



Completion of Evaluations of Research Houses

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Task 12.B.2: Performance Evaluation of Research House

Executive Summary

In 2005, Clarum Homes began construction on four high-efficiency prototype homes in Borrego Springs, CA. Each of the four homes is 1,920 sq. ft. with identical floor plans. Three of the homes have the same orientation (30° east of south) and the fourth is rotated 120° to face directly west due to site constraints. Two of the homes use DOW Chemical Company's 10" T-MASS[®]™ wall systems, one home uses Structural Insulated Panel (SIP) and the fourth home uses 2x6 wall framing. The HVAC systems vary from house to house utilizing three different advanced cooling systems.

This report focuses on the performance evaluation of the two houses built with exterior T-Mass walls.

Working with builder-partner Clarum Homes, the Davis Energy Group (DEG), the National Renewable Energy Laboratory (NREL) and other Building America Program (BAP) partners, the BIRA team evaluated production-scale performance benefits from the advanced systems used in two T-MASS homes. These homes are estimated to provide 52 to 53% without photovoltaics (PV) and 66 to 67% with PV whole-house energy savings relative to the Building America Program (BAP) Benchmark. Early short term performance comparisons between all four experimental houses are included in this report.

Evaluations of the T-Mass homes confirm energy savings for this and similar climate zones. The use of nighttime cooling to recharge the mass and carry the building through the hotter part of the day was beneficial to overall power consumption and peak shifting. The T-Mass structures provided the best thermal performance of the three construction methods evaluated. The, SIP and 2x6 frame houses, provide clear improvements over conventional construction, but still allowed the house to drift thermally, more than the T-Mass houses, requiring greater HVAC use and energy consumption.

The high thermal mass construction is more costly than wood frame construction. In addition to construction costs, delays were incurred in the permitting process and may have been coincidental or due to the complexity of the HVAC systems. Permitting delays could be expected to improve with training and more exposure to these new technologies. New technology also brings new fabrication and installation issues that can be resolved with proper training.

Introduction

This report describes the performance evaluation results from two prototype homes estimated to provide 52 to 53% due to overall energy efficiency measures and 66 to 67% combining energy efficiency measures and photovoltaics systems (PV) whole-house energy savings relative to the Building America Program (BAP) Benchmark. Both homes are constructed with DOW Chemical Company's 10" T-MASS[®] wall systems. Working with builder-partner Clarum Homes, the Davis Energy Group (DEG), the National Renewable Energy Laboratory (NREL) and other Building America Program (BAP) partners, the BIRA team evaluated production-scale performance benefits from the advanced systems used in these homes. This report includes:

- an evaluation of the benefits and estimated incremental retail costs of the tested advanced building design concepts
- results for whole house performance tests evaluating the impacts and benefits of advanced system designs relative to Benchmark building systems; and
- a summary of measurements and questions answered by the performance evaluation.

Background

Borrego Springs Location

The pre-production houses are located in Borrego Springs, 90 miles northeast of San Diego, CA. Figure 1 is a regional map of the Borrego Springs area.

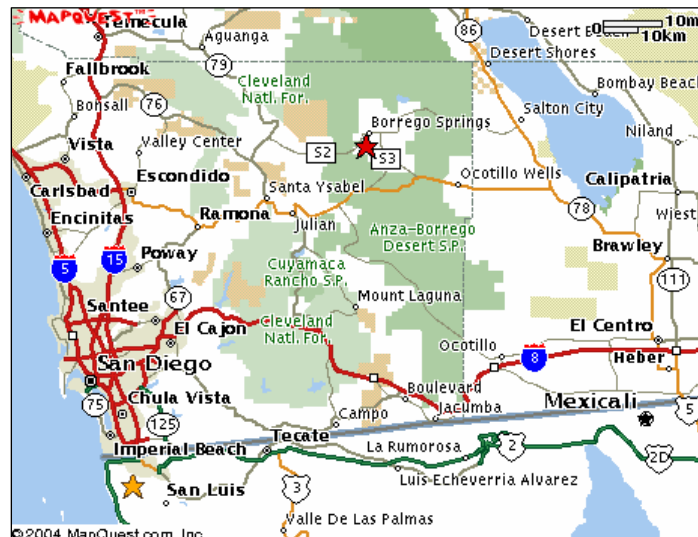


Figure 1: Regional Map – Borrego Springs

Figure 2 is a vicinity map of the Borrego Springs area showing the site locations for all four experimental houses. The two T-MASS homes are located at 742 Di Giorgio Road (Lot APN #140-070-03) and 3485 Country Club Road (Lot 96), the subjects of the evaluations within this

report. The Structural Insulated Panel (SIP) and 2x6 frame houses are located at 3234 Broken Arrow and 3224 East Star Road, respectively. Early short term testing comparing the performance between all four experimental houses is included in this report.



Figure 2: Vicinity Map – Borrego Springs

Climate

Borrego Springs is located in California Climate Zone 15 and has 1,075 HDD and 3,843 CDD; Climate Zone 15 is an extreme hot-dry climate zone and will serve as prototype for thousands of homes that are expected to be built in similar climate.

Heating Degree Days	1,075 HDD
Cooling Degree Days	3,843 CDD
Average Maximum Temperature	87.3°F
Average Temperature	72.3°F
Average Minimum Temperature	57.5°F

Table 1: Borrego Springs Climate Data

Project Highlights

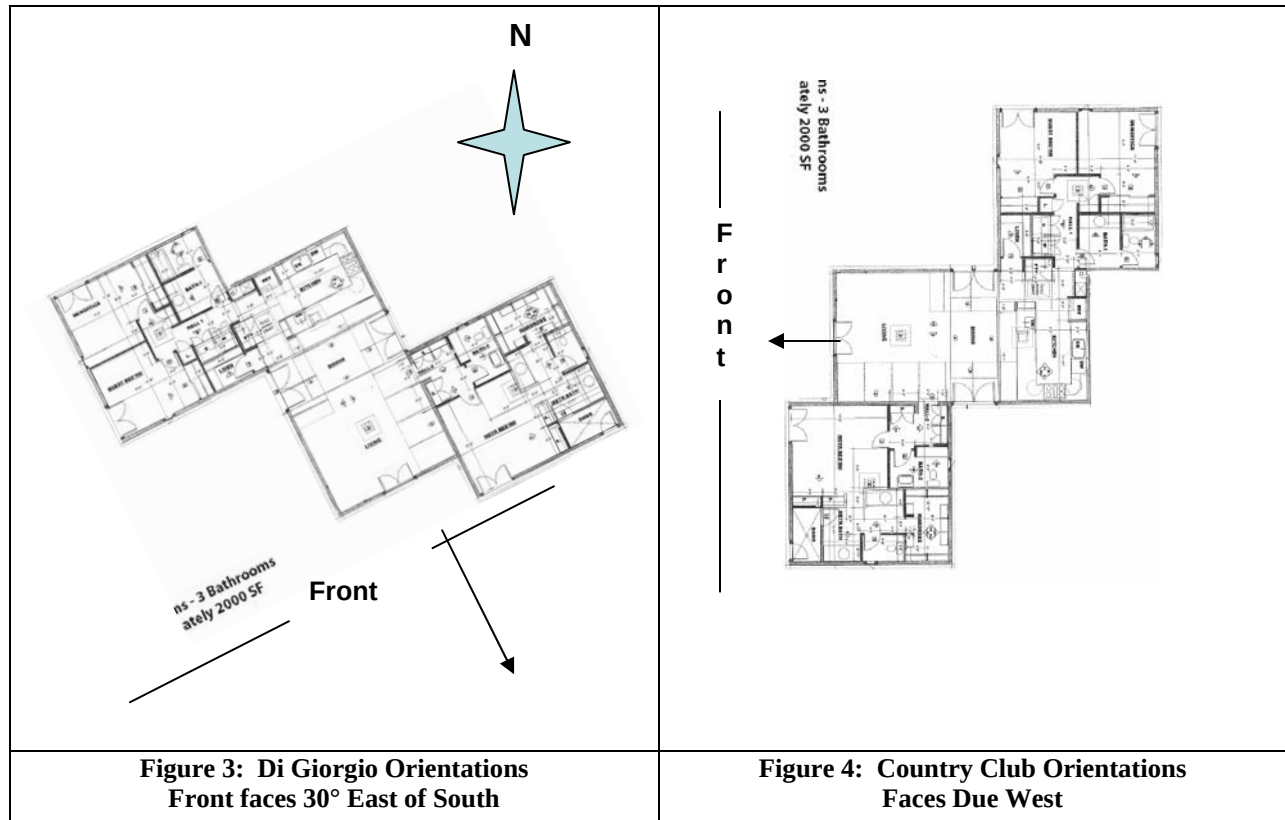
Construction was begun in 2005 on four high efficiency prototype homes. Each of the four homes is 1,920 sq. ft. The floor plans are the same; three of the homes (East Star, Broken Arrow and DiGiorgio) have the same orientation (front facing 30° east of south) and the fourth (Country Club) is rotated 120°s to the west due to sight constraints. The HVAC systems vary from house to house. This report focuses on examining the two homes using T-MASS[®] wall systems. Since the single major difference in the two homes is the cooling systems, this is a unique opportunity to compare their performance. A summary of the key differences in advanced systems for the two study houses is shown below.

