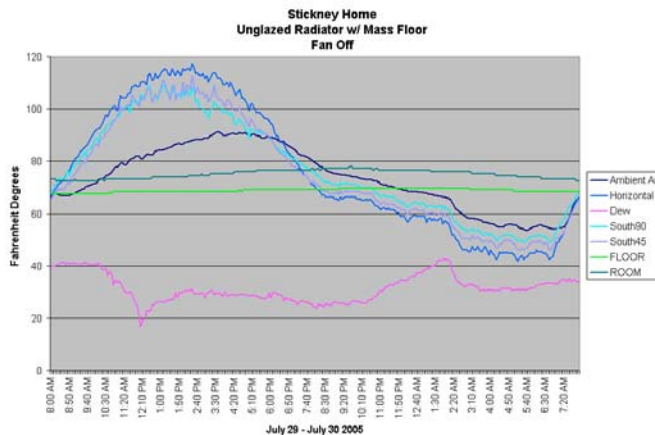


Figure 3

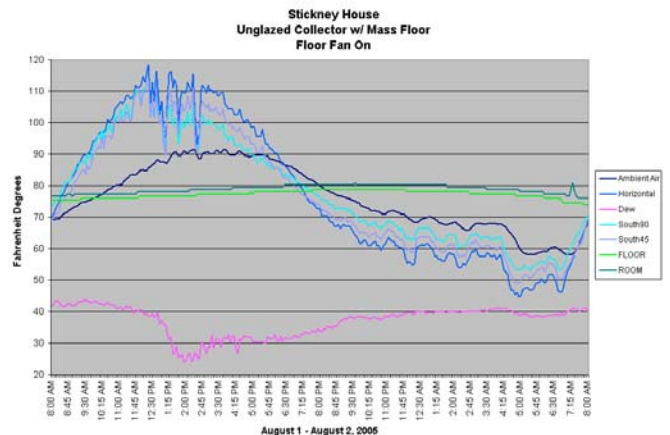


Figure 4

## Santa Fe Summary

The size of the mass floor tested in Santa Fe at the Herman home is 628 square feet of “radiant heated” concrete. Five solar heat panels were already installed on the roof and mounted at a 75 degree tilt. They include single glass covers and a black selective surface on the absorber plate that we are using as the radiator. **See Figure 5.** The panels are the kind commonly used for year round solar water heating, manufactured in the 1980’s by Yazaki Corporation. During the day, in summer, these panels are used to heat the water in a small exercise pool. The total radiator area of these panels was 101.6 square feet. This amounts to a radiator of about 1/6 of the size of the mass floor surface area.



Figure 5

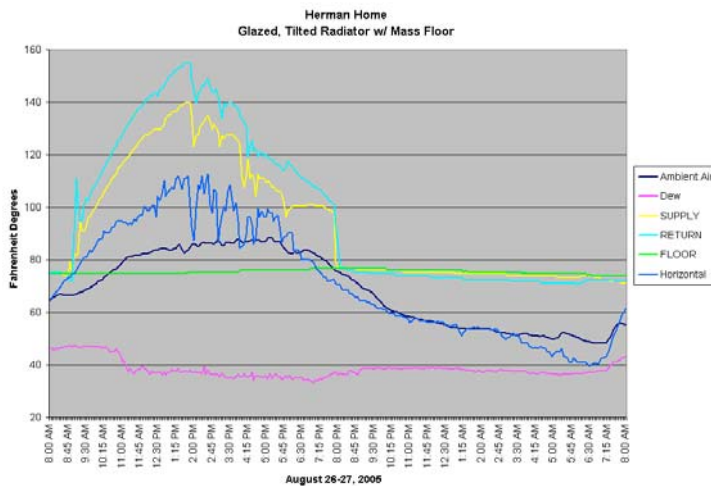


Figure 6

**Figure 6** shows the system response on a warm, clear day and night. The surface temperature of the floor is typically lowered by around 3 degrees over night. This cooler floor temperature is then available for cooling throughout the next warm day. The test room in this installation is the garage, which is in use by the owner and opened occasionally during the monitoring. The air temperature fluctuates widely when the garage is open, so the best indicator of radiant cooling performance is the floor temperature. We found in the Stickney tests in Tesuque that the air temperature in a closed room with a low ceiling followed the floor surface

temperature within 2 – 7 degrees (with and without a fan). So the air temperature in a closed room can be estimated the same way in this case by adding 2 – 7 degrees to the floor surface temperature.

## Albuquerque Summary

The size of the mass floor tested in Albuquerque is 1500 square feet of “radiant heated” concrete. A section of metal roof was retrofitted, and a system of metal fins and plastic tubes installed under the existing roof, mounted at a 22.5 degree tilt. The light colored metal roof becomes both a solar heat absorber by day and a radiator plate by night.

**See Figure 7.** This is a new product that

is intended for year round solar water heating. It is most effective in mild, warmer climates since it is unglazed. It is manufactured by Dawn Solar Corporation. During the

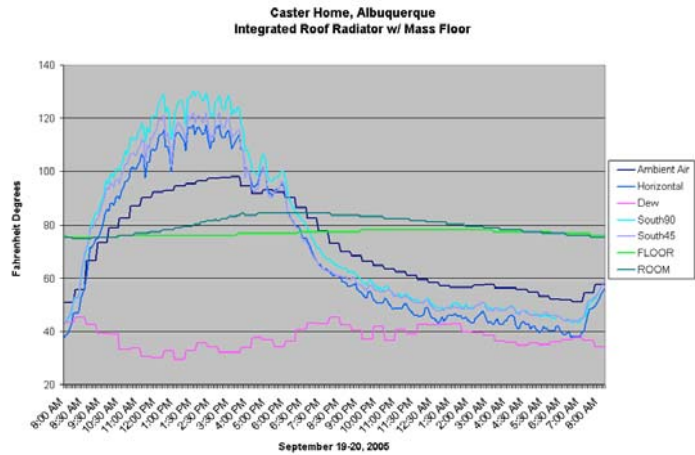


Figure 7

day, whenever sunny weather allows, this roof panel is used to solar-heat the water in a domestic

hot water tank using a heat exchanger. The total radiator area of this roof is 286 square feet. This amounts to a radiator of about 1/5 of the size of the mass floor surface area to be cooled.

**Figure 8** shows the system response on a warm, clear day and night. The surface temperature of the floor is typically lowered by around 2-3 degrees over night. This cooler floor temperature is then available for cooling throughout the next warm day. The test room in this installation is the main living area in the house, which was in use by the owner during the test period. No indoor fan was used, so the temperature stratification appears in the same range as in the Tesuque test with no fan, about 7-8 degrees from floor to ceiling. The cooling effect is apparent when looking at the afternoon temperatures. The floor surface peaks at about 78F, the indoor air peaks at around 85, while the outdoor air approaches a high of 100F.



**Figure 8**

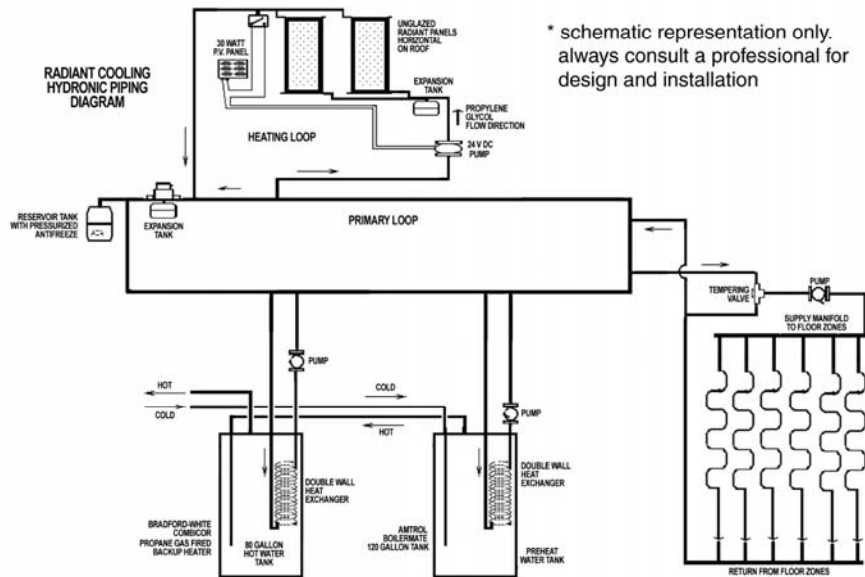
## Observations and Conclusions

As these systems were originally designed for heating only, The cooling radiators on these test buildings were not as large as they could have been. The tests prove that radiant night sky cooling can be delivered effectively and reliably to a concrete floor using this “Hydronic” pumping technique commonly used in “radiant heated” floor systems. However, no attempt was made in these initial tests to maximize or optimize the radiators on these buildings. When greater cooling is required, larger radiators can be installed. On flat roof buildings, nearly the entire surface of the roof may be available for horizontal radiators if needed. Our calculations show when using a “U” Value of 1.66 an area of 1/5 to 1/3 radiator to floor area to be adequate. A system such as the “Dawn” or steep pitched glazed collectors with a “U” Value closer to .4 an area of 1/2 to 100 percent of the roof area may be required.

The night sky radiator cooling rates (U values) estimated from the field tests appear to be within the same range as in the bench tests. This lends further confidence in the results from the earlier radiator test results shown in Section 5. The earlier bench tests show that unglazed “wetted plate” cooling radiators work better than glazed ones, and better than a tube-and-plate radiators. The field tests confirm these results as well.

There is a time lag due to the thermal flywheel effect of the concrete floor that delays the indoor peak temperature until the early evening, instead of occurring earlier in the afternoon when it is hottest outdoors. This could provide an additional energy saving advantage, allowing the cooler outdoor air temperature in the evening to be used to greater advantage in cooling the house.

The cooling effect from a mass floor may work twice as well with a fan mixing the room air.



\* schematic representation only.  
always consult a professional for  
design and installation

## Unglazed Hydronic Floor System Tesuque, NM

### Stickney Home Installation

**Advantages:**

- Simple retrofit to existing radiant heating system.
- Maximizes cooling with potential for providing heat
- Low cost collectors
- Easy to hide behind parapets.

**Disadvantages:**

- not as effective for extreme winter heating



primary loop and plumbing in mechanical closet

**Description:**

This system represents the basic system that can be easily added to a new or existing Radiant heating system. As the existing heating system already includes most of the operating parts, the additional needs for cooling are minimal. The heating system already has the distribution pump and coils in the floor, the thermal mass of the slab, the control thermostats and allocated space in the mechanical area. The addition of the unglazed collector/radiators on the roof, one check valve, an expansion tank, a 60-watt pump and 2 ball valves and the piping between, would add the cooling part of the integrated system. This addition will not add much more to the cost of the total heating/cooling system. We estimate it can be added by a licensed plumber complete for \$3,500 to \$4,000 for 400 SQ. FT. of radiator area. In all climate zones we recommend the use of Propylene Glycol to prevent accidental freezing of the system.

**Summer**

**Day:** during the day this system should be utilized to provide domestic hot water and or hot water for a swimming pool or hot tub.

**Night:** Fluid is pumped through the radiators for 10 hours each night to remove heat from the floor slab and radiate to the night sky. This system can radiate on average 300 BTU's per sq. ft. per night. They can also absorb on average 1,000 BTU's per sq.ft. per day heating. This makes the heating potential very important to the payback cost of the system.

**Winter:**

**Day:** During winter, these collectors can be utilized for space heating or for heating or preheating hot water. This depends on the severity of the outside ambient temperature and wind speed. Fluids in the collectors should be The angle to the horizon can be adjusted to maximize winter heating angle of 45 to 55 degrees with not more than a 15% drop in cooling potential. Further analyzing in the various Climate Zones can be done to develop the optimal angle to provide heating and cooling in the most efficient way. A secondary storage tank may be utilized to store excess hot water until the building or hot water source calls for it.



