Peak Electric Savings Raise the Importance of Increased Thermal Mass and Passive Solar

Bruce Baccei
ConSol/BIRA
7407 Tam O'Shanter Dr., Ste 200
Stockton, CA 95210-3370
BBaccei@ConSol.ws

ABSTRACT

Across the country electrical consumption is increasing and is causing escalating concerns for peak electrical demands and the prospect of black outs. Part of the U.S. Department of Energy's Building America research has documented significant cooling and peak energy savings attributed to integrated high levels of thermal mass in homes and is giving more reasons to support the widespread good design and use of increased thermal mass than in recent times. Increased thermal mass utilized to take advantage of off peak cooling and photovoltaic systems combine to have very positive affects on utility grid systems at times that these positive contributions are most valued.

1. Introduction

As part of the U.S. Department of Energy's (DOE) Building America Program (BAP), Clarum Homes, working closely with the Building Industry Research Alliance, BIRA/ConSol, one of BAP's six teams, the Davis Energy Group (DEG) and the National Renewable Energy Laboratory (NREL) has built four advanced prototype homes in the hot-dry desert of Southern California in Borrego Springs, CA. Near side-by-side testing of these four homes has provided experimental results demonstarting the peak energy savings achieved with high thermal mass homes.

2. Clarum Homes' Goal of 90% Cooling Savings in the Extreme Heat of Borrego Springs, CA.

In 2003 and 2004 Clarum Homes tested the notion of combinging high levels of energy efficiency and photovoltaics in a 20 home development in East Palo Alto, CA followed by a 257 single family and townhome development in Watsonville, CA. Their construction, marketing and sales experiments were "phenomenally successful" in the words of Clarum' VP for Marketing, Nicole Gittleson, after selling out the entire 257 home development in one year, "at least three times as fast as expected". It should, also, be noted that in December 2006, Clarum was recognized as being the top builder-developer in California and presented an Award for Enironmental and Economic Leadership by Governor Arnold Schwarzenegger.

Expanding on these successes, Clarum is targeting new home development projects in the more challenging climate of the hot-dry southwest where demand for housing has been very high. To this end, Clarum approached BIRA, DEG, NREL and others with the challenge to design, build and test four advanced prototypes employing three different wall and insulating systems and advanced cooling systems with the goal of reducing cooling requirements by 90%.

3. Borrego Springs: Location and Climate

The prototype homes are located in Borrego Springs, 90 miles northeast of San Diego, CA.

Fig. 1: Borrego Springs, 90 Miles NE of San Diego

Figure 2 is a vicinity map of the Borrego Springs area showing the site locations for all four experimental houses. Note that the homes are identified by the street names of the street each home is located on: 742 Di Giorgio Road (referred to as Di Giorgio), 3485 Country Club Road (Country Club), 3234 Broken Arrow (Broken Arrow) and 3224 East Star Road (East Star).

Fig. 2: Four Prototype Home Locations

TABLE 1: BORREGO SPRINGS CLIMATE

Heating Degree Days	1,075 HDD
Cooling Degree Days	3,843 CDD
Average Maximum Temperature	87.3ºF
Average Temperature	72.3ºF
Average Minimum Temperature	57.5ºF
Average June Temperature	85.1ºF
Average July Temperature	91.0ºF
Average August Temperature	90.2ºF
Average September Temperature	84.4ºF

Table 1: Borrego Springs Climate Data

4. The Four Borrego Springs Protypes.

The four prototype homes have been constructed using three different wall systems and four different combinations of advanced cooling sytems, all but one relying principally on evaporative cooling. Each of the four homes is 1,920 sq. ft. with identical floor plans. These four homes are each equipped with tankless water heaters that provide both space and water heating and 3.1 kW AC photovoltaic systems (PV).

The wall system used to construct two of the homes is a concrete sandwich consisting of 4 inches of extruded polystyrene between a 2 inch outside and 4 inch inside layer of concrete, called T-Mass. Tables 2, 3 and 4 identify the wall systems, heating and cooling systems, orientations and estimates of energy savings of each of the four homes.

Fig. 3: Concrete Sandwich Wall System With 4 Inches of Concrete Inside

TABLE 2: WALL AND HEATING SYSTEMS

House Location-Name	Wall System	Heating: Tankless for Space & Water Heating
Di Giorgio	T-Mass	Fan coil with ducts
Country Club	T-Mass	Radiant Floor w/ Tubing in Floor
Broken Arrow	SIP	Radiant Floor w/ Tubing in Floor
East Star	2x6 Frame w/Spray Foam Insulation	Radiant Floor w/ Tubing in Floor

TABLE 3: COOLING SYSTEMS

House Location-Name	Cooling Systems
Di Giorgio	Freus, Evap cooled condenser ducted w/ NightBreeze.
Country Club	OASys, 2 Stage Evap. w/ Condenser Chilling Water to Fan Coil of Dehumid. And through floor for sensible cooling.
Broken Arrow	OASys, 2 Stage Evap. w/ Condenser Chilling Water to Fan Coil of Dehumid. And through floor for sensible cooling.
East Star	Lennox 20.5 SEER AC

TABLE 4: ORIENTATIONS AND ESTIMATES OF ENERGY SAVINGS

House Location-Name	Orientation	Energy Efficiency Energy Savings	EE + PV
Di Giorgio	Front- 30° East of South	49%	65%
Country Club	Front-Due West	51%	65%
Broken Arrow	Front- 30° East of South	44%	61%
East Star	Front- 30° East of South	52%	66%

5. The Night Cooling-Off Peak Experiment

Shortly after the construction of the homes was completed and tested for air tightness, NREL conducted tests of the three homes that remained unoccupied. The Di Giorgio home was sold before construction was completed and the new owners moved in as soon as they could, so unavailble for the test.