Lot	Di Giorgio APN # 140-070-03	Country Club Lot 96
Orientation	Front- 30° East of South	Front- Due West
Wall System	T-MASS [®]	T-MASS [®]
Ground System	Radiant Floor Heating using Rinnai Tankless Water Heating	Radiant Floor Heating using Rinnai Tankless Water Heating
HVAC System	Freus + NightBreeze	OASys + Conventional AC

Table 2: Prototype Home vs. Key Advanced Systems

Orientation

The figures below show the site orientation for the Di Giorgio and Country Club homes. Country Club faces SSE (30°) and Di Giorgio faces due west.



The orientation of the roofs will also be important for assessing the efficiency of the PV array. The roof orientations are shown in the figure below. Due to installation problems, the DiGiorgio PV panels have not been installed at the time of this report.

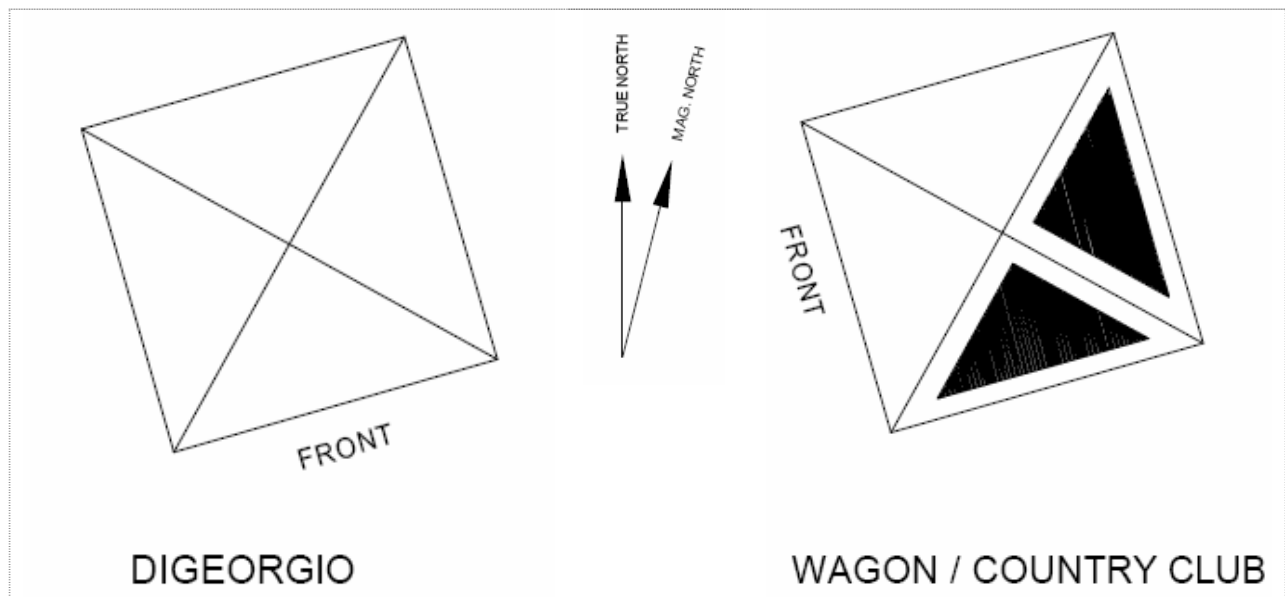


Figure 5: Roof Orientation with PV Array

Calculated Energy Requirements

To achieve 40% minimum energy savings below the base case house with energy efficiency alone, the Prototype BA Houses required the following advanced systems:

	Di Giorgio APN # 140-070-03	Country Club Lot 96
Roof	R-38 w/ radiant barrier	R-38 w/ radiant barrier
Walls	T-MASS (R-28 equivalent)	T-MASS (R-28 equivalent)
Windows	Dual pane vinyl frame windows with spectrally selective glass. SL (U = 0.35, SHGC = 0.35), FX (U=0.35, SHGC = 0.35) Patio Dr (U = 0.35, SHGC = 0.35)	Dual pane vinyl frame windows with spectrally selective glass. SL (U = 0.35, SHGC = 0.35), FX (U=0.35, SHGC = 0.35) Patio Dr (U = 0.35, SHGC = 0.35)
Air Infiltration	0.30 ACH	0.30 ACH
HVAC System	Freus w/ Ducts and Floor Pre-cooling + NightBreeze	OASys Evaporative Cooler + Radiant Floor Heating and Cooling
Water Heater	Tankless w/ Energy Factor = 0.84 & Space Heating	Tankless w/ Energy Factor = 0.84 & Space Heating
Lights	CFL's throughout	CFL's throughout
Appliances	ENERGY STAR [®]	ENERGY STAR [®]

Table 3: Summary of Energy Efficiency (EE) Features

Analyses of Multiple Energy Efficiency Options

The following tables summarize the calculated energy savings derived from major features using Micropas simulations. The detailed analyses are included in Appendix A. The total Building America whole house saving for the DiGiorgio house vs. the BA Benchmark is 52%. When PV systems are included, the total savings is 66% over the Benchmark.

	Base Case House (kBtu/yr)	Di Giorgio (kBtu/yr)	Energy Savings
Heating (from Micropas simulation)	5,203	2,611	52%
Cooling (from Micropas simulation)	150,662	50,918	66%
Water Heating (from Micropas simulation)	24,307	15,283	37%
Lighting	23,969	7,191	70%
Other Uses/Appliances/Plug Loads	59,213	51,091	0%
Whole House Energy Savings	263,355	127,095	52%
Site Generation (2.4kW DC PV system)		-38,703	
Total	263,355	88,392	66%

Table 4: Summary of DiGiorgio Energy Savings (Micropas simulation)

The table below summarizes the calculated energy savings for the Country Club house. The total Building America whole house saving for this house vs. the BA Benchmark is 53%. When PV systems are included, the total savings is 67% over the Benchmark.