glazed collectors tilted for heat optimization

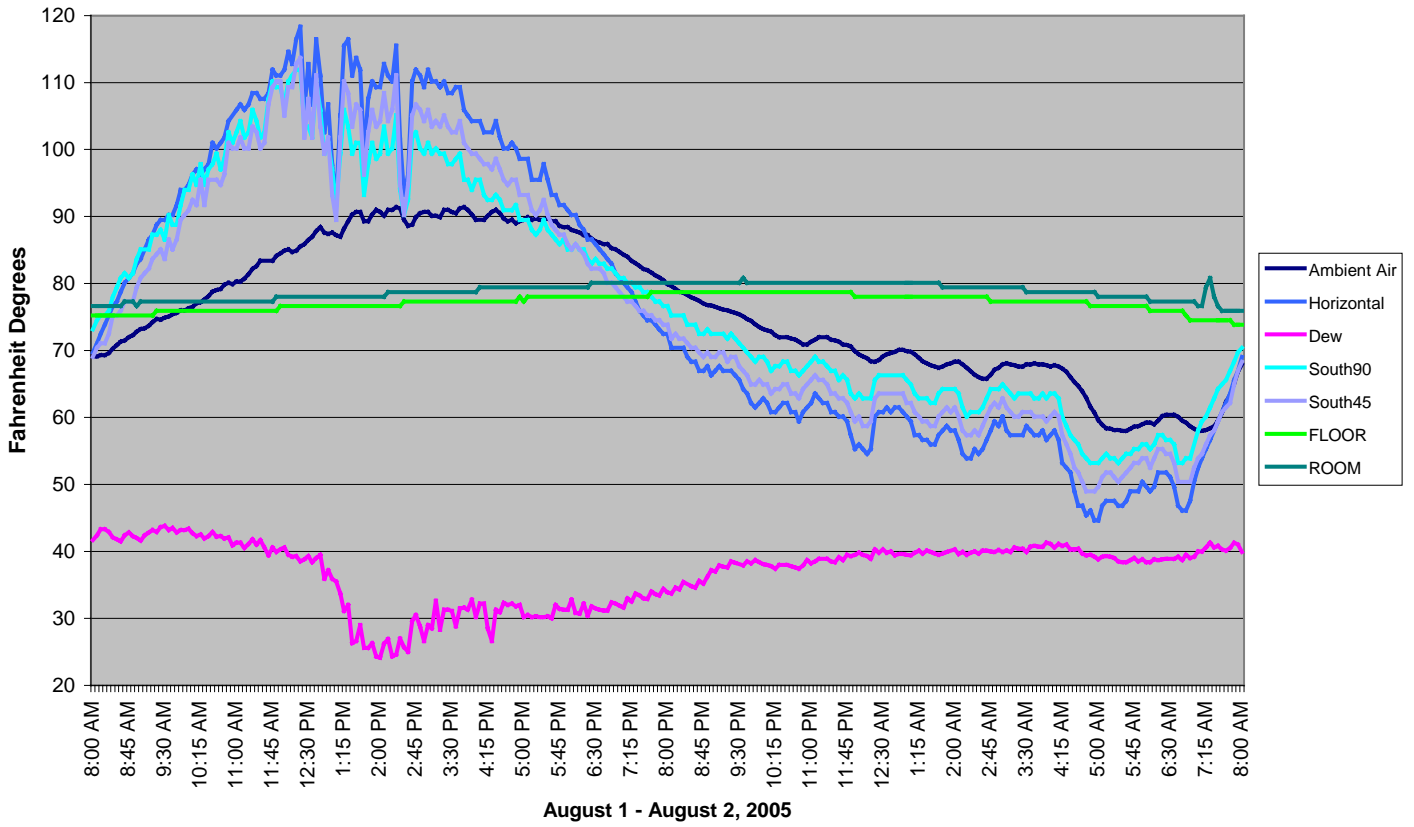


un-glazed horizontal radiators

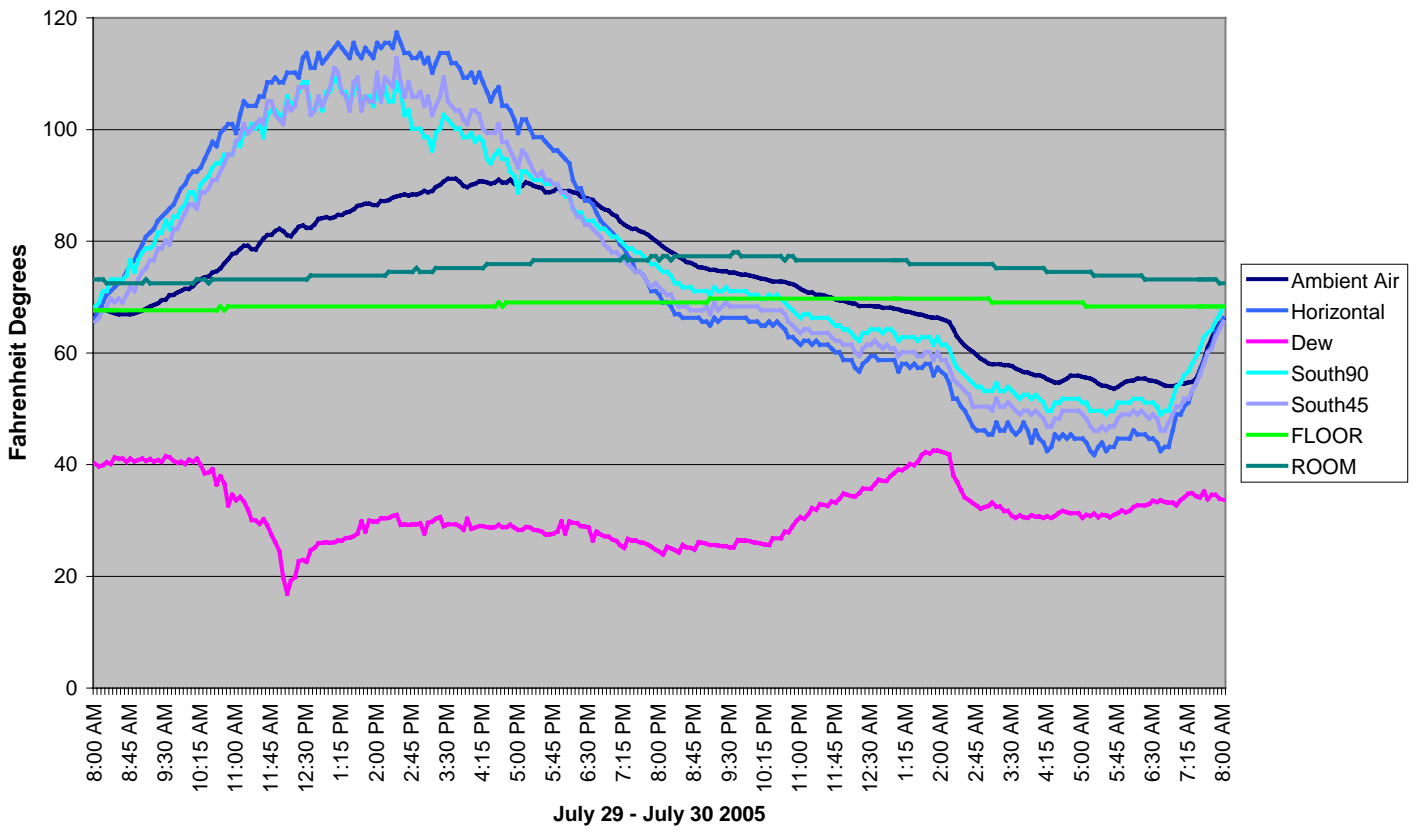
**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

Mark Chalom Architect  
Bristol Stickney Consulting

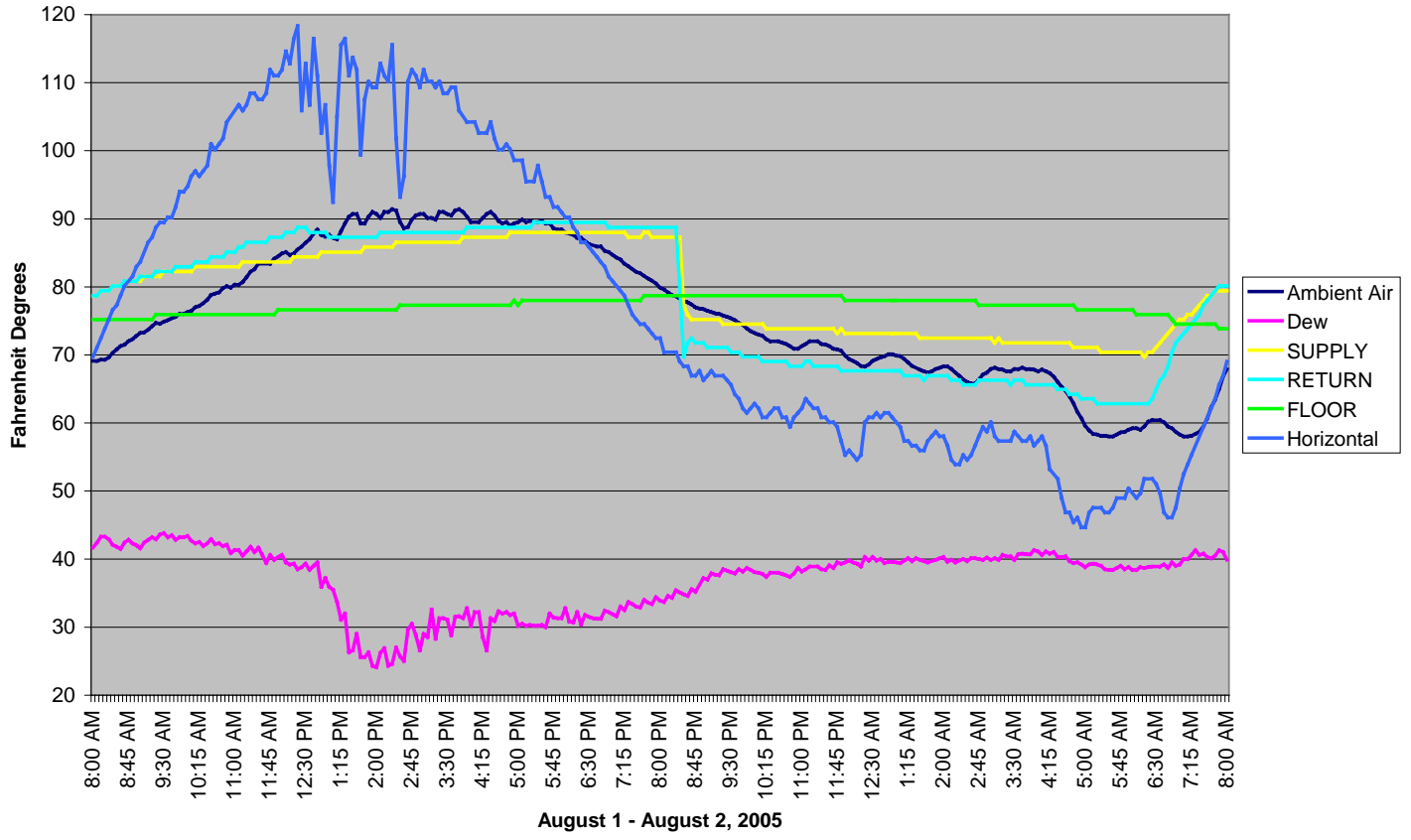
**Stickney House  
 Unglazed Collector w/ Mass Floor  
 Floor Fan On**

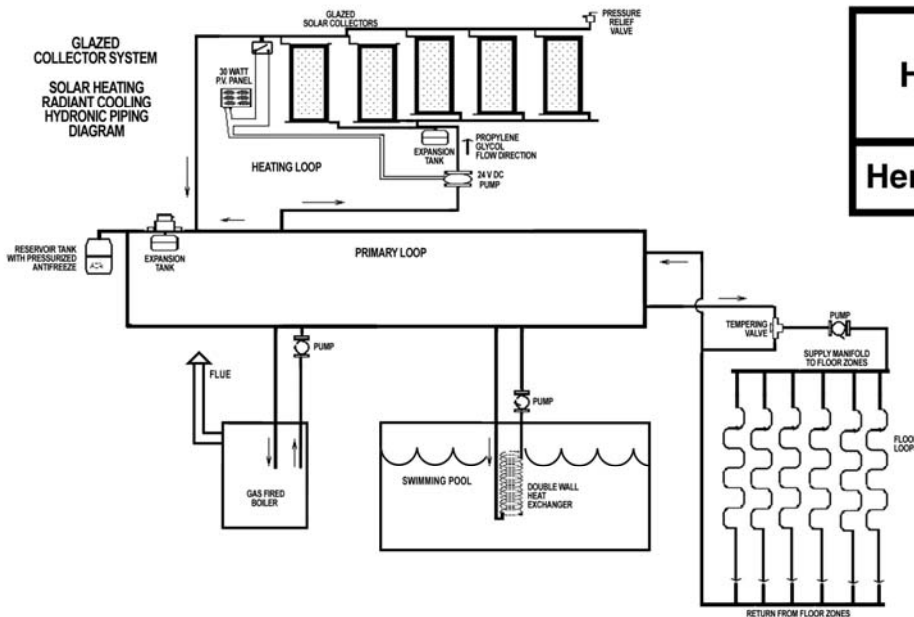


**Stickney Home  
 Unglazed Radiator w/ Mass Floor  
 Fan Off**



**Stickney Home  
Unglazed Radiator w/ Mass Floor**





**Glazed Only  
Hydronic Floor System  
Santa Fe, NM**

---

**Herman House Installation**

**Advantages:**  
simple retrofit for an existing solar hydronic system

**Disadvantages:**  
glazed collectors are much less efficient for cooling



view of mechanical closet

\* schematic representation only.  
always consult a professional for design and installation

**Description:**

This system uses only glazed solar hot water collectors for both heating and cooling. This system is especially easy for applications where solar hot water collection is already taking place. Any typical hydronic radiant floor heating system can easily be modified to incorporate this system of solar heating and radiant cooling with very little cost. Glazed solar hot water collectors mounted on the roof of a building are used for both heating and cooling. While this system is optimized for heating, cooling is also possible at night during the summer months though it is not as efficient as other systems. The solar thermal energy collected can be used to heat or pre-heat water for domestic use or space heating, while the glazed units can radiate heat from the space to the night sky during the summer for cooling.

**Summer**

**Day:** Heat collected from the glazed collectors is used as a preheat mechanism for domestic hot water use.

**Night:** Solar heating loop is inactive. Radiant cooling loop is active. Propylene glycol is pumped through glazed collectors at night to cool the fluid. The fluid is then pumped through hydronic radiant floor loops absorbing heat from the floor and cooling the living space.

**Winter**

**Day:** Propylene glycol is pumped through glazed roof mounted solar collectors (set at optimum tilt) and then run through the hydronic floor loops to heat the space. Excess heat is dumped into an insulated water storage tank and used to preheat domestic hot water.

**Night:** Systems are inactive.



glazed collectors tilted at optimum angle for heating can also be used for cooling