The objective of the experiment was to cool the three particpating homes through the night, then turn off the additional airconditioning determine how much the inside temperatures would rise by 10:30 the next evening to determine if the amount of thermal mass in the homes played a signicant role in dampening the flutuations of termperatures in the homes. It should be noted that the evaporative airconditioners, OASys, were not yet in operation, so backup conventional airconditioners were used. The three participating homes, one T-Mass, one SIP and one 2x6 Frame were cooled to 72°F from 10:30 at night until noon the next day when airconditioners were turned off.

On the day of the test the outside high rose to 105°F, yet the high thermal mass home's interior surface of exterior walls rose only 5°F between 12:00 noon and 10:30 when the thermostat was programed to turn the airconditioner on again.

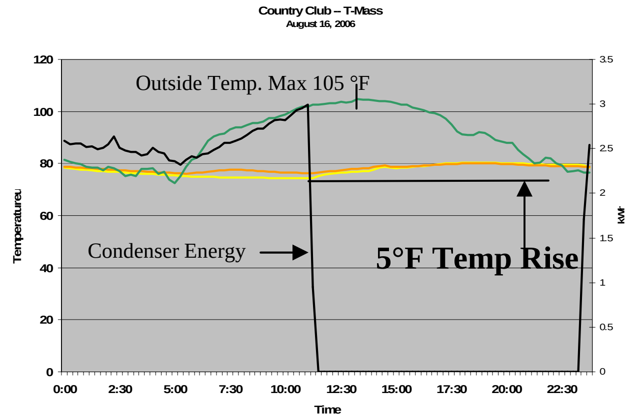

Fig. 4: T-Mass Home Only Rises

The SIP home's inside temperature rose about 9°F. The 2x6 Frame home rose more, but was found to have higher levels of infiltration that were later reduced. These two house have similar levels of insulation and the same amount of mass in floors and walls and would be expected to perform at similar levels.

As stated before, these four homes are each equipped with 3.1 kW AC photovoltaic systems (PV). This means that the owners of the high mass homes, if pre-cooled, can sell most of the electricity produced from noon to sunset back to the utility at peak rates where time of use rates are offered. As peak demand, driven by residential air-conditioning, become more and more critical, utilities may advocate the benefits of thermal mass and off peak cooling along with alternative means of cooling like night cooling and modern 2 stage evaporative cooling or evaporative cooled condensers.

6. Shading Critical to Good Passive Solar Design

These homes are well designed for shading with minimal glazing in this hot-dry climate and large overhangs.

Fig. 5: Well Designed With Large Overhangs and Minimal Glazing

7. Conclusion

A high thermal mass house (exterior walls and floor) coupled with nighttime cooling to discharge (cool) the mass or off peak cooling, can result in significant energy and cost savings in homes that can benefit both the home owner and utility. If the high thermal mass home is also designed to admit and absorb the winter sun, theses cooling benefits are added to passive solar heating benefits and further energy savings. With the documentation of cooling and peak energy savings there are more reasons to support the widespread good design and use of thermal mass than in recent times:

1. Cooled mass acts as a heat sink minimizing temperature rising throughout the peak demand period.
2. Decreases mean radiant temperature significantly enhancing comfort summer comfort when cooled.
3. Energy cost savings for the home owner and utility.
4. The mass will also serve to absorb solar heat through windows and skylights in winter to provide stored warmth at night. When heated, thermal mass will provide a higher mean radiant temperature that will significantly enhance comfort during under heated periods of the year.

Areas of the country where there is a significant swing in temperature between day and night in summer or in areas with significantly higher electrical rates during peak periods can benefit significantly from increased thermal mass. These two homes with T-Mass walls as the exterior walls and tile covered floors performed better than the SIP and 2x6 frame homes.

While these benefits are significant the cost increases due to the concrete sandwich walls are substantial. It is conceivable that increased thermal mass above the levels of normal wood frame construction with ½ inch drywall can be achieved less expensively and more effectively than with exterior T-Mass walls.

For example all walls, exterior and interior could have 5/8 inch drywall installed. For pre-cooling at night, surface area of thermal mass is more important than thickness, so increased thickness of drywall combined with tile floors may perform well too. Use of thicker drywall, interior plaster walls, even phase change materials in walls and ceilings need to be further tested and may be far more likely to be employed by production builders than exterior concrete walls. A BAP home is under construction in Fresno, CA that will test the concept of increased surface area of thermal mass and greater surface area by employing cement boards on the outside and inside of exterior SIP walls and plaster on interior walls.

It is recognized that these homes were unoccupied and cooled more than many occupants might agree too, even so it is believed that added thermal mass can be very beneficial as outlined above.

Fig. 6: "Country Club", Borrego Spring Prototype Home