	Base Case House (kBtu/yr)	Country Club (kBtu/yr)	Energy Savings
Heating (from Micropas simulation)	5,338	3,014	44%
Cooling (from Micropas simulation)	158,265	50,841	68%
Water Heating (from Micropas simulation)	24,941	15,283	39%
Lighting	23,970	7,191	70%
Other Uses/Appliances/Plug Loads	59,213	51,092	14%
Whole House Energy Savings	271,727	127,422	53%
Site Generation (2.4kW DC PV system)		-38,703	
Total	271,727	88,718	67%

Table 5: Summary of Country Club Energy Savings (Micropas simulation)

Monitoring

BIRA, DEG, and NREL are responsible for the installation of monitoring equipment in all homes short term testing and on-going analysis of data. The four prototype homes are being monitored in great detail, examining the performance of the both the structure of the homes and the advanced heating and cooling systems. The following table gives the total number of sensors per home:

52	Wagon/Country Club	T-Mass	OASys w/Conventional
46	Broken Arrow,	SIP	OASys + Conventional Ducted AC
42+17=59	Di Georgio	T-Mass	Freus(17 NREL sensors) + NightBreeze
51	East Star	OVE	Lennox
208			

Figure 6 Total Sensors Per Home x 4.

The following summarizes the sensors pertaining to the focus of this report:

Subsystem	Monitoring Points
Wall System: SIPs and 2x6 frame	– Outdoor Wall temp – Interior Wall Temp – Indoor Wall Temp
T-Mass Walls	– Near the Outside Surface – At the Interface of the Insulation and Outside 2” Layer of Concrete – At the Interface of the Insulation and Inside 4” Layer of Concrete – Near the Interior Surface
Floor/Slab system (with slab edge insulation) at: 1. center of room, 2. near edge of slab & 3. ½ way between other two	– Surface Temp – Interior Temp – Temp of ground right below the slab, 12 inches and 3 ft below the slab
HVAC System (OASys cooling in SIP home, Lennox 20.5 SEER in the 2x6 frame home	– Monthly/Yearly Water Consumption – Monthly/Yearly kW consumption
PV output	– Daily/Monthly generation – Solar Insolation
Indoor/Outdoor Temperature	
Indoor/Outdoor Relative Humidity	
Tankless water heater (space and domestic hot water heating)	– Flow Rate – Gas Usage (therm)

Table 6: Detailed Monitoring Points

Performance Measurement and Evaluation

The focus of this study was on evaluation of whole-house performance and the contribution of the advanced systems to the energy efficiency of the experimental- homes. A secondary purpose was the evaluation of cost-effectiveness of the advanced systems in supporting energy efficiency.

Inspection Data

ComfortWise test and inspection results are available in Appendix A of this report.

Third Party testing was done on each home to verify duct leakage and air infiltration. DiGiorgio was the only home with ducts, and passed with a leakage of 4.5%. Both T-Mass homes had problems with air infiltration. Initial tests of the homes resulted in SLA values of close to five. The Clarum/BIRA goal for these homes was SLA's of two. It was determined, after numerous hours of troubleshooting, that both homes had the same problems. The problems were largely the result of all skylights and windows were custom, built on site as those shown in Figure 6 and 7.



Figure 7: Example Custom, Site Built Skylight Penetrations



Figure 8: Custom Site Built Glazed Areas: Wall Penetrations

It became very apparent that the custom built windows and skylights were not been properly sealed to prevent air leakage. Once the project manager was instructed on proper measures, the homes were re-tested and found to have an SLA of approximately four. This was a marked improvement, but lower than the performance level originally intended. Clarum takes full responsibility and has carefully noted this lesson learned to avoid problems on future projects.

On further inspection, the reason for continued air infiltration was found in the baseboards, shown in Figure 8. Air was infiltrating from the attic air space through the stud bay of the interior walls and entering into conditioned space between the gaps created where the interior wall meets the slab. After caulking all the interior wall baseboards, SLA's dropped to reasonable, yet still not our projected level of air infiltration as seen from Test and Inspection results in Appendix A.



Figure 9: Floor to Wall Infiltration Gap

T-Mass Wall Performance

The figure below shows the initial T-Mass wall performance after completion of construction in April. For the data seen below, the northeast external sensor is located at the outside edge of the insulation at the juncture with the exterior width of concrete and the internal sensor is located near the interior surface of the exterior wall for the Wagon Road house provide a consistent example of the wall performance in April 2006. The exterior walls, in all orientations, provide a high thermal barrier to the ambient temperature and incident solar radiation while the interior walls help maintain a constant, “comfortable” temperature.

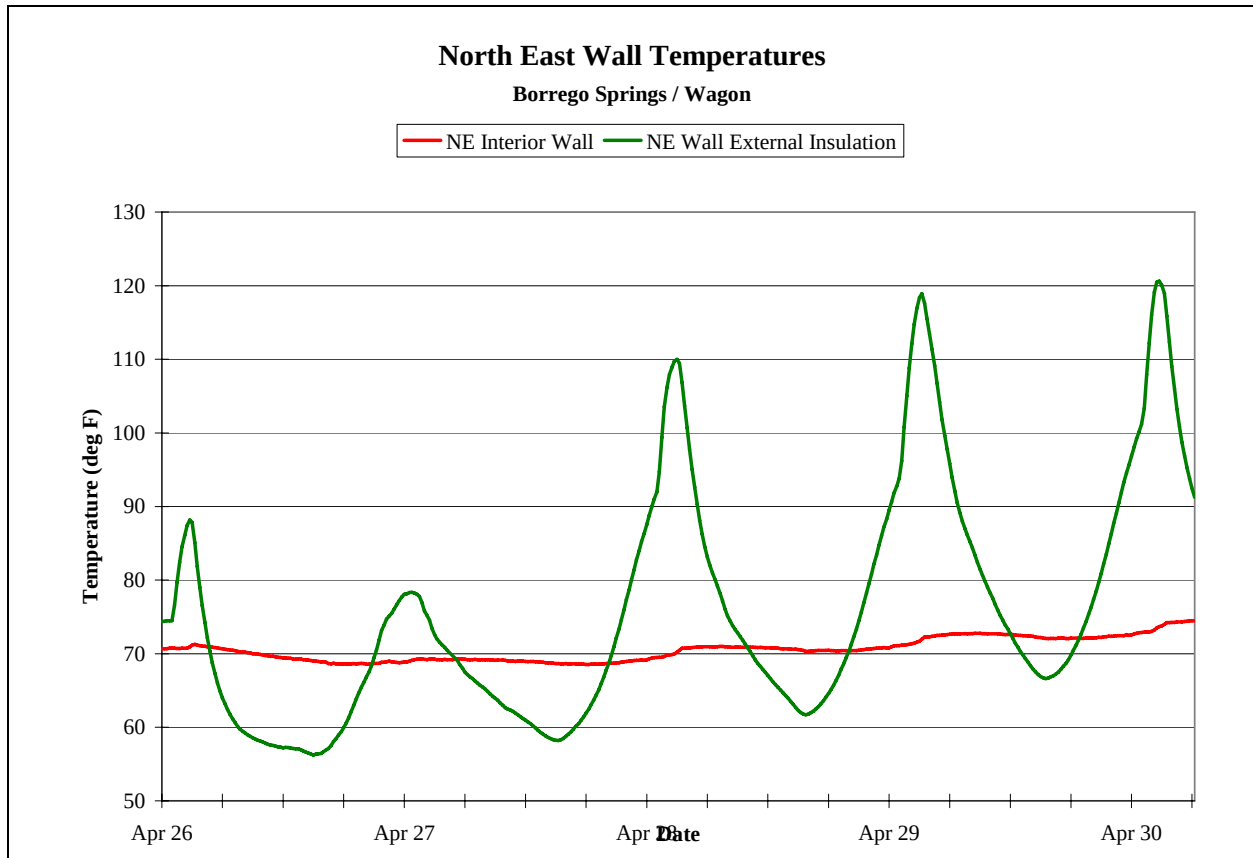


Figure 10: General Performance of T-Mass -- Northeast Wall

Pre-Cooling T-Mass House (and the others) to Test Coasting (without AC) through Utilities' Peak Demand Period, Maintaining Reasonable Comfort.