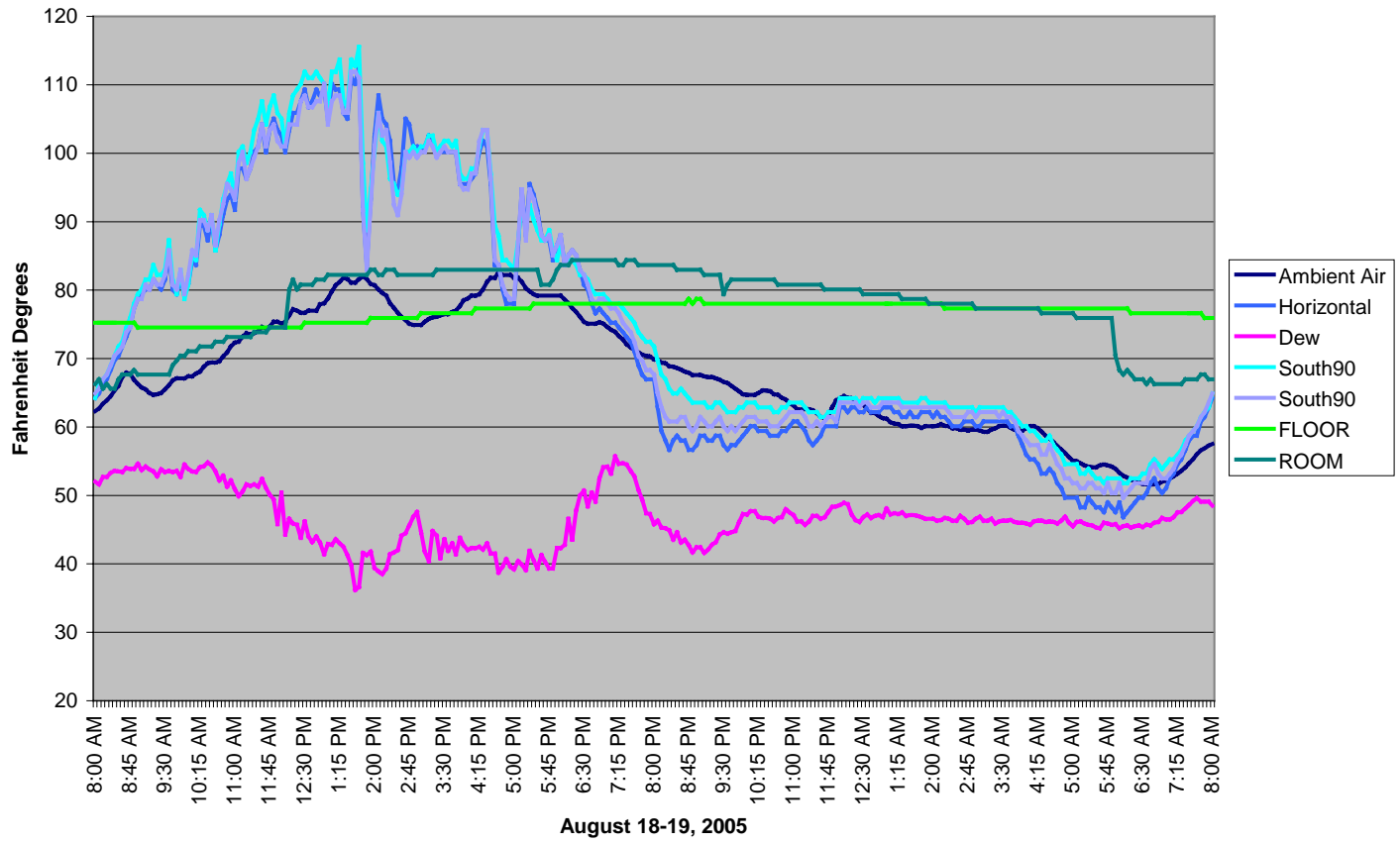


white plate tilt test

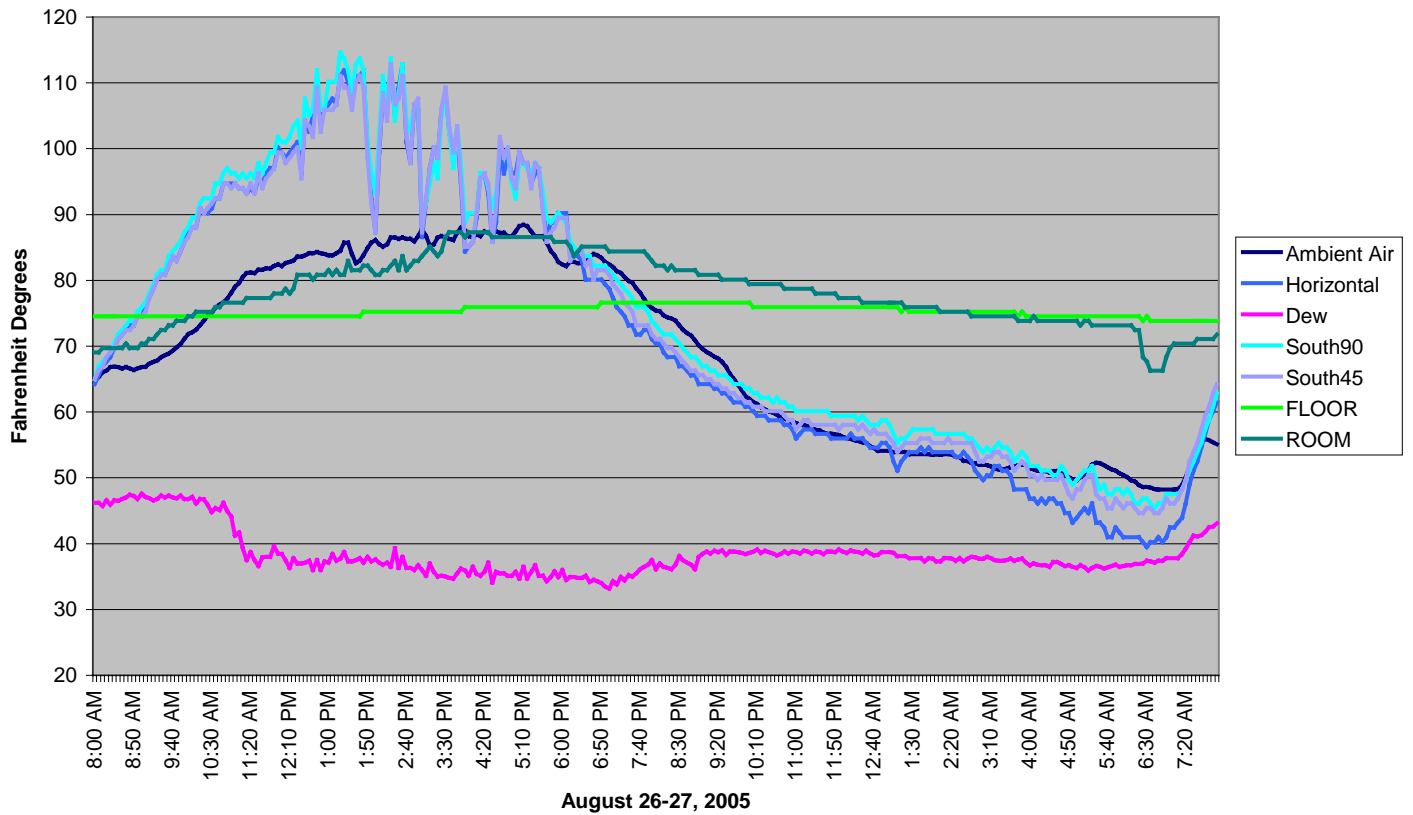
**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

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Bristol Stickney Consulting

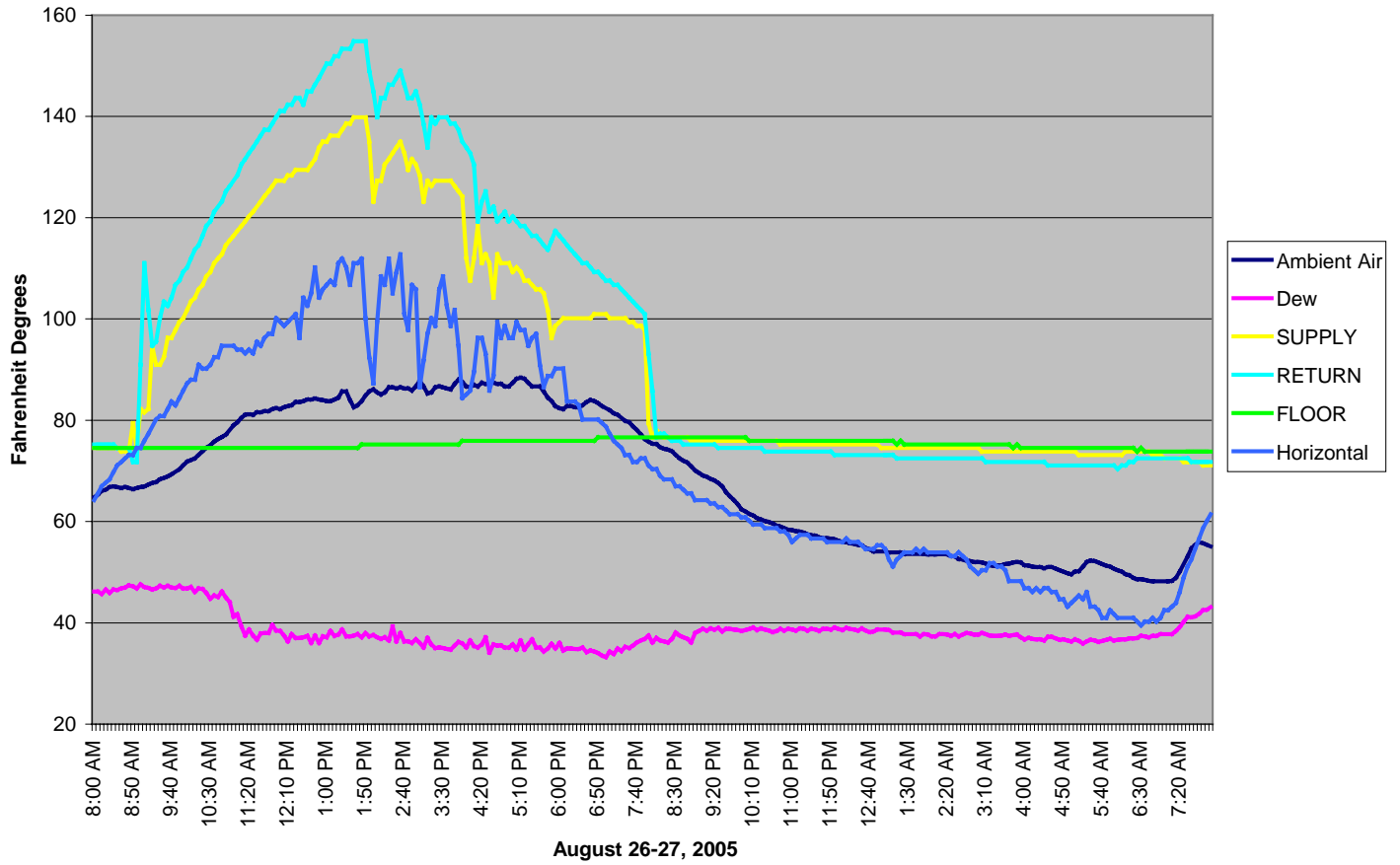
**Herman Home  
Glazed, Tilted Radiator w/ Mass Floor**



**Herman Home  
Glazed, Tilted Radiator w/ Mass Floor**

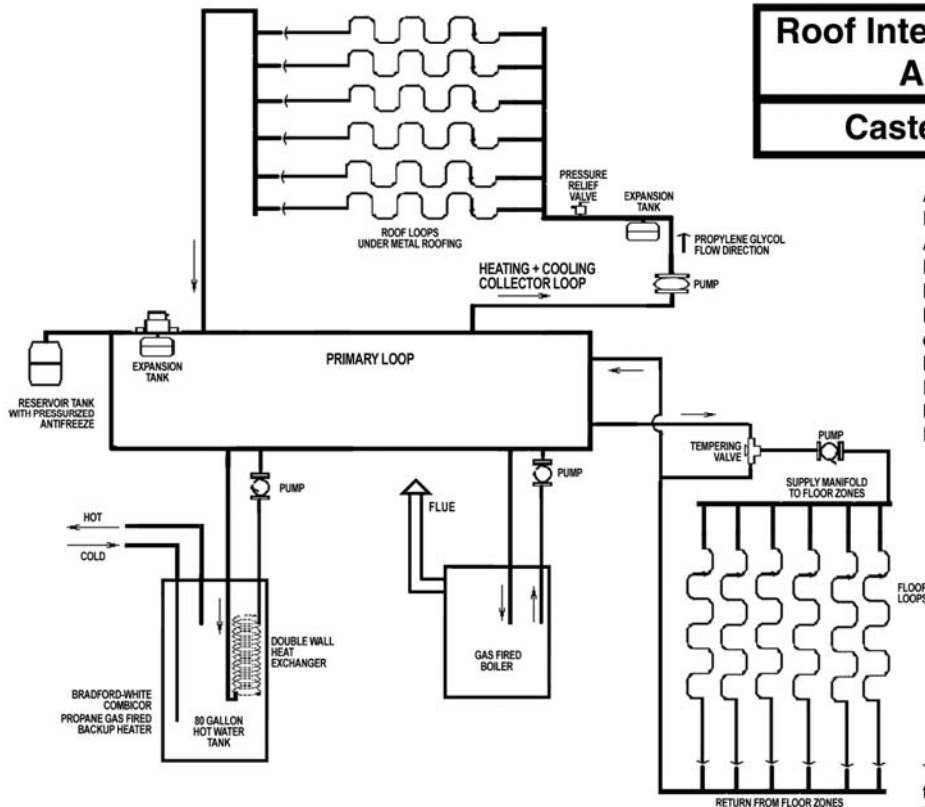


Herman Home  
Glazed, Tilted Radiator w/ Mass Floor



# Roof Integrated Radiant System Albuquerque, NM

## Caster Home Installation

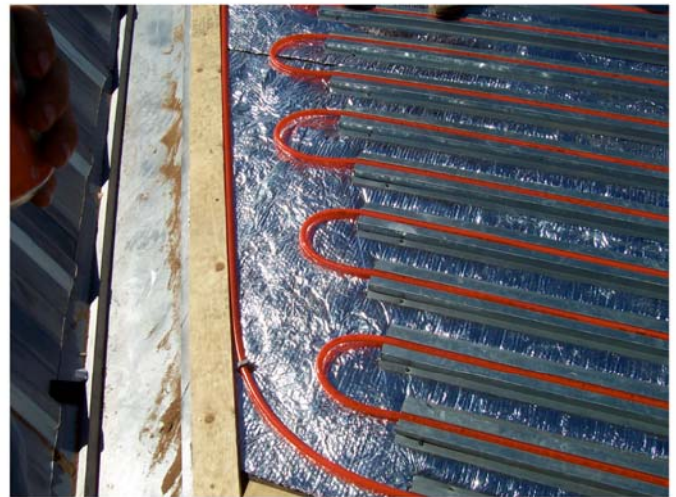


### Advantages:

- Invisible
  - Allows for maximizing radiator/ collector area
  - Effective for both heating and cooling
- ### Disadvantages:
- Less efficient if optimized for both heating and cooling
  - Less efficient per square foot than other options
  - Requires proper roof orientation
  - New construction or major renovation required
  - Relatively expensive

The Caster Home in Albuquerque, NM employs the Dawn Solar roof integrated system to both heat and cool.

\* schematic representation only.  
always consult a professional for design and installation



Installation of Dawn Solar Systems showing integrated roofing and tubing

### Description:

The roof integrated radiant system is an architecturally integrated system used to collect and distribute solar-heated water from a roof or wall area. The solar thermal energy collected can be used to heat or pre-heat water for domestic use or space heating. This system can be slightly modified so that the modules can also be used as thermal radiators for cooling. Photovoltaic integration is also possible with the with some systems.

### Summer

**Day:** The radiators/ collectors on the roof can be used during summer days to pre-heat the domestic hot water. Heated water is stored in an insulated water storage tank. Once domestic hot water is heated to maximum capacity, excess heat can be used to heat a hot tub or pool.

**Night:** Propylene glycol is pumped through radiators (tubes installed beneath Dawn Solar Metal Roofing) at night to cool the fluid. The fluid is then pumped through hydronic radiant floor loops absorbing heat from the floor and cooling the living space.

### Winter

**Day:** The radiators/ collectors on the roof are used during the winter days to pre-heat the domestic hot water.

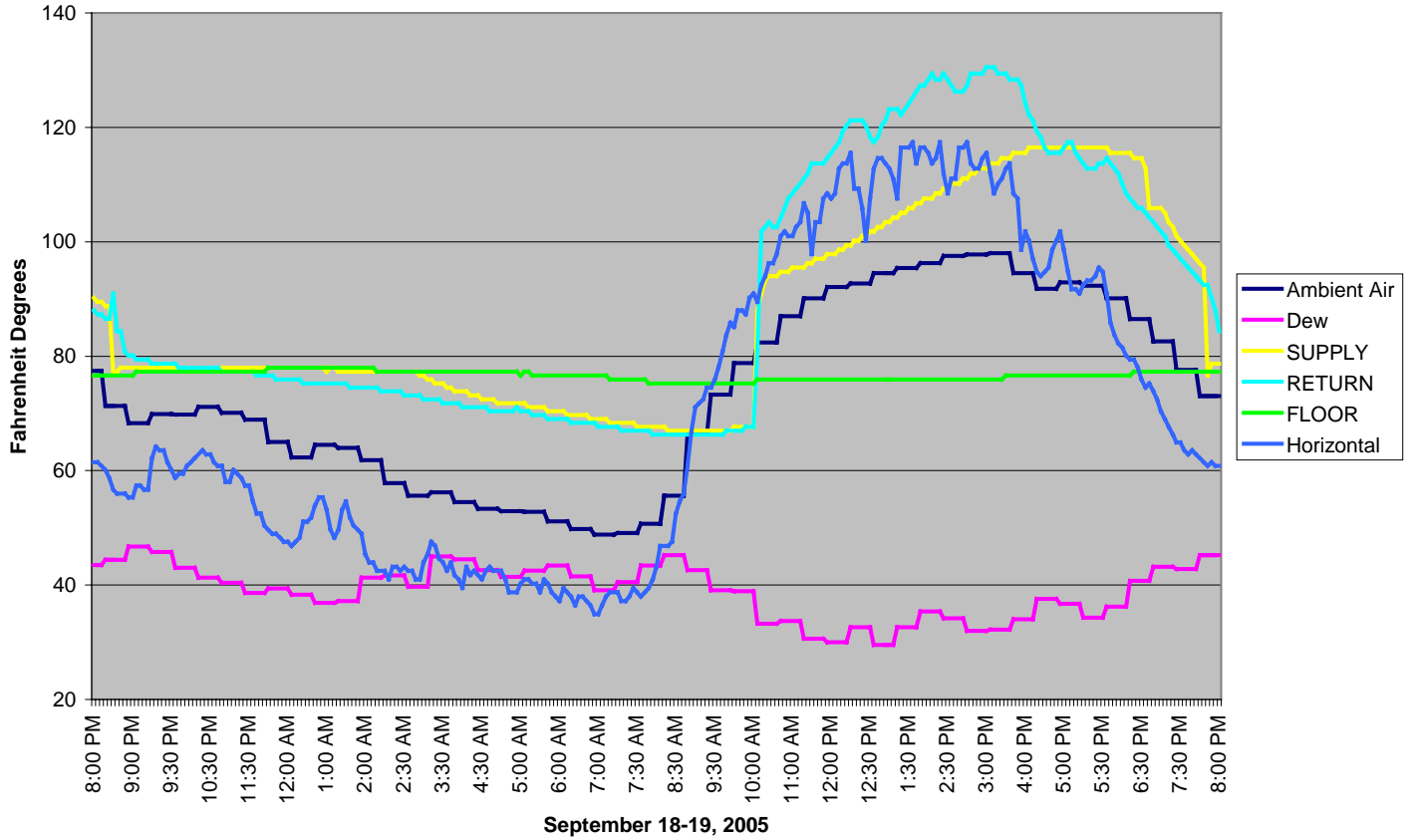
**Night:** System is inactive.

## Night Sky Radiant Cooling Potentials For the State of New Mexico

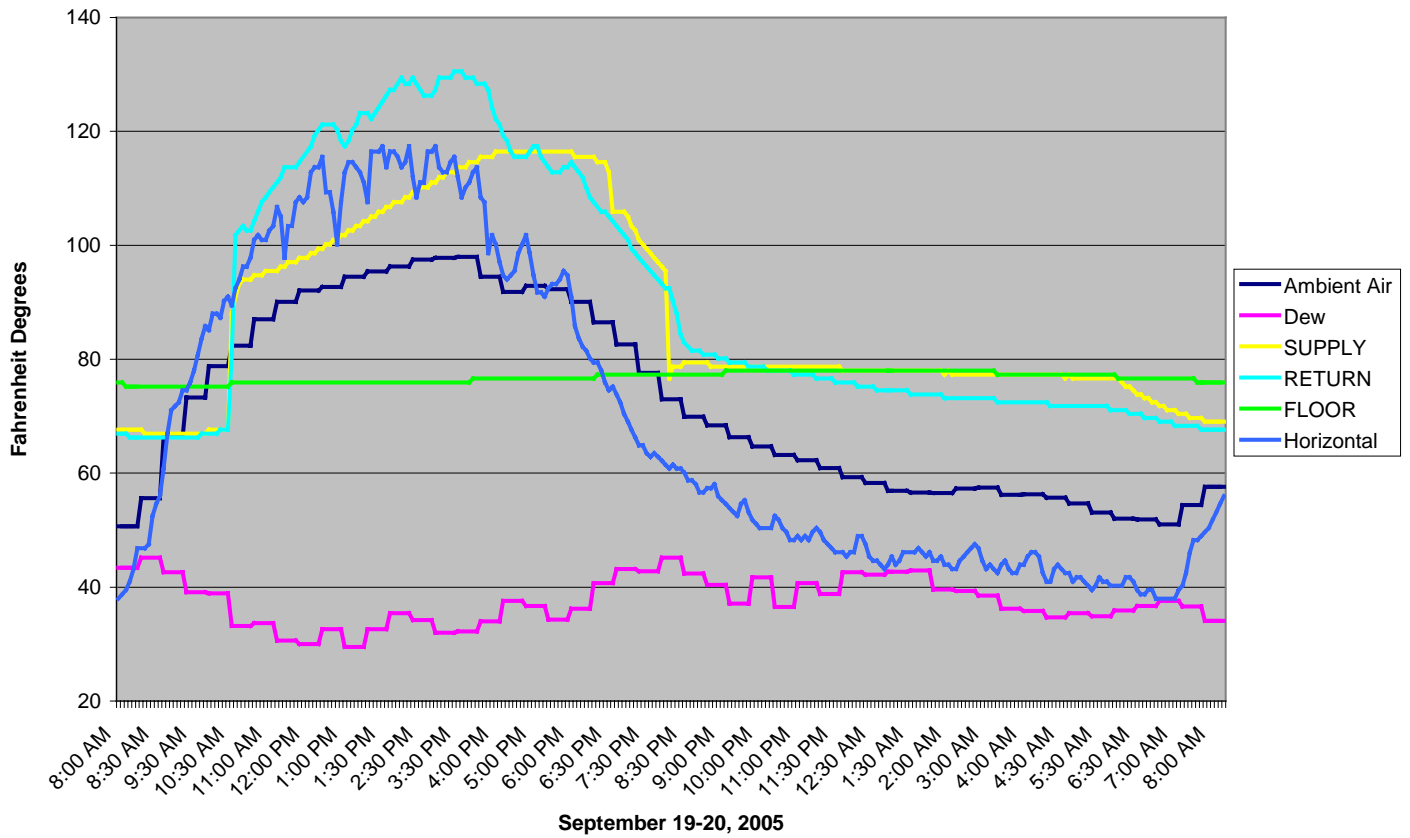
Mark Chalom Architect  
Bristol Stickney Consulting



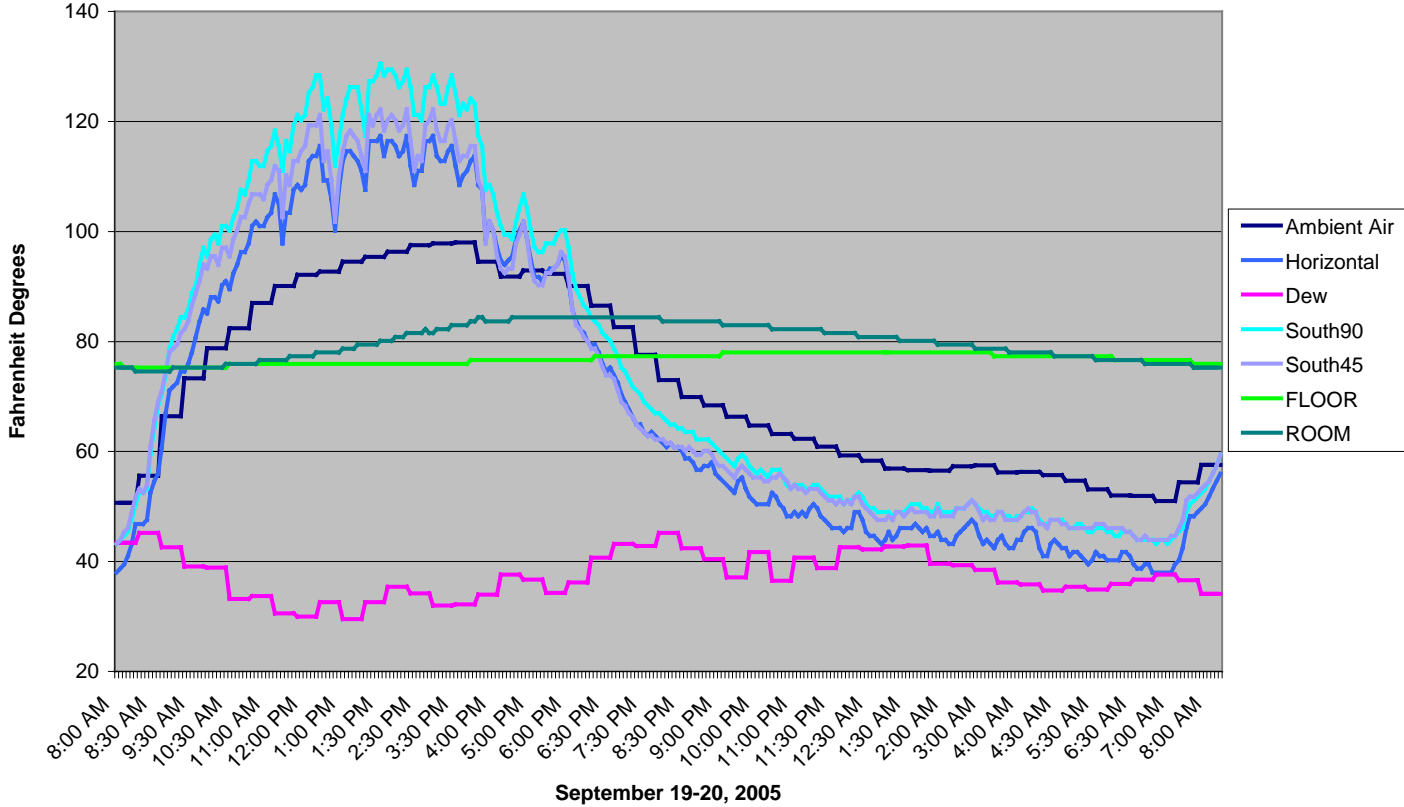
**Caster Home, Albuquerque  
Integrated Roof Radiator w/ Mass Floor**



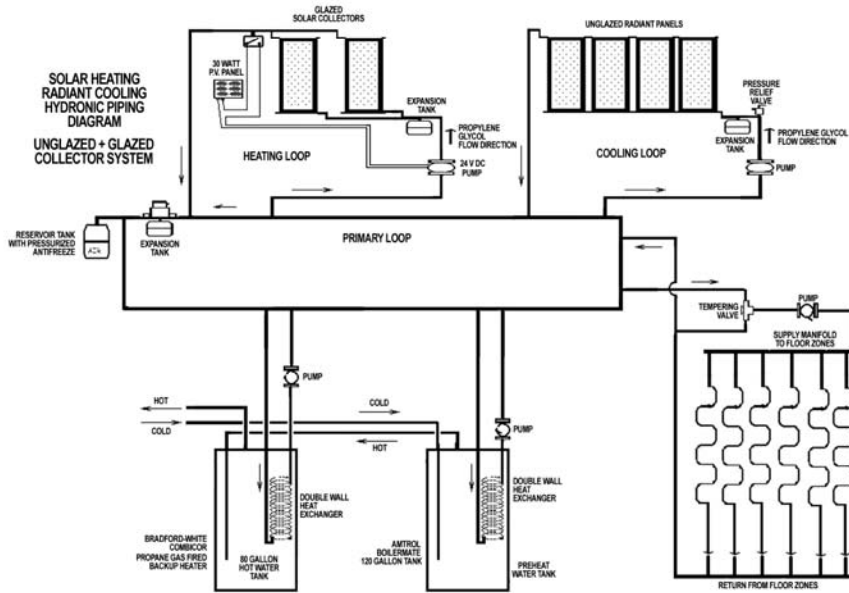
**Caster Home, Albuquerque  
Integrated Room Radiator w/ Mass Floor**



Caster Home, Albuquerque  
Integrated Roof Radiator w/ Mass Floor



# Glazed + Unglazed Hydronic Floor System



**Advantages:**  
 most effective incorporating both heating and cooling  
 a relatively simple retrofit for an existing solar hydronic system

**Disadvantages:**  
 uses 2 different types of collectors



primary loop and plumbing in mechanical closet

\* schematic representation only.  
 always consult a professional for design and installation

## Description:

This system uses both glazed and unglazed solar hot water collectors for both heating and cooling respectively. Any typical hydronic radiant floor heating system can easily be modified to incorporate this system of solar heating and radiant cooling. 2 separate sets of solar hot water collectors are mounted on the roof of a building- one set consists of tilted glazed solar collectors for heating, and the other is an unglazed horizontally mounted radiator for cooling. The solar thermal energy collected can be used to heat or pre-heat water for domestic use or space heating, while the unglazed units radiate heat from the space to the night sky during the summer for cooling.

## Summer

**Day:** Heat collected from both the glazed and unglazed collectors is used as a preheat mechanism for domestic hot water use.

**Night:** Solar heating loop is inactive. Radiant cooling loop is active. Propylene glycol is pumped through the unglazed collectors at night to cool the fluid. The fluid is then pumped through hydronic radiant floor loops absorbing heat from the floor and cooling the living space.

## Winter

**Day:** Propylene glycol is pumped through glazed roof mounted solar collectors (set at optimum tilt) and then run through the hydronic floor loops to heat the space. The horizontal unglazed collectors can be used to pre-heat water before putting it through the glazed collectors. Excess heat is dumped into an insulated water storage tank and used to preheat domestic hot water.