In this test, the goal for the Tuesday and Wednesday pre-cooling strategy was to cool the homes at night and early morning (72 degrees), then to set a high setpoint (85 degrees) at the beginning of the Utilities' Peak Demand Period to determine if temperature would rise without any further cooling through the peak power consumptions periods. See the table below for schedules of temperature settings. On the third day, Thursday, the settings were changed slightly. From the hours of 12pm-4pm the setpoint was changed to 74 degrees instead of 72. At 4pm the setpoint was raised to 85 degrees. This strategy was implemented to see how the homes perform during the Sacramento Municipal Utility District's (SMUD) peak power consumption hours later in the day. This strategy was used understanding that Borrego Springs Temperatures in August are typically hotter than Sacramento's hottest days, so if this worked in August in Borrego, it would work anytime during Sacramento's summer.

Experimental Setup

To perform this experiment, each house was set to a specific temperature profile for the week, described in the Table 7 and shown graphically in Figure 10. The temperature set points were maintained for the entire month of August 2006.

Week Day	Time	Set Point (°F)
Tuesday	12 AM – 12 PM	72
	12 PM -12 AM	85
Wednesday	12 AM – 12 PM	72
	12 PM -12 AM	85
Thursday	12 AM – 12 PM	72
	12 PM – 4 PM	74
	4 PM -12 AM	85
Friday	12 AM -12 AM	78
Saturday	12 AM -12 AM	78
Sunday	12 AM -12 AM	78
Monday	12 AM -12 AM	78

Table 7: Super-Cooling Experiment Set Point Temperatures

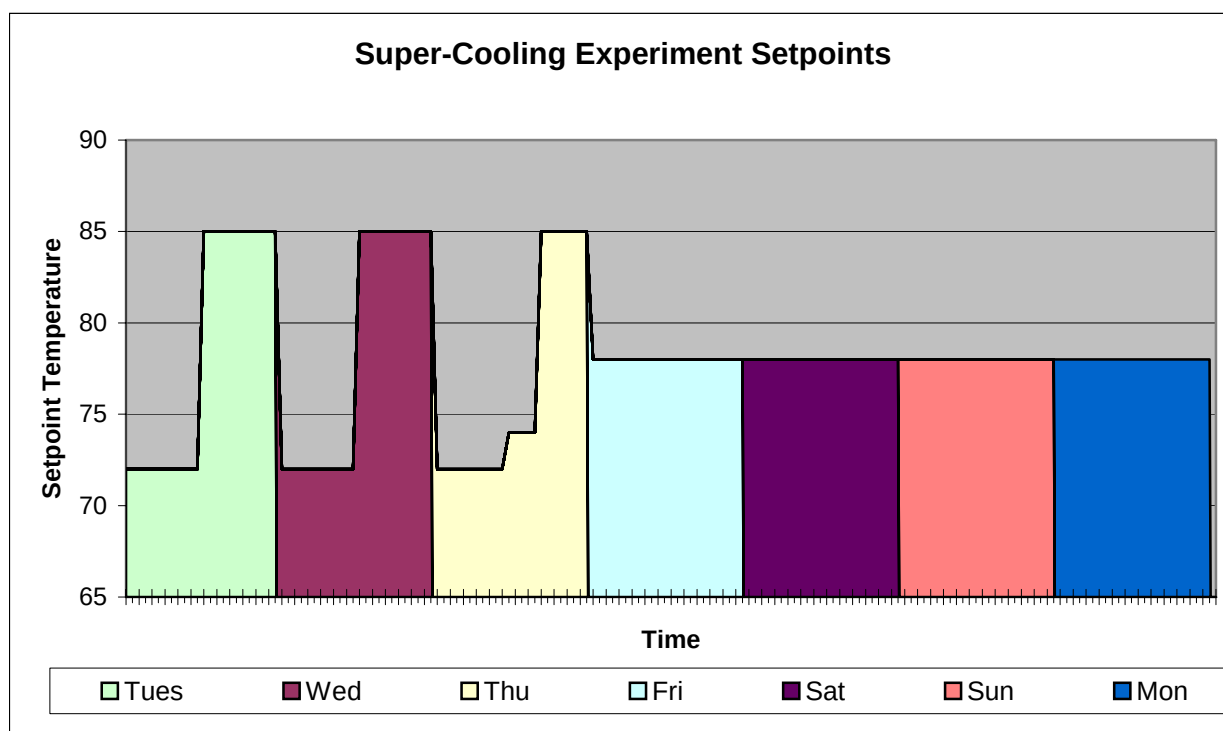


Figure 11: Super-Cooling Experiment Temperature Set Points

Super-Cooling Results

The data presented is for the Country Club house. The DiGiorgio house is currently owner-occupied and did not participate in these short term cooling tests. The results shown in the following figures are for Wednesday, August 16. The house was in the third week of the experimental cooling cycle and had completed one super-cooling cycle.

Figure 11 shows the interior temperature of the Master Bedroom and Kitchen along with the Condenser Energy Use. Note that when the HVAC system is set to 85°F from 12 PM to 12 AM, which includes the afternoon peak hours, the interior temperature rises approximately 5 degrees. The HVAC system does not run during this 85°F-period even though the outside air temperatures climbs to 105°F.

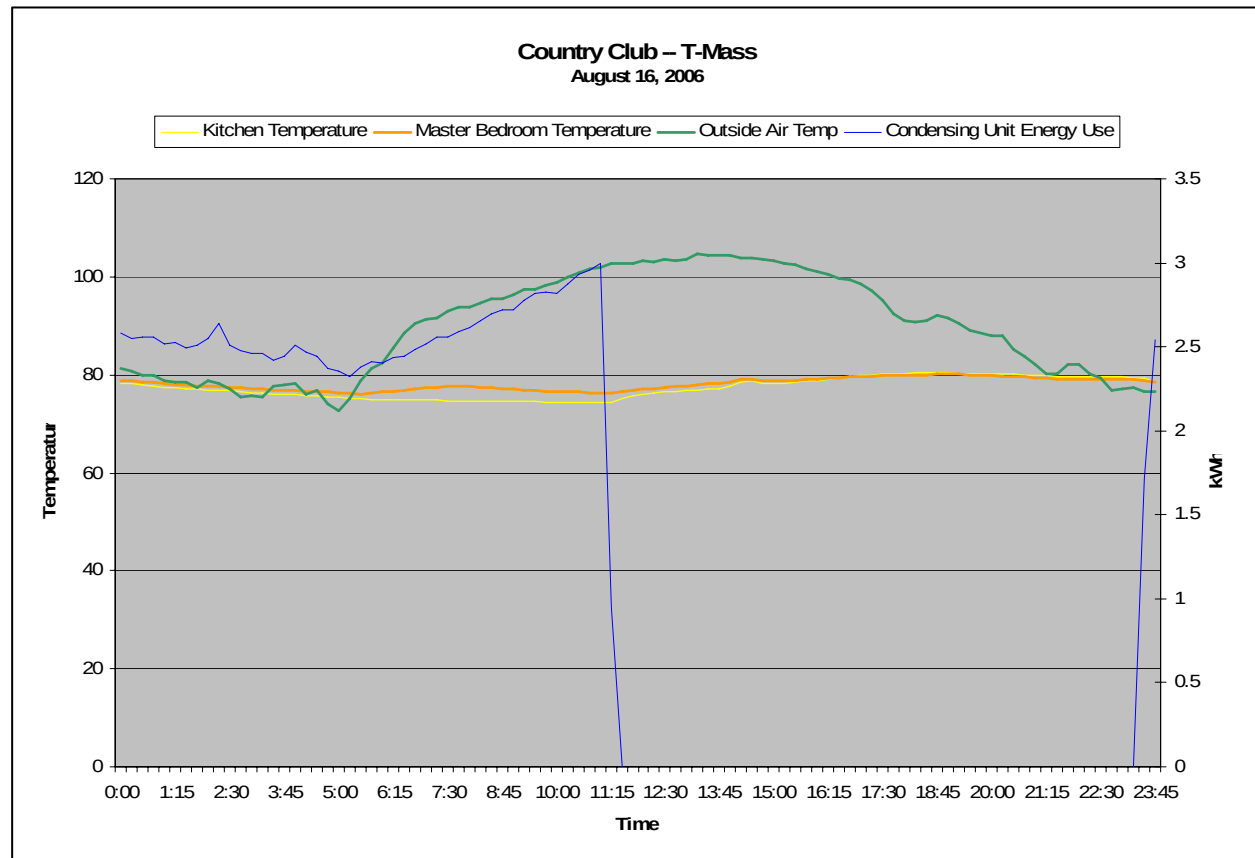


Figure 12: Super Cooling Experiment

Figure 12 shows other interior and exterior wall temperatures during this same period. Both the NE and SW external walls reach peak temperatures of 115° and 122°, even though the outside air temperature peaks at 105°. Recall that the HVAC system is set to 85°F from 12 PM to 12 AM, but the interior wall temperature peak at 80°F and the cooling system does not come on.

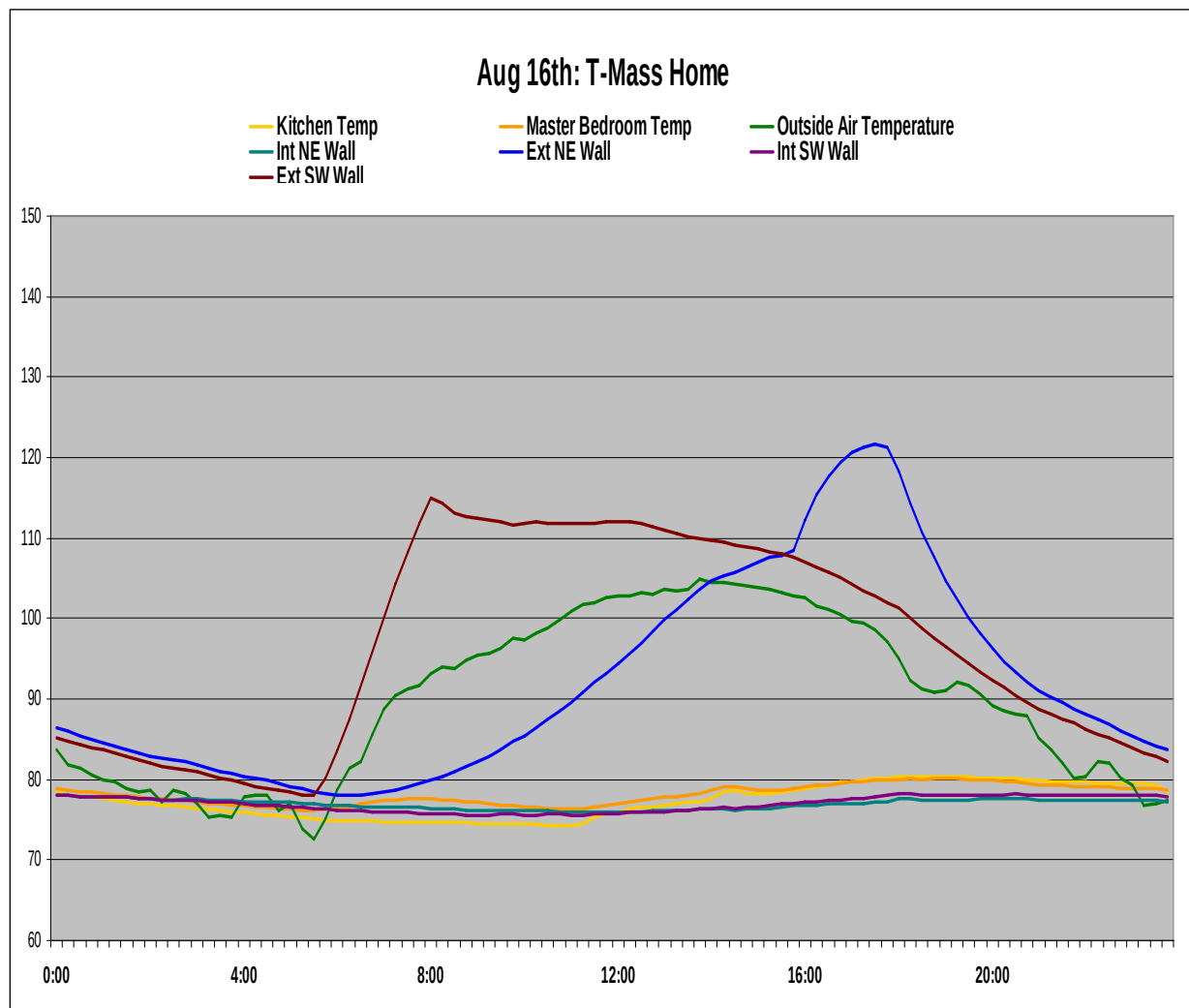


Figure 13: Super-Cooling Results – T-Mass House

For comparison, the following two figures show the wall temperature data from the SIP and 2x6 frame houses. Figure 13 shows that the SIP house never reaches the 85° set point and exhibits a temperature change of 8° during the afternoon coast period. The interior wall temperatures are also less stable than was seen in the T-Mass walls indicating that the mean radiant temperature would be higher than in the T-Mass house making occupants warmer. The 2x6 frame house, however, reaches the 85° set point in 4.5 hours and experiences a temperature change of 9° over the 11 hour interval. Note that the exterior surface of the Northeast exterior walls also reaches a temperature of 140°. The home with the T-Mass walls, in comparison, never reaches the 85° set point and experience a temperature rise of only 3.5°.