**Night:** Systems are inactive.



un-glazed horizontal radiators



glazed collectors tilted for heat optimization

## Night Sky Radiant Cooling Potentials For the State of New Mexico

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 Bristol Stickney Consulting



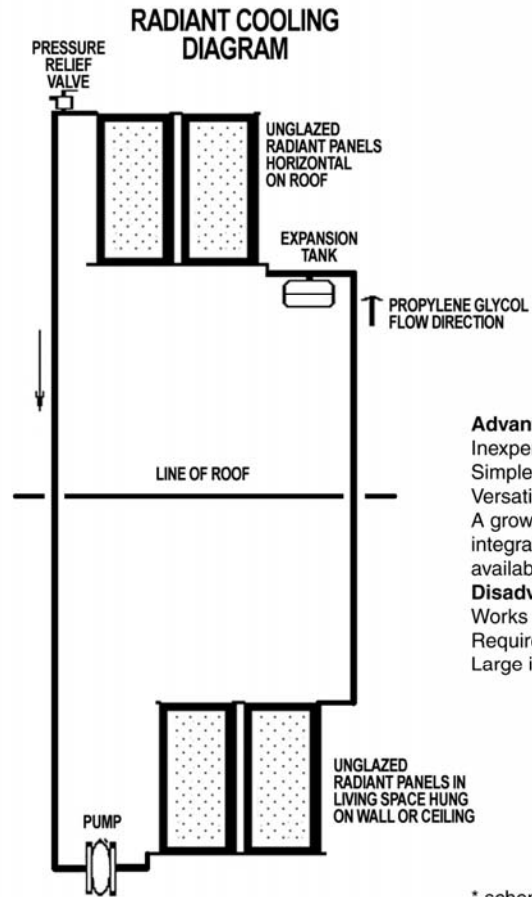
# Unglazed Radiator System



interior radiators



valves, expansion tank, and pressure relief



- Advantages:**  
 Inexpensive  
 Simple retrofit  
 Versatile interior radiator  
 A growing number of architecturally integral radiator panels are becoming available.
- Disadvantages:**  
 Works only for cooling  
 Requires flat roof area  
 Large interior radiator

\* schematic representation only.  
 always consult a professional  
 for design and installation

## Description:

The Unglazed Radiant Cooling System, perhaps the most simple and cost effective of all the systems, functions solely as a radiant cooling system during the summer months. It consists of two separate sets of unglazed collectors. The first is an interior radiator that can be hung on a wall or ceiling, and the second is another unglazed collector that is mounted horizontally on the roof. The interior system functions simply as a radiator of "coolth" or an absorber panel that absorbs the heat of the room into the cool fluid running through it. The heated water is pumped up to the radiator on the roof which radiates this heat to the night sky and cools down the fluid to be pumped back into the room. This system does not use any storage tanks.

## Summer

Day: System is inactive.

Night: Water or propylene glycol is pumped through horizontal unglazed radiators on the roof at night to cool the fluid. The fluid is then pumped through an interior unglazed radiator positioned on a wall or the ceiling, absorbing heat from the space and cooling the room.

## Winter

Day: System is inactive.

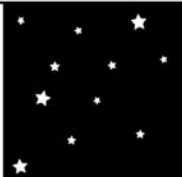
Night: System is inactive.



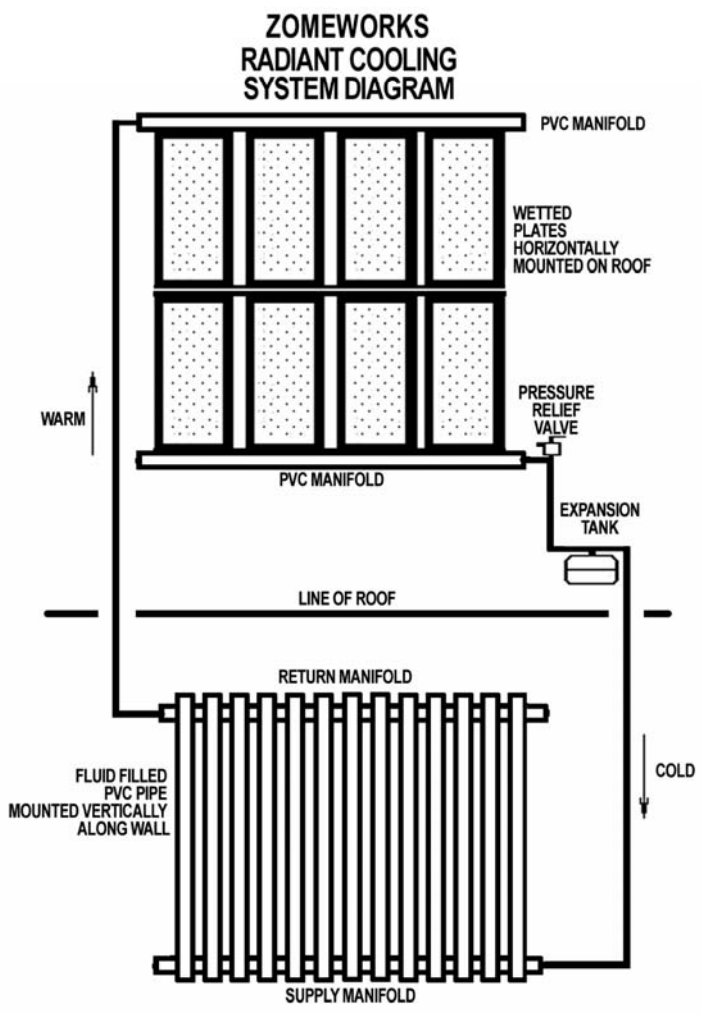
exterior radiators on the roof

## Night Sky Radiant Cooling Potentials For the State of New Mexico

Mark Chalom Architect  
 Bristol Stickney Consulting



# Zomeworks Double Play™ Passive Radiant System



\* schematic representation only.  
always consult a professional for design and installation

- Advantages:**  
 Passive operation- requires no electricity for cooling  
 Can be easily modified for heating (with the addition of a pump)  
 Doesn't require an existing hydronic floor system  
 Easy retrofit
- Disadvantages:**  
 Large interior radiating element  
 uses PVC



Interior PVC thermal radiators be large in diameter to allow for thermosyphoning

**Description:**

This fully passive system requires no pumping and no electricity. Using the principal of thermosyphoning, warm fluid from vertical PVC tubes mounted on the wall of the living space rises to the manifold on the roof. The warm fluid then begins to cool and course through the tilted array of radiator panels. The warmed fluid continues to release heat to the night sky and as it moves through the radiators and back down to the pipes in the living space. A pump may be added to the system so it can function in the heating season as well.

**Summer**

Day: System is inactive.

Night: Fluid is moved through the system passively-absorbing heat via vertical PVC tubes within the living space and radiating that heat through fully wetted radiator plates on the roof.

**Winter**

Day: A pump can be added to the system during the winter to run the system backwards and act as a heating mechanism.

Night: System is inactive.



Wetted plastic plate 'sky mat' radiators are mounted on the roof at a slight angle to encourage passive thermosyphoning.

**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

Mark Chalom Architect  
Bristol Stickney Consulting

# 8

## Water and Power Usage of Evaporative Cooling, Air Conditioning and Night Sky Radiant Cooling

In this research, the water use data needed to project savings from using NSRC were all across the board. Water use in evaporative coolers has been documented to be as much as 4 times what the numbers of this grant utilized, and power usage also ranged greatly. Water usage at the power plant to produce one kilowatt also was varied. This is a function of the age of the plant and the fuel used at the plant. Not knowing all the factors contributing these published numbers we set out to document the most realistic numbers without trying to inflate our results. This wide range of numbers (and their sources) and the justifications for the base case numbers we have utilized to project our savings are shown in this section. The calculator, at the end of this report, allows for these variables to be changed to represent various efficiencies of equipment at the home as well as water use at the power plant as a function of age and fuel.

**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

Mark Chalom Architect  
Bristol Stickney Consulting



## Data utilized to generate our numerical conclusions

To generate our numerical conclusions we had to establish many numbers based on data collected from other sources. These numbers range greatly depending on where and how that data was generated. In this section we have provided the sources and sections we reviewed for our data. In all cases we utilized the more conservative numbers.

In reviewing this data we see we are very conservative in our estimates. For example [A Waterwise guide to Evaporative Coolers](#), published by the state Engineers offices list a 1500 SQ. FT. home in Albuquerque, using 7,261 to 18,686 gallons of water, where our efficient model 1800 SQ.FT. home in Albuquerque uses an efficient evaporative cooler with 4,477 gallons used. This would make our 2,795 gallon savings look more like 7,176 to 18,600 gallons saved. We have researched equipment specs and actual basic ASREA heat loss/gain calculations on a building model, chose a specific evap. unit and feel our numbers are a more realistic calculation.

Published Power estimates are also wildly ranging. PNM's chart [Refrigerated vs. Evaporative Cooling: Which Is Right For You?](#) Shows about 4800 gal of water used in Albuquerque for swamp cooling which is very close to our estimates but the power usage cost is \$105 for swamp cooling and \$355 for air conditioning where The efficient 1800 SQ. FT. building utilizes \$37 for Evap. And \$134 for AC Based on 8.5 cents per KW. This is a factor of 2.5 times. Again we utilized efficiency and well documented data and always on the conservative side.

Please review these references we have provided and compare them to the numbers we utilized and explained in the input data sheet. We have purposefully developed our computer program to allow these input numbers to change making it a useful tool as variables change over time. For example, if someone wanted to look at water used to produced power at a new gas fired power plant, that number can be changed and all the data and charts will be updated. If one wanted to double the cost of power or ½ the water used in a new efficient indirect/direct evaporative cooler, this can be done easily on the input page.

**A Waterwise Guide to Evaporative Coolers. Santa Fe, NM: Water Use And Conservation Bureau, New Mexico Office of the State Engineer.**

"In an average weather year, a 1,500 square foot home in Santa Fe might use 2,980 gallons of evaporative cooling water (based on the evaporative cooler running 696 hrs.) The same sized home in Albuquerque would use 7261 gallons (1130 cooling hours), while a similar house in Las Cruces would use 12,457 gallons (1,718 cooling hrs.)... Bleed off water can increase overall evaporative cooler water use by 50% or more which would increase total evaporative cooler water use to 4,470 gal. Per year in Santa Fe, 10,892 gallons in Albuquerque, and 18686 gallons in Las Cruces.

**Refrigerated vs. Evaporative Cooling: Which is right for you?. Albuquerque, NM: PNM.**

	electricity used/ month	Water use directly by cooler/ month	Water used in plant to create electricity/ month	Total water used/ month	Electricity use cost/ month
Traditional swamp cooler	250 kwh	775 gallons	185 gallons	960 gallons	\$21
Refrigerated air conditioner	850 kwh	0 gallons	625 gallons	625 gallons	\$71

Figures above are rounded monthly averages for a typical home in Albuquerque from the months of May- September. Actual usage will vary depending on many factors, including how often you run your appliance and its efficiency. Swamp coolers with dump pump or bleed off valve features often can use 45 percent to 235 percent more water than a traditional swamp cooler.

**Karpiscak, Martin, and Mary H. Marion. "Evaporative Cooler Water Use." Arizona Cooperative Extension. University of Arizona College of Agriculture. July 1991.**

How much water does an evaporative cooler use? Data for evaporative cooler water use are scarce since little research on this topic has been undertaken, and many factors, from household composition to location of the cooler, influence cooler water use. In *Cool Houses For Desert Suburbs*, Jeffrey Cook, a Phoenix architect, estimates that a 4500 CFM (cubic foot per minute) cooler, under certain weather conditions, uses 200 gallons of water per day.<sup>3</sup> On the other hand, in a television interview in Tucson in September 1990, a Tucson Water Company employee stated that an evaporative cooler adequate to cool a 1,500 square foot home uses approximately four gallons of water per hour or 96 gallons per day, an estimate 50 percent lower than Cook's. Further, the Arizona Department of Water Resources estimates that a typical Tucson household cooler uses a year-round average of 16 gallons per day.<sup>4</sup> These projections of water use convert to annual water costs in Tucson ranging from about \$16 to \$97 for a 26-week cooling season. Recently, a research study was initiated by the Office of Arid Lands Studies at the University of Arizona and the Water Services Department at The City of Phoenix with funding from the Arizona Department of Water Resources. This study monitored evaporative coolers at 46 homes in Phoenix. The preliminary data from this study indicates that water usage of an evaporative cooler in Phoenix was about 7.6 gallons for each hour that the cooler was operated (4.4 gallons per hour for systems without bleed-off and 10.4 gallons per hour for systems with bleed-off).<sup>5</sup>

**United States Department of Energy Building America Program and The Midwest Research Institute National Renewable Energy Laboratory Division. New Evaporative Cooling Systems: An Emerging Solution for Homes in Hot Dry Climates with Modest Cooling Loads. Boulder, CO. Southwest Energy Efficiency Project.**

Evaporating a pound of water yields about 1061 Btu of cooling. Accordingly, if the process were 100% effective, a gallon of water could yield 8,700 Btus of evaporative cooling.

While an evaporative cooler does consume a significant amount of water, it also saves water consumed at the power plant (assuming a less energy-efficient compressor-based air conditioner would be used for cooling if the evaporative cooler were not used). Generating a kWh of electricity with a new coal plant in the Southwest uses about 0.67 gallons of water, while a new natural-gas-fired plant consumes about 0.33 gallons of water per kWh generated. Since conventional direct expansion (DX) air conditioning systems use substantially more energy than do evaporative coolers, water use at the power plant (source) is proportionally greater. SWEEP used Energy 10 software to estimate the energy consequences of DX versus evaporative cooling using modern equipment in six Southwestern cities. Results are shown in Table 2. The homes modeled are quite efficient 1800 square foot structures whose overall energy use is 48 percent lower than homes that just meet the requirements of the year 2000 International Energy Conservation Code for the weather regions associated with each city. We assumed the DX systems have an energy efficiency rating (EER) of 11.1 (roughly corresponding to a seasonal energy efficiency rating, SEER, of 12.9) and a thermostat set point of 76 degrees F. We also assumed a run time of the evaporative coolers to exceed that of the replaced conventional air conditioning systems by 43% at an average power consumption of 800 watts.

Table 2. Water and energy use in the Southwest. Estimates of energy and water use in an 1800 square foot new home in six Southwestern cities that exceed ENERGY STAR® standards by about 15% , comparing DX and evaporative cooling systems. Averages weighted by projected population growth.

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%
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

<sup>1</sup> See The New Mother Lode: The Potential for More Efficient Electricity Use in the Southwest, SWEEP, 2002. Available for downloading at [www.swenergy.org/nml/index.html](http://www.swenergy.org/nml/index.html).

According to this analysis, modern residential evaporative coolers in the Southwest use an average of 5,754 gallons of water per year at the site, ranging from 2,435 gallons in Cheyenne to 8,619 gallons in Phoenix. For single-family households, this amount of water use represents an average of only 3.3% of annual water

use. However, from the overall environmental point of view that takes into account water used at the power station, net water use averages 3,941 gallons of water per year, ranging from 1,692 gallons in Cheyenne to 5,884 gallons in Phoenix. On average in the Southwest, net water use is 68% of the water used at the site. Nonetheless, because evaporative coolers increase local water consumption and water savings at the power plant are not provided to the local water district, the increase in local water use which results from the use of evaporative cooling can have an impact on water planning.