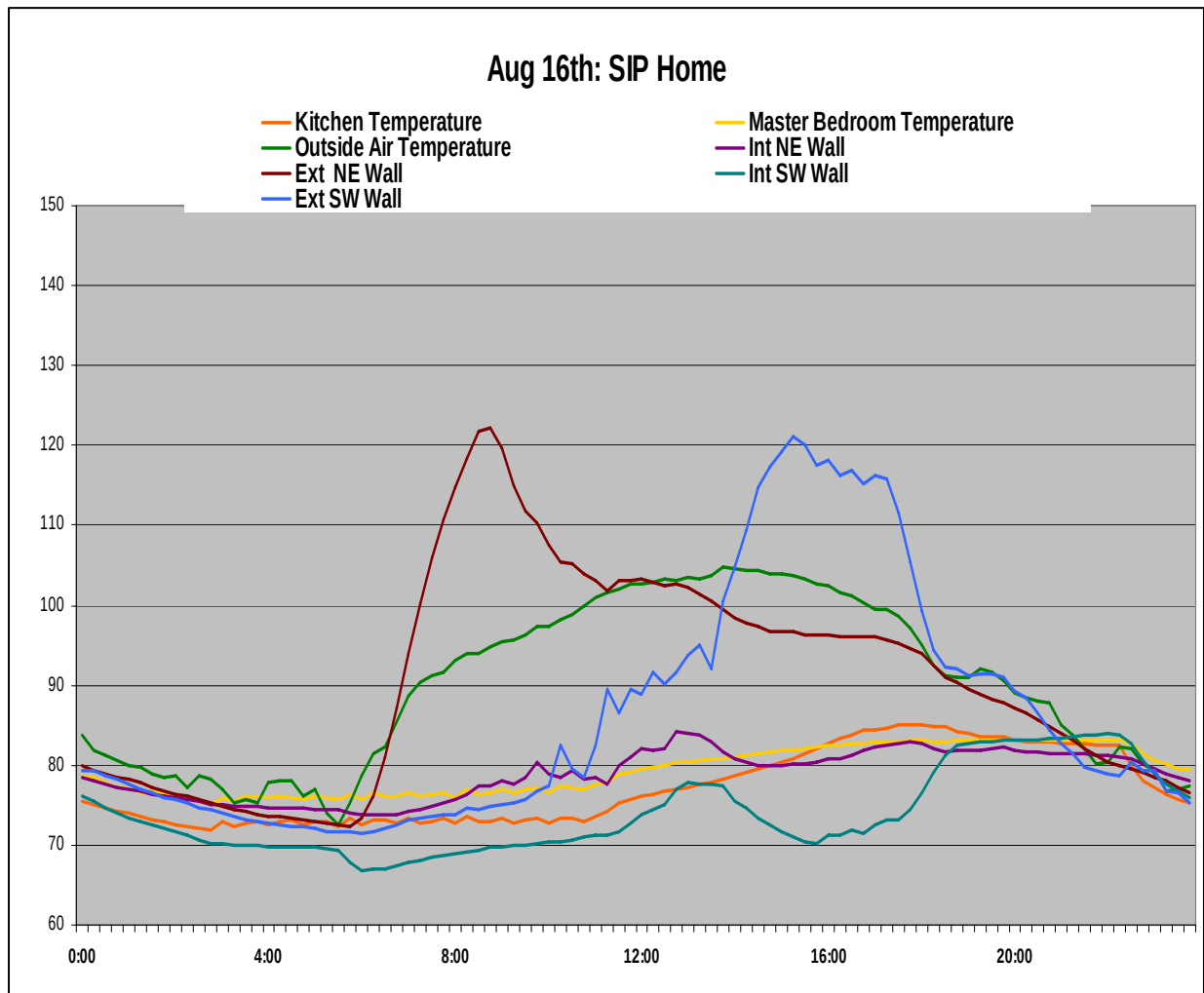


Figure 14: Super-Cooling Results – SIP House

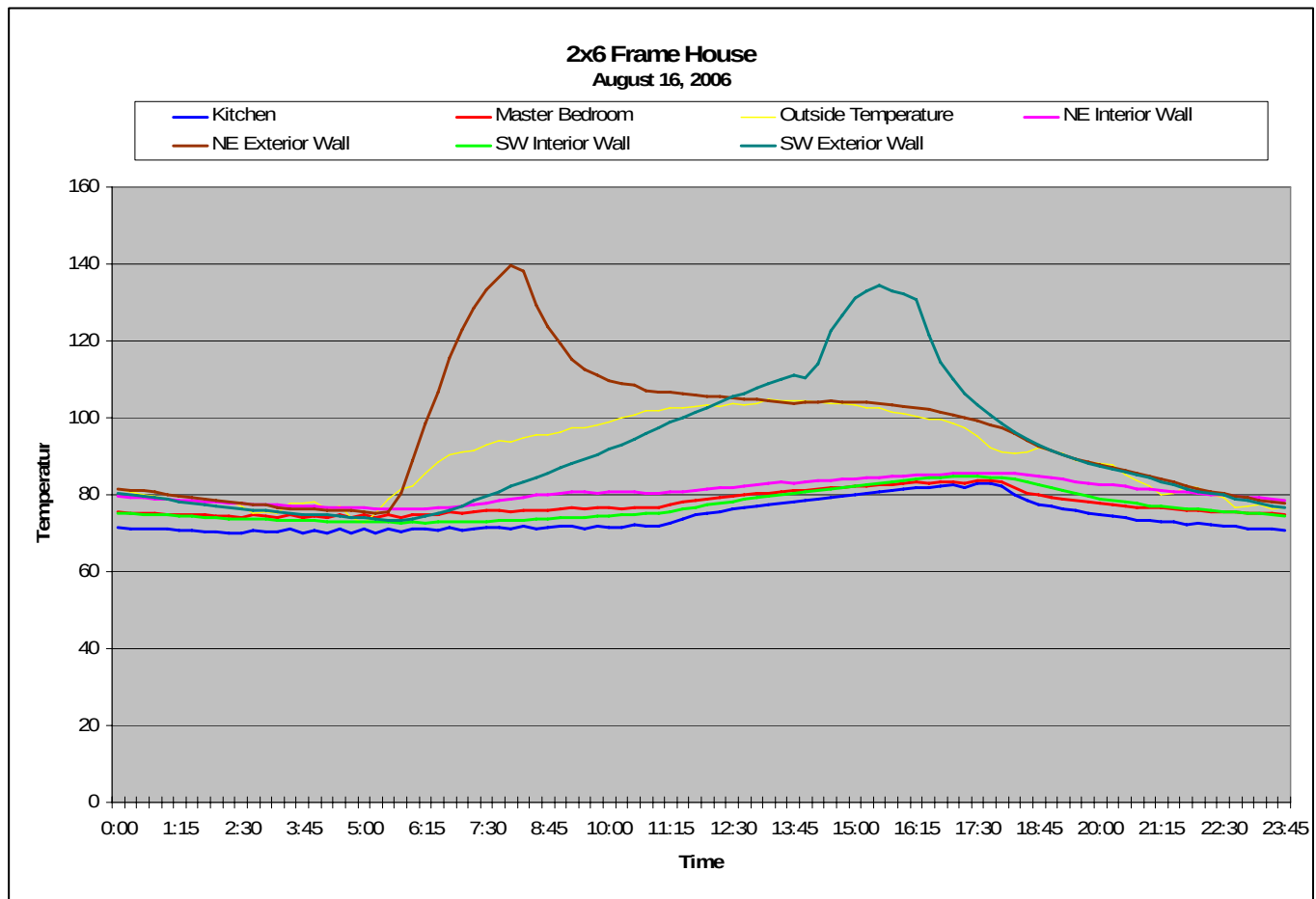


Figure 15: Super-Cooling Results – 2x6 frame House

Single Set Point Results

At the end of the 3-day super-cooling cycles, the thermostat is set to a constant 78° for the remainder of the week. The figure below shows how the walls perform during the second day of this constant set point cycle.

The outside air temperature reaches a maximum of 107° between 12 and 1 PM. The NE external wall peaks at a temperature above 120° while the internal walls maintain a nearly constant temperature near the 78° set point. The cooling system runs, almost continuously from 3 to 7 PM to maintain the 78° set point.