The above analysis ignores the very significant use of water associated with the generation of electricity with hydroelectric plants. Damming a river to harness its potential to generate electricity raises the surface area of the newly-formed lake by several orders of magnitude. Nationally, the result is that 18 gallons of water are evaporated for every kWh of hydroelectric energy produced. In the Southwest, where the air is frequently both hot and dry, the average (weighted by consumption) is 69 gallons per kWh of hydroelectric energy generated. Accordingly, were we to include hydro in our estimates of total water use at the generator, the average in the Southwest would be 4.88 gal/kWh instead of the 0.5 gal/kWh figure used. The rationale for not including hydro is that it is already fixed in place, typically used as base load generation, and not likely to be expanded to meet new demand. Accordingly, the energy and demand savings achieved by substituting energy-efficient evaporative cooling equipment for CAC equipment will save having to add additional thermo-electric generation capacity, typically gas and coal-fired power plants.

Savings in electricity use—and cost—achieved by using evaporative instead of DX-based cooling are also quite substantial. Operating cost figures is shown in Table 3.

Table 3. Cooling cost comparisons. Annual cost to the end user of cooling 1800 square foot new homes in six Southwestern cities that exceed ENERGY STAR standards by about 15%, comparing DX and evaporative cooling. When local water rates are higher with increased consumption, the computations shown assume the higher marginal cost per gallon of water used. Water and electricity rates applicable to single family residences in each city in 2003 were used to estimate costs.

City	Cooling Energy DX Cost (\$/yr)	Cooling Energy Evap Cost (\$/yr)	Cooling Energy Saved with Evap (\$/yr)	Evap Water Cost (\$/yr)	Total Evap Cooling Cost (\$/yr)	Net Savings Evap vs DX (\$/yr)
Albuquerque	\$214	\$29	\$185	\$5	\$33	\$181
Cheyenne	\$151	\$24	\$126	\$6	\$30	\$121
Denver	\$141	\$20	\$121	\$5	\$25	\$116
Las Vegas	\$444	\$47	\$397	\$13	\$60	\$384
Phoenix	\$502	\$48	\$454	\$20	\$68	\$434
Salt Lake City	\$185	\$23	\$161	\$5	\$28	\$157
SW Average	\$335	\$36	\$299	\$12	\$48	\$287

<sup>2</sup> P. Torcellini, N. Long, and R. Judkoff. NREL/CP-550-35190. November 2003. "Consumptive Water Use for U.S. Power Production." Available electronically at <http://www.nrel.gov/docs/fy04osti/35190.pdf>  
New Evaporative Cooling Systems Page 10

Annual water costs for evaporative cooling average \$12 per year in the efficient homes analyzed in the Southwest, ranging from \$5 in Albuquerque, Denver, and Salt Lake City to \$20 in Phoenix. On average, water costs with evaporative cooling diminish energy saving dollars by only about 4%. Even accounting for water costs, overall cooling season savings average \$287 per year in energy efficient homes in the Southwest, ranging from \$116 in Denver to \$434 in Phoenix. Further, lower electricity demand may help delay building new power plants with their associated water use, air pollution, and fossil fuel consumption, provided that they are designed and installed in a way that they effectively reduce peak cooling loads even during the monsoon seasons in areas where they occur

# 9

## Calculator/ Worksheet

Our tabulated results have been calculated by an Excel Spreadsheet developed specifically for this project. Bristol Stickney Solar Consultant should be credited for this development. We have included it here for the option of utilizing it to change the allowable inputs to specifically look at the effects of different variables and their effect on water and power usage in each Climate Zone.

To utilize this spread sheet one must have Microsoft Excel and a fair amount of memory. Open the program to the data input page and modify any of the inputs and review the summary graphs

### Explanation of Data Input Sheet

The input page allows for many variables to be modified:

- The house size and its thermal qualities.
- The radiator “U” value, size, hours of operation and temperature coming from the slab.
- The efficiency and outputs of the air-conditioner and evaporative coolers
- The evaporative and bleed off rates of the evaporative cooler
- The cost of electricity and water used at the power plant to produce that power

COP - Coefficient of Performance. The ratio of how much heat energy that is moved compared to how much energy is consumed in moving it.

EER - (Energy Efficiency Ratio) the ratio of cooling capacity of an air conditioning unit in Btu’s per hour to the total electrical input in watts under specified test conditions. California Code of Regulations, Section 1602(c)(6).

**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

Mark Chalom Architect  
Bristol Stickney Consulting

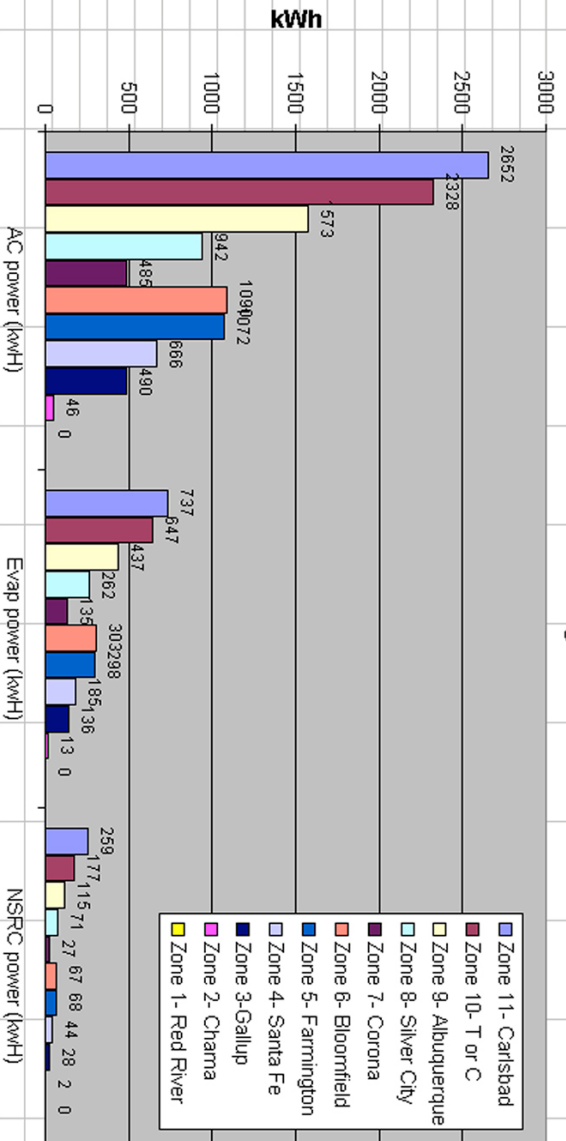


**NIGHT SKY RADIANT COOLING IN NEW MEXICO ENERGY & WATER USAGE COMPARISON IN ELEVEN CLIMATE ZONES.**

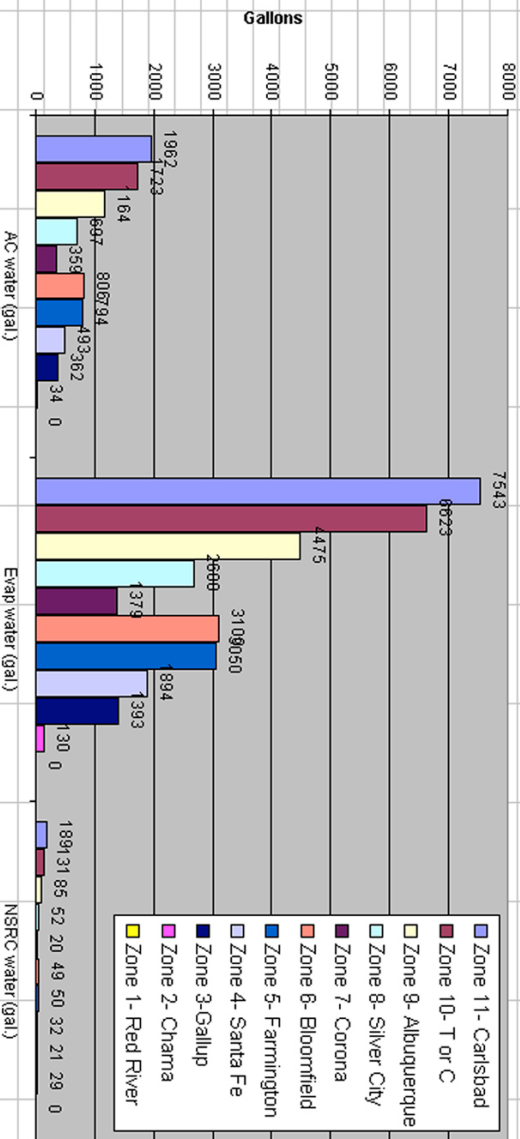
**SAMPLE HOUSE VARIABLES - ENTER VALUES IN RED PRINT**

Value	Description and (Units)
	SAMPLE HOUSE INPUTS
1800	Floor Area (Square Feet)
5.64	Heat Loss Rating (BTU's per Square Foot per Degree Day)
	NIGHT SKY RADIATOR INPUTS
400	Radiator Area (Square Feet)
1.7	Radiator Night Sky "U value" BTU/Hour-F <sup>2</sup> -F
120	Radiator Pump & Controls Electric Rating (Watts)
	EVAPORATIVE COOLER INPUTS
800	Fan, Pump and Controls Electric Rating (Watts)
3.6	Ratio - Cooling Advantage over Air Conditioner (unitless)
9.5	Water Use - Evaporation and Bleed off (Gallons per KWH)
	AIR CONDITIONER INPUTS
800	Fan, Compressor & Controls Electric Rating (Watts)
2.4	COP - Coefficient of Performance Ratio (unitless)
	ELECTRIC POWER SUPPLY INPUTS
0.066	Cost of Electricity (Dollars per KWH)
0.74	Water Consumed at the Power Plant (Gallons per KWH)
	NIGHT SKY RADIATION PERFORMANCE INPUTS
73	Average Over Night Source Temperature (F)
10	Hours per Night Available for Cooling (Hours)
0.441	Ratio - Climate Correlation Air-Dew Temperature (unitless)

**Annual Household Power Use for Cooling in New Mexico**  
Air Conditioning, Evaporative Cooling, & Night Sky Radiant Cooling  
for a SAMPLe Home @ base 65 CDD

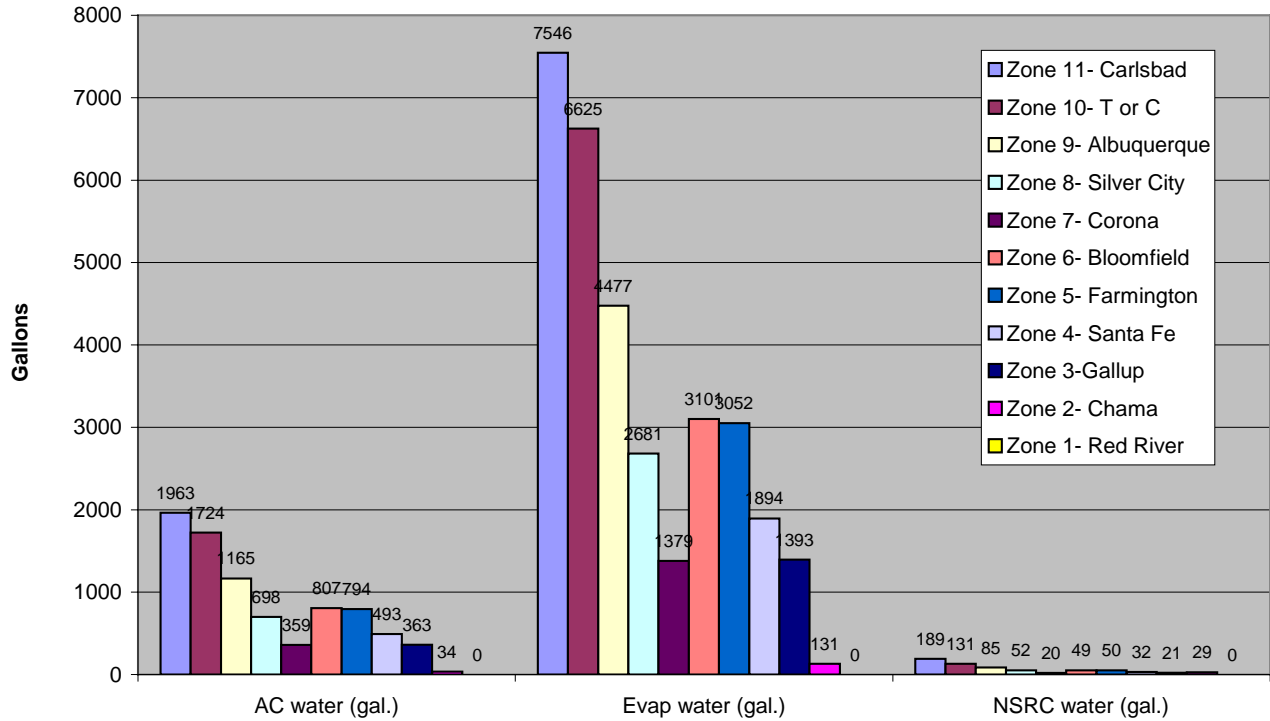


**Annual Household Water Use for Cooling in New Mexico**  
Air Conditioning, Evaporative Cooling, & Night Sky Radiant Cooling  
for a SAMPLe Home @ base 65 CDD



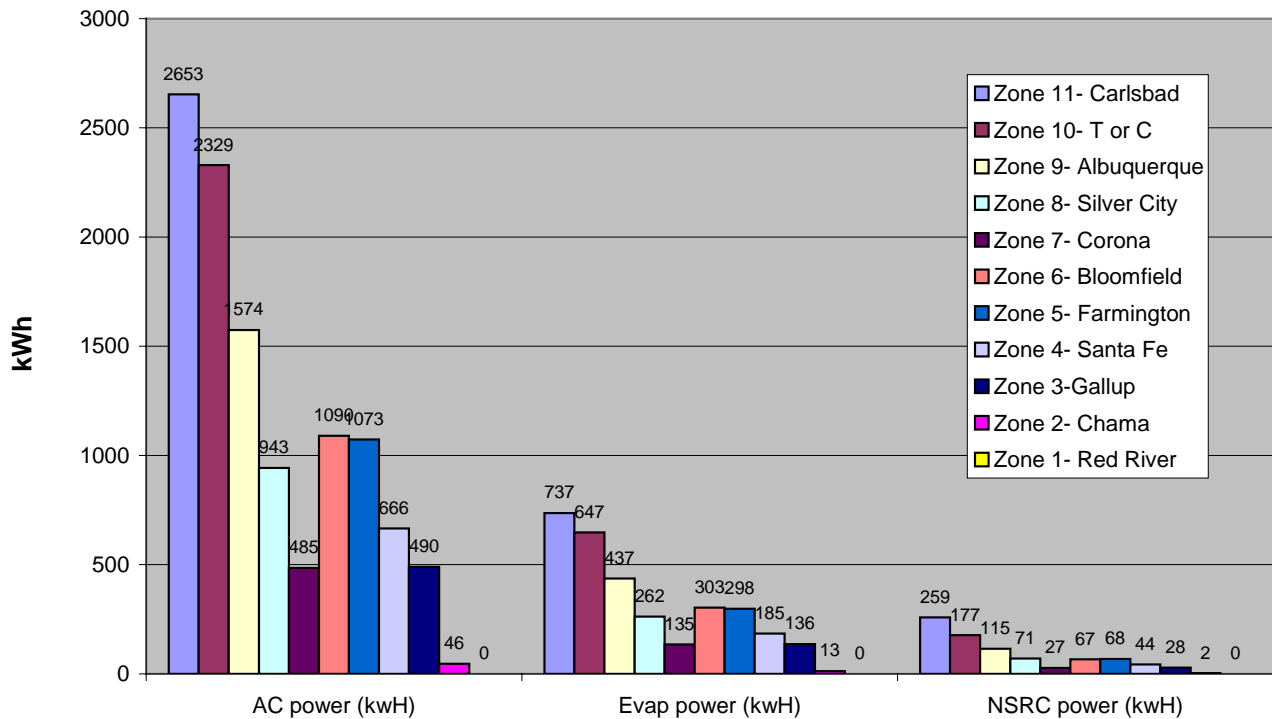
# Annual Household Water Use for Cooling in New Mexico

Air Conditioning, Evaporative Cooling, & Night Sky Radiant Cooling  
for an 1800 sf. Home @ base 65 CDD



# Annual Household Power Use for Cooling in New Mexico

Air Conditioning, Evaporative Cooling, & Night Sky Radiant Cooling  
for an 1800 sf. Home @ base 65 CDD





# 10

## Appendix

The Appendix contains various documents utilized during the process of developing this report. The references are extensive and a good bibliography for anyone taking this work further.