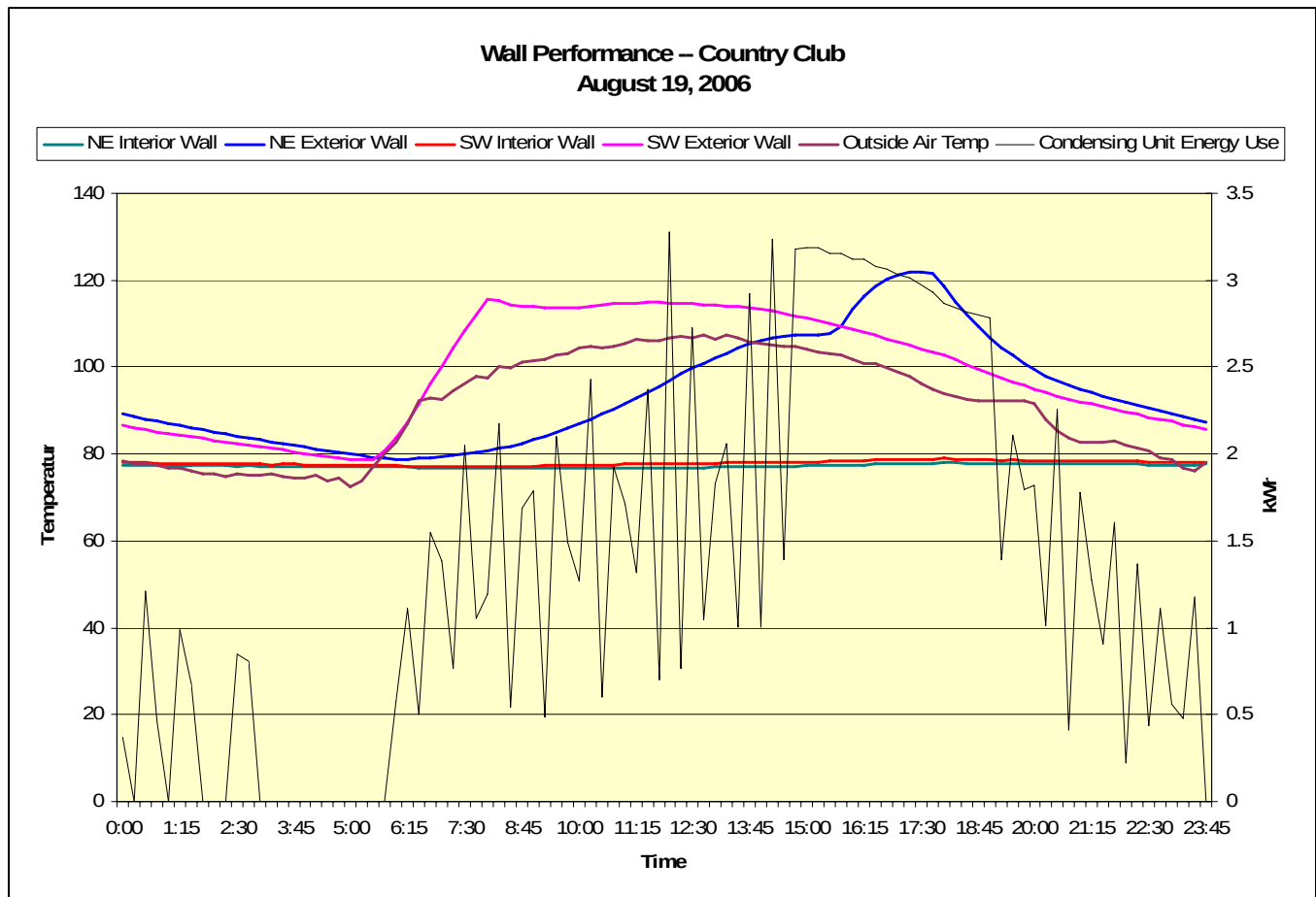


Figure 16: T-Mass Wall Performance -- 78° Set Point

When compared with the 2x6 frame house, during peak afternoon hours, the T-Mass cooling system runs from 3PM until 7PM. The 2x6 frame house begins running at 2PM and runs until 9PM to maintain the 78° set point, two hours longer than the T-Mass home.

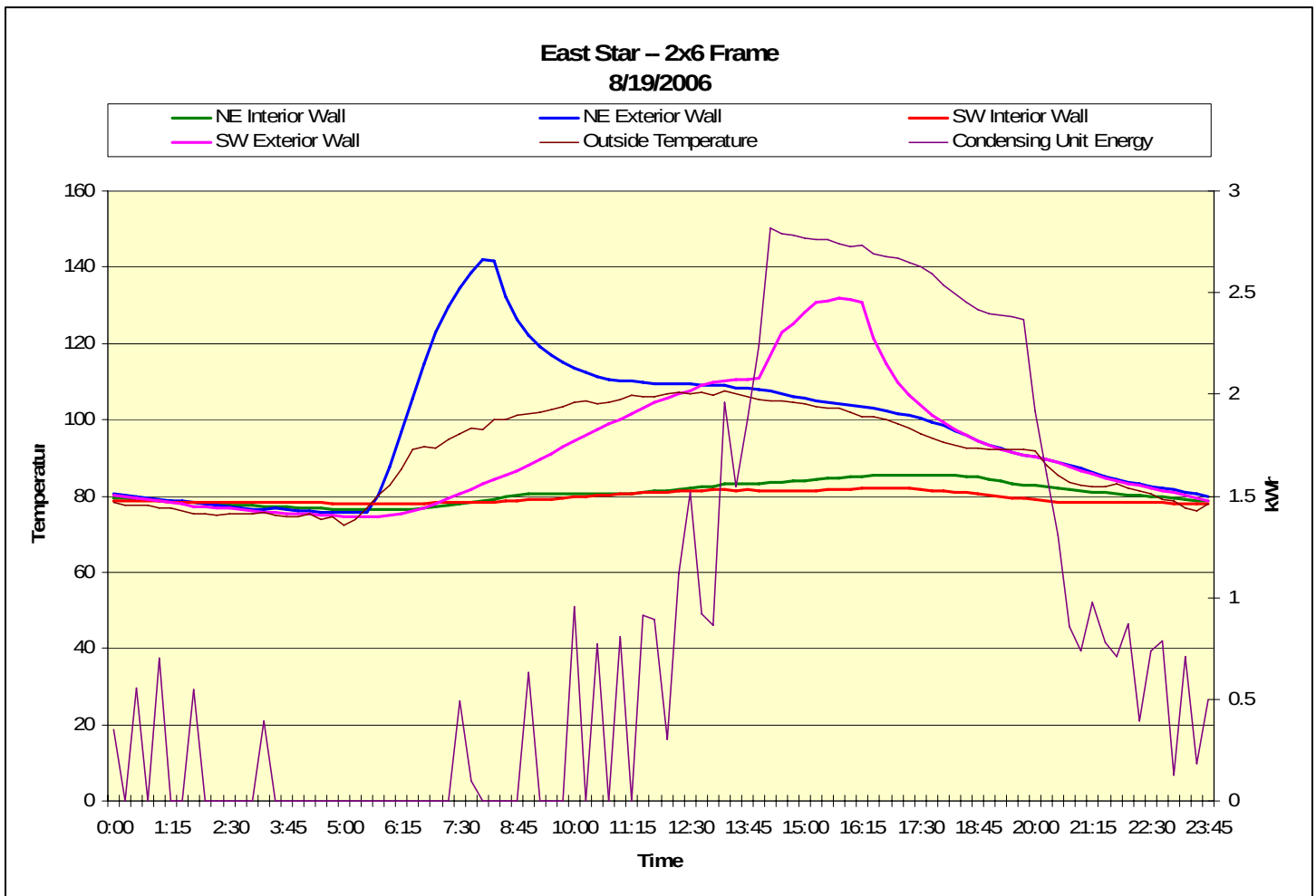


Figure 17: 2x6 frame Wall Performance -- 78° Set Point

When compared with the SIP house, during peak afternoon hours, the cooling system cycles from 1PM until 7:30PM to maintain the 78° set point. This cycling behavior is somewhat different from either the T-Mass or 2x6 frame houses. The SIP house HVAC begins two hours earlier than the T-Mass but cycles on and off rather than running continuously. Also, during the peak hours, the southwest interior wall temperature drops to 66°, when the HVAC system is running the hardest.