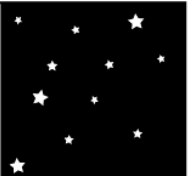
The weather data explains the various Climatic zones in the state of New Mexico and a tabulation of the characteristics of each Zone. This is not inclusive but a generalization of the data we utilized. Most of the weather information is imbedded in the Calculator program.

Escalation of Fuel costs were generated by Cedar Mountain Solar and is a rough estimate of the escalation of propane over the past 4 years.

For documentation purposes and to make the report thicker we included the first 3 quarterly reports.

**Night Sky Radiant Cooling Potentials  
For the State of New Mexico**

Mark Chalom Architect  
Bristol Stickney Consulting



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NEW MEXICO DEW  
POINTS

CLIMATE ZONE	NEW MEXICO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DD COOLING
9	ALAMOGORDO	25	24	24	28	32	42	54	54	46	39	27	24	1801
9	ALBUQUERQUE	19	22	21	24	31	38	48	52	44	33	24	20	1271
11	ARTESIA	23	23	23	28	38	48	56	56	47	40	27	23	1725
9	CANNON AFB-CL	20	24	26	31	41	53	56	58	51	40	27	20	
11	CARSLBAD	23	23	24	34	40	52	58	56	50	41	26	22	2152
5	CLAYTON	15	17	20	26	38	47	54	54	45	33	23	17	872
9	CLOVIS	21	23	23	29	40	51	56	56	49	39	27	22	1333
10	COLUMBUS	26	26	27	31	35	44	56	57	50	41	29	25	1955
10	DEMING	26	27	25	22	25	35	53	55	46	40	25	26	1588
5	FARMINGTON	18	22	21	23	29	34	46	49	39	31	24	19	864
9	FT. SUMNER	21	24	23	29	36	45	56	56	47	41	25	21	13731
3	GALLUP	20	21	20	22	27	32	47	49	36	29	21	18	380
3	GRANTS	18	20	20	21	26	33	47	49	39	31	23	19	475
11	HOBBS	25	26	24	31	40	51	58	56	52	42	28	26	1853
9	HOLLOMAN AFB	22	24	24	27	33	42	52	56	49	39	27	23	
10	LAS CRUCES	24	23	22	27	30	40	54	54	46	38	27	23	1761
4	LAS VEGAS	16	17	18	25	34	41	51	50	42	32	20	16	307
9	ROSWELL	23	25	27	30	40	50	51	58	52	40	29	23	1547
4	SANTA FE	18	19	19	25	33	37	50	50	41	31	20	17	344
8	SILVER CITY	23	21	21	22	28	37	51	55	43	36	25	22	760
9	SOCORRO	24	25	26	28	36	45	51	51	44	38	30	24	1249
10	TRUTH OR CONS	20	19	19	23	29	38	51	53	42	34	22	19	1874
9	TUCUMCARI	20	22	22	30	41	50	57	57	48	38	25	21	1510
9	WHITE SANDS	24	25	24	27	33	42	53	57	51	40	28	25	1655
2	CHAMA	22	25	31	40	49	58	64	62	55	45	33	24	37
6	BLOOMFIELD	28	35	43	51	61	70	76	73	66	54	40	30	828
7	CORONA	35	37	42	49	59	67	70	68	63	53	41	33	392
1	RED RIVER	20	24	30	38	46	54	59	57	51	42	29	22	0

\*COOLING DEGREE DAYS BASE 65

The following listing shows major population areas reporting from each climatic region.

Climatic Region 1:

Red River  
Questa  
Eagle Nest

Climatic Region 2:

Cuba  
Tierra Amarilla  
Chama

Climatic Region 3:

Gallup  
Grants  
Luna Range  
Cloudcroft

Climatic Region 4:

Raton  
Cimarron  
Springer  
Las Vegas  
Mountainair  
Santa Fe  
Taos  
Los Alamos  
Sandia Ranger Station  
Ruidoso

Climatic Region 5:

Shiprock  
Farmington  
Aztec Ruins  
Chaco Canyon  
Clayton

Climatic Region 6:

Bloomfield

Climatic Region 7:

Magdalena  
Corona  
Mayhill

Climatic Region 8:

Carrizozo  
Silver City

Climatic Region 9:

Clovis  
Tucumcari  
Vaughn  
Roswell  
Tatum  
White Sands  
Alamogordo  
Albuquerque  
Socorro  
Lordsburg

Climatic Region 10:

Las Cruces  
Deming  
Truth or Consequences

Climatic Region 11:

Hobbs  
Artesia  
Carlsbad  
Orogrande

**Source:**

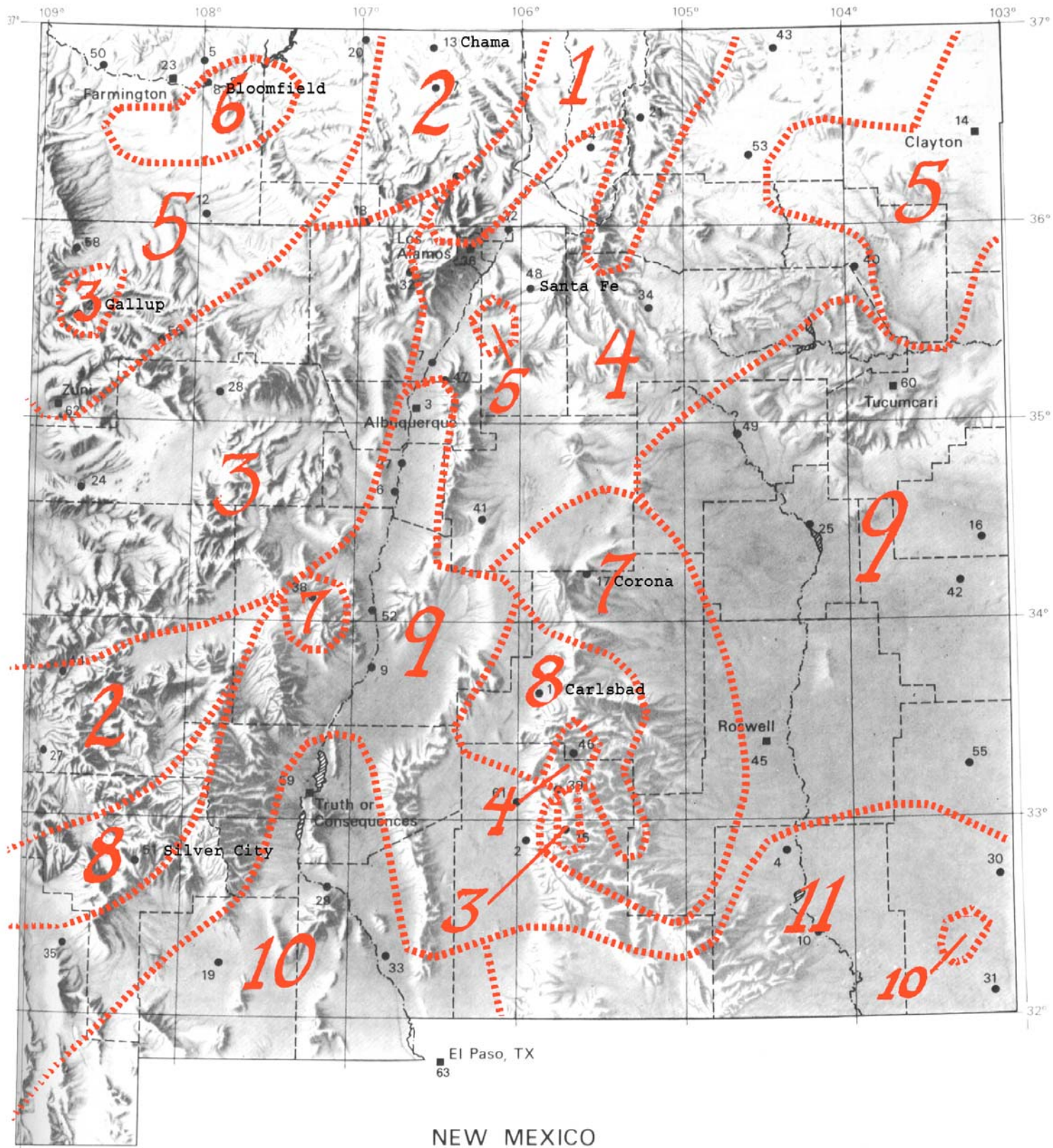
Energy Conservation Code Applications Manual  
NMSU, Oct. 1977

CLIMATIC REGION	WINTER	SUMMER DRY BULB	SUMMER WET BULB	DEGREE DAY HEATING	DEGREE DAY COOLING
1	-8° F	82° F	60° F	9316	7
2	-4° F	86° F	63° F	7681	113
3	-3° F	86° F	62° F	7082	230
4	+9° F	86° F	63° F	6018	537
5	+9° F	93° F	65° F	5720	537
6	+10° F	94° F	67° F	5321	830
7	+12° F	90° F	65° F	4919	544
8	+14° F	88° F	63° F	4418	701
9	+17° F	97° F	66° F	3911	1443
10	+23° F	97° F	69° F	3203	1582
11	+19° F	99° F	71° F	2803	1911

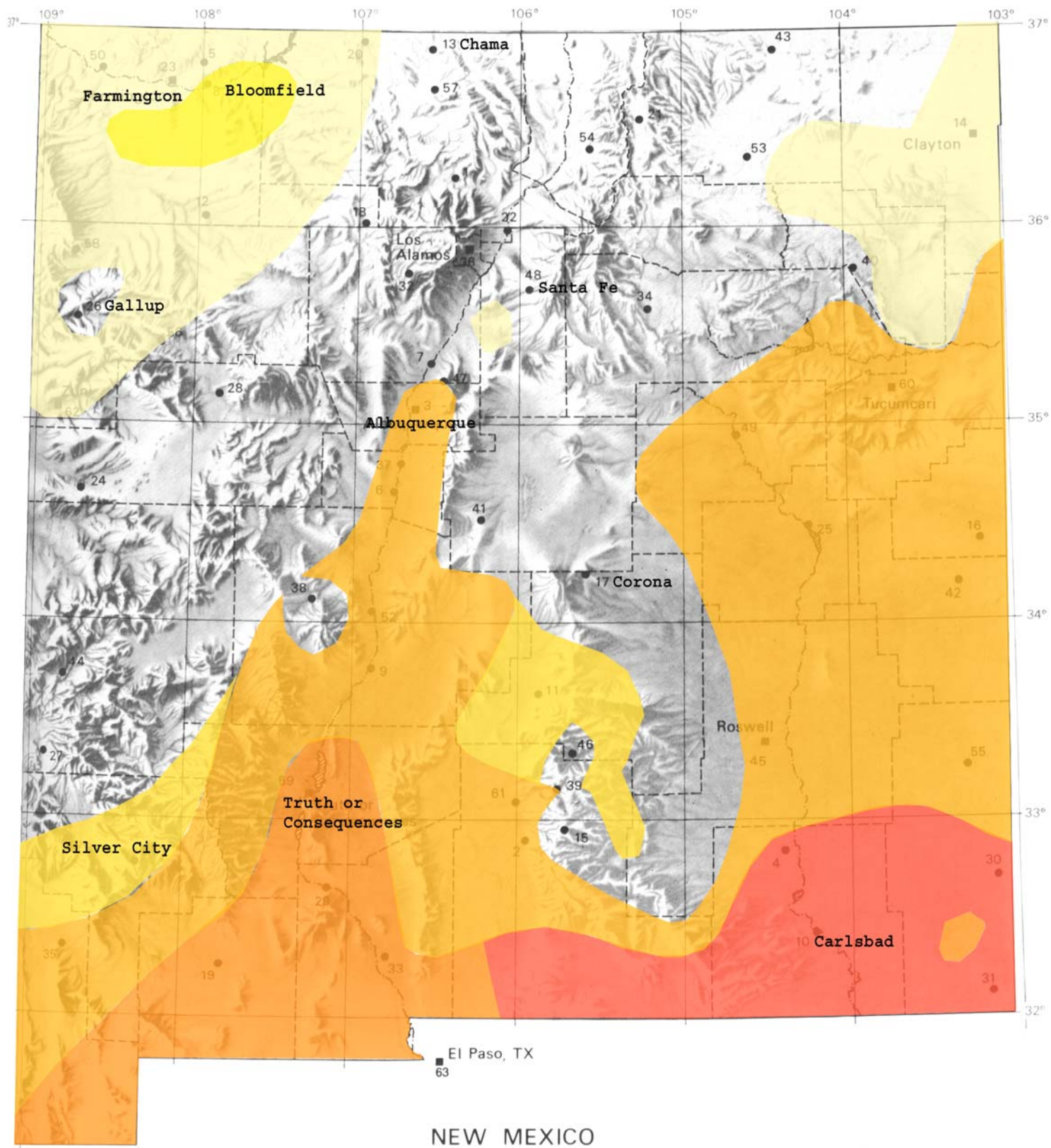
## NEW MEXICO DESIGN CONDITIONS

**Source:**

Energy Conservation Code Applications Manual NMSU, Oct. 1977

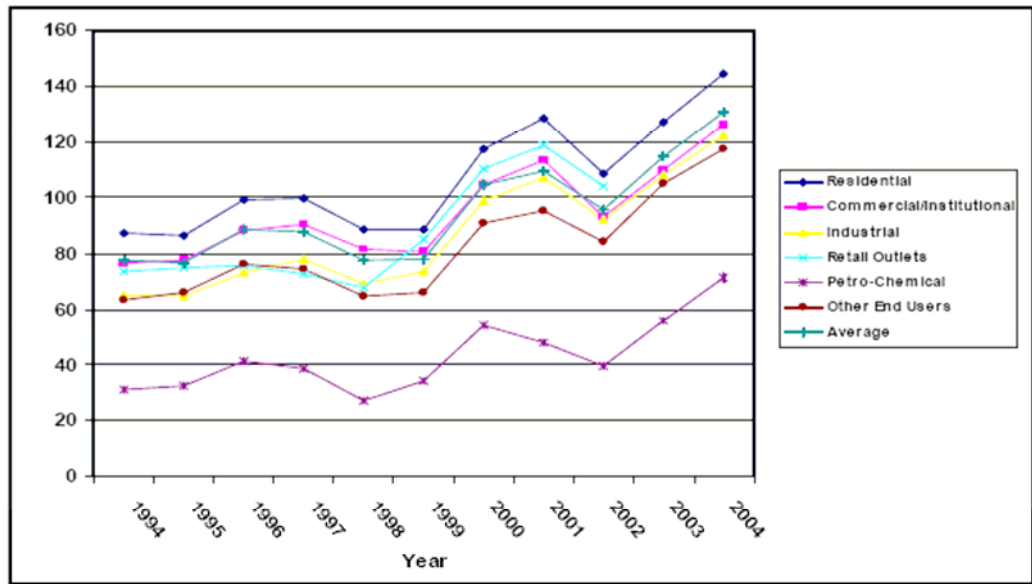


Shaded relief courtesy of New Mexico Bureau of Mines and Mineral Resources



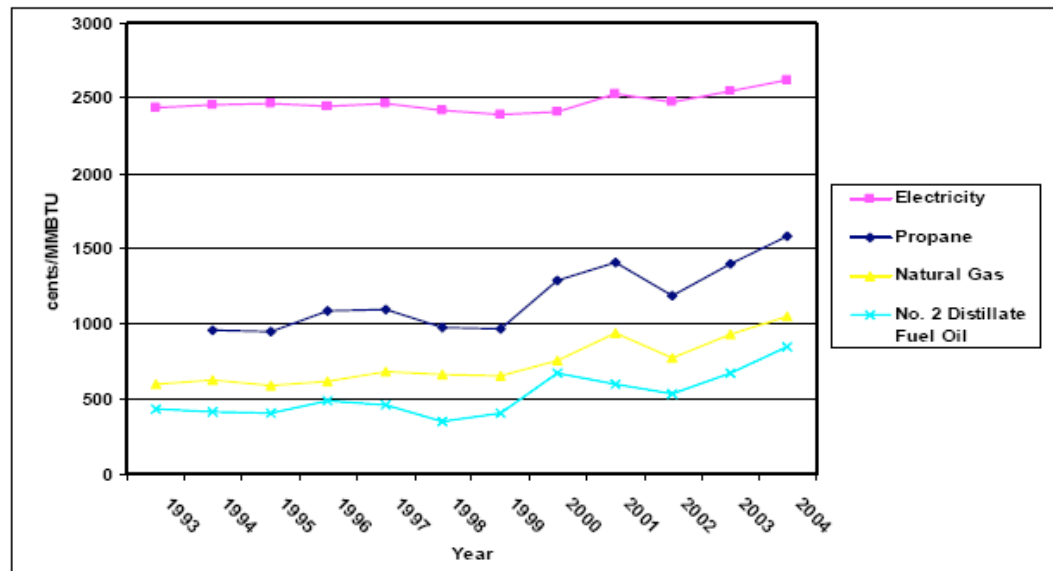
Shaded relief courtesy of New Mexico Bureau of Mines and Mineral Resources

Figure 1. U.S. Consumer Grade Propane Prices by Sales Type, 1994 to 2004



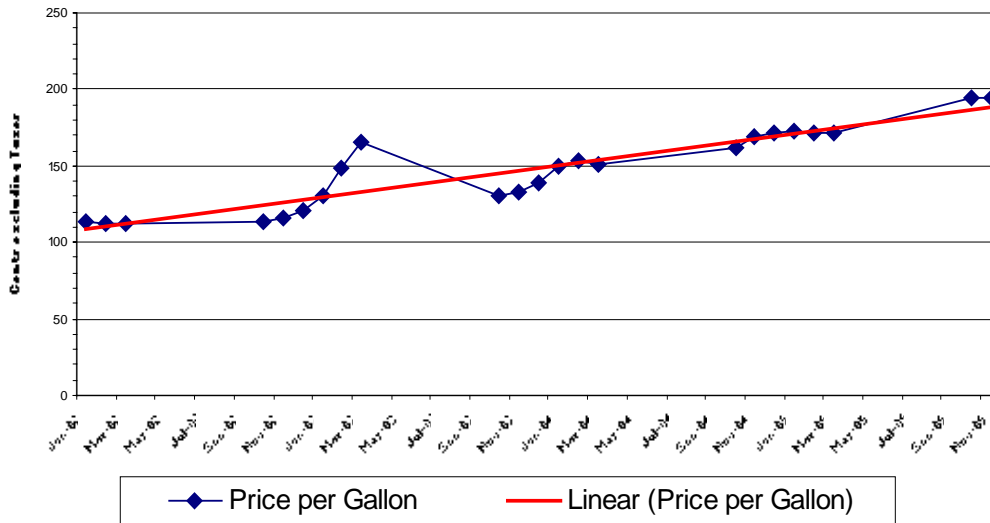
Source: Energy Information Administration, 2005.

Figure 2. Residential Consumer Grade Propane and Residential Electricity, Residential Natural Gas and No. 2 Distillate Fuel Oil Prices, 1993 to 2004



Source: Energy Information Administration, 2005.

**U. S. Residential Propane**  
Price per Gallon - Average all Regions



Source: U.S.D.O.E. Energy Information Administration (updated 12/21/2005)



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(505) 983-1885

Mr. Jim Sizemore  
Water Rights Division  
PO Box 25102  
Santa Fe, NM 87504

April 26, 2005  
Jim,

I am requesting payment for completion of the 1<sup>st</sup> quarters work on Governor Richardson's Water Innovation Fund. Document # 05-973-000643. I hope you find everything in order and understandable. If not, please feel free to contact me at the above number.

I have submitted to you a copy of the 1<sup>st</sup> quarter's breakdown and the completed percent of each item to arrive at this statement. I have includes copies of invoices for equipment and materials purchased to date.

We have completed the work as specified in our contract for the 1<sup>st</sup> quarter. As itemized in our Budget breakdown we have completed most tasks except our field trip to Albuquerque. This will happen in the second phase and the funds have been deferred until then.

The bulk of our work has been to set up test and calibrate the testing facility, build the test stands and tables, securing the monitoring equipment and collectors to test. We have set up and plumbed 2 collectors with all pumps, storage reservoirs, monitoring probes, the weather stations and data loggers. This is the troubleshooting phase and all seems to be working as planned. We have taken data and secured and developed the software necessary to merge this data into a spreadsheet for analytical purposes and have tested all for operational compliance. The testing facility is up and running. We will be taking some data as to swing season potentials for daytime water preheating but most of the testing will come in the warm part of the year...

We have purchased the equipment, monitoring probes and data loggers needed for the Stickney Slab test. We are 75% complete in plumbing the radiant cooling loop to the existing radiant floor system. Pipes and connections through the roof are complete. The adjustable collector mounts are built and ballasted to the roof. We are now ready to hook up radiant panels and start testing when the weather warms up.

You are encouraged to visit the testing facility which we have named "Skylab" but it may not be running as we are waiting for the warm weather. Please call to schedule a visit as we are not always there. Bristol's phone # (505) 989-7029. he can also give you directions to 1-C Avenida de Melodia in Tesuque. I have included a CD of pictures for your review and records...

Thank You,

Mark Chalom, Architect



## Mark W. Chalom, Architect

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Mr. Jim Sizemore  
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Santa Fe, NM 87504

7/26/05

Bi-monthly status report, Second Quarter

Jim,

I am requesting payment for completion of the 2nd quarters work on Governor Richardson's Water Innovation Fund. Document # 05-973-000643. I hope you find everything in order and understandable. If not, please feel free to contact me at the above number.

I have included a spreadsheet showing the expected % complete per qtr with the actual completed % shown. I then calculated % complete to date ( including 1 & 2<sup>nd</sup> qtr.) I then subtracted payment of 1<sup>st</sup> Qtr to arrive at payment due.

Bi-monthly status reports

We are completing the work specified for the second quarter of the project. The collectors are up and running the data is being recorded and correlated with the weather station data and patterns are being observed. We are looking at various collector models and different slopes and orientations. The data is showing great potentials for radiant cooling. We have plumbed a zone in a home and it is working as expected. We will in the next qtr set up another system in a room and set it up with out any pumps and controls. It will be totally passive operated. We are now in the stage of documenting the room with out any radiant cooling. This will be in lue of the Las Cruces home monitoring. The Caster home test will be monitored in the 3<sup>rd</sup> qtr. as the system is being re designed with a new radical type of solar collector. We are fortunate to be able to test this system when it comes on line.

We are now starting to reduce the data collected. We are seeing the potentials we hoped to see from our testing. We are better understanding the qualities of specific collectors and what makes one work better then another. We are discussing the various ways to graphically present the data and performance potentials. This report includes some of the preliminary data collected to date for your review. We have included some photos of the ongoing work. See Appendix. Again you are more then welcome to schedule a visit to the testing facility see the collector testing rack, The data collection system, The retrofitted cooling zone and actually feel the difference... Please call to schedule a visit as we are not always there. Bristol's phone # (505) 989-7029. he can also give you directions to 1-C Avenida de Melodia in Tesuque. I have included a CD of pictures for your review and records...

During the second quarter of our night sky research project, we have made progress in the following areas.

1. **DATA LOGGING** - The test equipment that we acquired or built in the first quarter to compare radiator plates has been started up. Side by side tests of two radiators at a time have been continuously monitored using Hobo Data loggers and the Davis weather station.

2. **TEST RUNS** – Data has been collected from eight different radiators. The radiators are tested in pairs, side by side. The test duration has been typically for two week periods for each pair. Test data is inspected once a week to confirm proper operation of the data loggers. So far, six plastic radiator plates and two metal ones have been successfully tested.
3. **DATA REDUCTION** – During the inspection of the data each week, we have begun to reduce the data to find preliminary comparisons and initial results. Spread sheet calculations have been developed to allow initial comparisons of heat emitted from the different radiators and to determine the Night Sky “U” value for each radiator, so the different test subjects can be directly compared to one another on a “level playing field”.
4. **TILT EFFECT** - A test that identifies the effect of tilting the radiators, has been set up and is being monitored with a data logger. The results from this test will be used to predict the performance of radiator plates that are not mounted horizontally. We have also begun to look at other weather effects using the constant stream of weather data from the Davis weather station to develop correlations to the effect of coolant temperature, dew point and wind speed.
5. **FLOOR TEST** – An existing radiant mass floor at the test location in Tesuque has been retrofitted for night sky cooling. Two of the test radiators that seemed to perform well in the earlier tests were installed on the roof, and connected to the radiant floor tubing. A timer switch runs coolant through the floor for 10 hours each night. The response of the system is monitored with a Hobo Data logger, which is inspected once a week.



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Mr. Jim Sizemore  
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Santa Fe, NM 87504

12/16/05

Bi-monthly status report, Third Quarter

Jim,

I am requesting payment for completion of the third quarter work on Governor Richardson's Water Innovation Fund. Document # 05-973-000643. I hope you find everything in order and understandable. If not, please feel free to contact me at the above number.

I have included a spreadsheet showing the actual completed % shown. I then calculated % complete to date ( including 1, 2<sup>nd</sup> and 3<sup>rd</sup> qtr.) I then subtracted payment of 1<sup>st</sup> and 2<sup>nd</sup> Qtr to arrive at payment due.

Third Quarter Summary

We have found this quarter to be the most productive and exciting for us. We are now seeing results of our work and the answers we are generating are within our predictions and the potentials of night radiant cooling within the state of New Mexico are true, valid, effective and we hope to show economic viability in the next quarter. We are now working towards our final report. The Skylab test facility has now been dismantled but not until a representative from the State Engineers Office was able to visit and have a tour and explanation of the facility and one of our installed systems.

Parts of the final report have been developed and some major parts are included in this 3<sup>rd</sup> qtr. report.

1. What is Radiant cooling and the History of Radiant , and other types of cooling systems , their implications to water and energy is complete and included.

2. Description of collector testing phase. We have completed all our collector tests. The collector testing phase and data reduction are explained in this section, The Data has been broken down, correlated to site generated weather data and we have developed test data summary sheets.

3. Collector Summary sheets for all tested collectors. From that, we now have the U value for each collector as well as an average. This will help us with economic analysis in the final report. Summaries are included.

4. Water and energy used for cooling. We are documenting the amount of energy and water used locally for cooling as well as at the power plant. As no water may be used in an air conditioner at it's location but much has been utilized at the power plant to generate the energy used.

5. Weather data for the state.

Our weather data came from various sources.

"New Mexico Energy Institute and published in the Applications manual, The Energy Conservation Code Oct 1977".

Climate Regions with in the state

Map

Population areas with in each climate region  
New Mexico design conditions per Climate region as clarified

“The Western Regional Climatic Center.”

Dew Points, Cooling degree days, wet and dry bulb temperature history were derived from posted historic data. Dew point temperatures are scarce for New Mexico and we were able to find historic Data for all but 4 Climate regions. These Regions, Chama, Bloomfield, Corona and Red River, Dew points were either estimated from similar climates in New Mexico or Private weather stations posted through the weather underground. We will now be able to generate radiant potentials for all climate regions in New Mexico.

#### 6. Monthly cooling rates in BTU's per 10 hour night

This is one of the first summaries of test data correlating radiant cooling potentials to other climate regions within the state. We have developed correlation's to the dew point, exterior temperature and our white plate temperatures. This will be explained more in our final report.

This correlation utilizes the average potential generated from the average of all the collectors tested. 1.66 BTU/HR/SQFT U-value and listed Dew Points. We have extended this to include all months as large commercial buildings in many parts of the state utilize cooling all year round and the potentials are 2 to 3 times greater in the winter months. Process heat rejection should also benefit from this method of cooling. This chart show us that this method of cooling is very effective for new Mexico and we should pursue this grant to the final stages of presentation. This summary is included here less the 4 regions we had no dew point for. We now have this data as explained above and will be part of the final report.

7. System designs. Five different radiant cooling systems have been diagramed, Photographed and explained. Three systems have been monitored during the cooling season. We have included the system descriptions, advantages and disadvantages here for review and will publish monitored results in our final report.