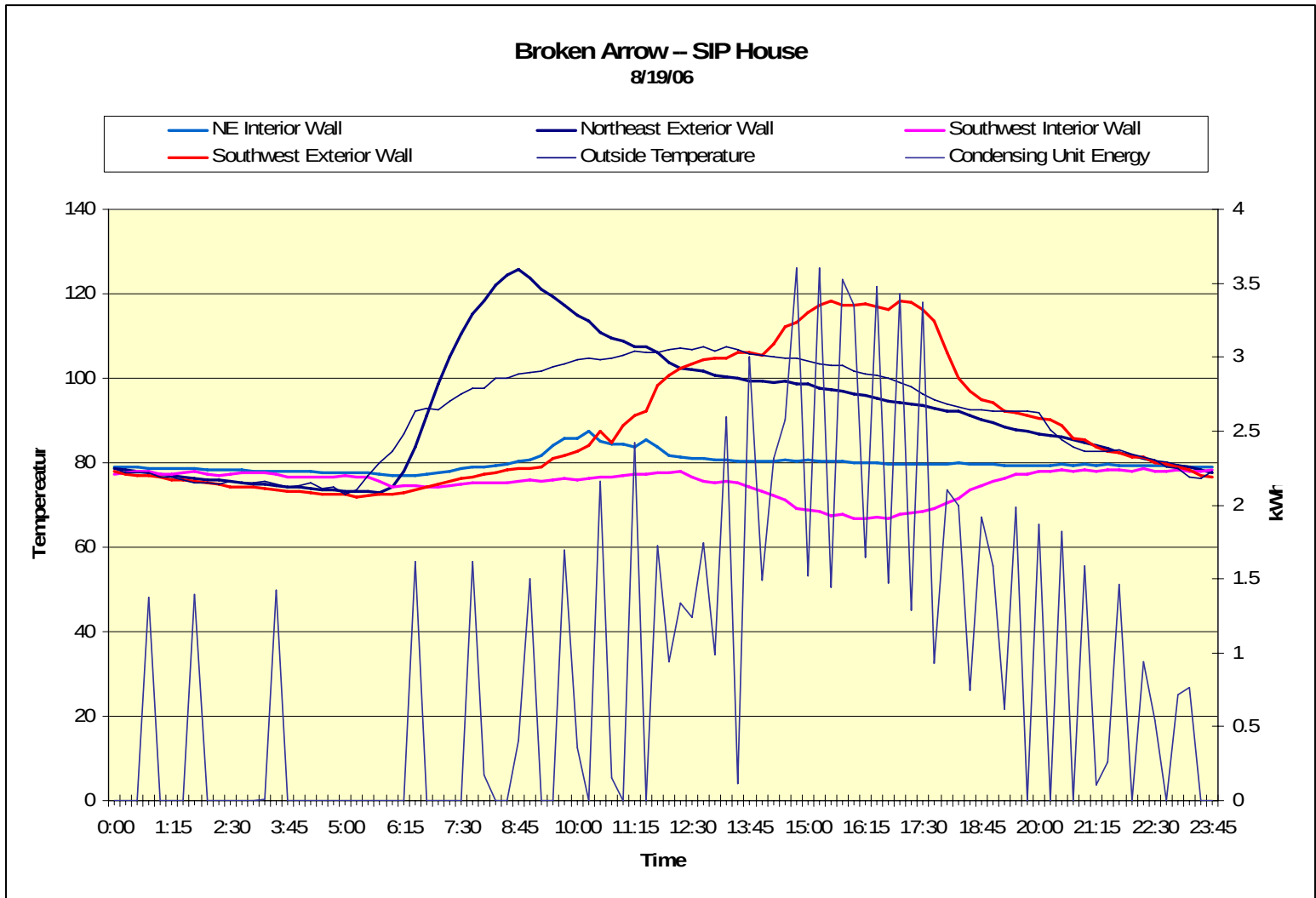


Figure 18: SIP Wall Performance -- 78° Set Point

Costs

Clarum collected and shared costs for their own planning of future projects, for this report and with the explicit purpose of adding useful information for other builders on the Clarum/Borrego Springs Project website. The cost of each wall system and each cooling system is listed below. In that the 2x6 frame house is constructed by more typical means, comparisons of costs are made to that house. The 2x6 frame house also employs the most conventional cooling system, though rated with a very high SEER of 20.5, so it is used for comparisons. In comparing cooling systems keep in mind that the climate is particularly challenging with a 4 to 6 week period of high humidity in the summer so that the homes with evaporative cooling systems also have conventional air conditioning to provide cooling during the periods of high humidity.

It should also be noted that these are prototype home built in a remote location and that costs would expect to come down if produced on a volume basis and in a more easily and less expensively accessed construction site.

The comparative costs show that the T-Mass walls cost 75% more than the 2x6 Frame house. The comparisons also show that the SIP house wall construction is 27% higher than the 2x6 house.

Comparisons of costs of the cooling systems to the high SEER Lennox system are that the Oasys 2 Stage Evaporative Cooler in the T-Mass house on Country Club Drive costs 13% more than the Lennox. As noted above, if these homes were built in other areas of the Hot-Dry climate zone, like Sacramento, CA the cost without the back up conventional AC might be the same or less than the Lennox high SEER. In the case of the second house with Oasys, it also required ducting which is atypical of evaporatively cooled homes and would probably reduce the 33% price increase above the Lennox. The third comparison for cooling is for the DiGiorgio Road, T-Mass house which is cooled with the Freus, evaporatively cooled condenser and NightBreeze system. Here again is another level of duality that adds to the cost and is expected to add significantly to the performance, particularly in spring and fall. It is conceivable that this T-Mass house could be cooled only with the NightBreeze in many parts of California's central valley, in areas of New Mexico, Arizona and Colorado. Subsequent monitoring from this project is expected to bare this out.

Energy Features	Site	Costs	Costs Compared to 2x6 Frame	Percent Increase
Walls				
TMass Walls w/standard interior framed walls & garage	Country Club Drive	\$99,762	\$42,520	74%
TMass Walls w/standard interior framed walls & garage	Di Giorgio Road	\$100,301	\$43,059	75%
SIPS w/standard interior framed walls & garage	Broken Arrow Drive	\$72,674	\$15,432	27%
2x6 Frame	East Star Road	\$57,242		
HVAC			Costs Compared to Lennox	Percent Increase
Oasys 2-Stage Evaporative Cooler	Country Club Drive	\$17,923	\$2,077	13%
Freus+NightBreeze	Di Giorgio Road	\$20,440	\$4,594	29%
Oasys w/Conventional Ducted A/C	Broken Arrow Drive	\$21,009	\$5,163	33%
Lennox	East Star Road	\$15,846		

Table 8: Builder Costs

Construction Issues

In addition to issues with infiltration discussed in the earlier section on Test and Inspection, the following construction issues were collected by the builder. The table below describes the issues identified by the builder during the construction of these four prototype homes.

Energy Features	Site	Permitting Issues	Construction Issues
Walls			
TMass Walls w/standard interior framed walls & garage	Country Club Drive	Longer Plan Review	• Inconsistency with panel colors. • Cosmetic surface cracking of wall panels • Application of wood trim, cabinets and bath hardware into concrete. • Inadequate provisions for electrical wiring. • Difficulty providing adequate flashing at window and doors • "Wet-set" electrical boxes not level or plumb. • Costly and time consuming to ship, handle and erect. • Difficult to match color and texture when patching walls
TMass Walls w/standard interior framed walls & garage	Di Giorgio Road	Longer Plan Review	• Inconsistency with panel colors. • Cosmetic surface cracking of wall panels • Application of wood trim, cabinets and bath hardware into concrete. • Inadequate provisions for electrical wiring. • Difficulty providing adequate flashing at window and doors • "Wet-set" electrical boxes not level or plumb. • Costly and time consuming to ship, handle and erect. • Difficult to match color and texture when patching walls
HVAC			
Oasys 2-Stage Evaporative Cooler	Country Club Drive	N/A	
Freus	Di Giorgio Road	N/A	

Table 9: Construction Issues

Conclusion

A high thermal mass (exterior walls and floor) coupled with nighttime cooling to discharge (cool) the mass, can result in significant energy and cost savings in homes that can benefit both the home owner and utility. The thermal mass benefits are quite significant:

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
5. 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 significantly better.

While these benefits are significant the cost increases are very 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.

Phase change materials for use in residential construction are available in Europe and Australia and DOW Chemical Company has stopped providing the T-Mass product, but is working with Oakridge National Lab. testing products focused on building applications for heating and cooling.

BIRA is following up with recent discussions with DOW representatives to determine the prospect of building prototype homes with phase change materials in walls and/or ceilings.

Appendix A: ComfortWise Test Results

Country Club

[illegible]

Di Giorgio

Aug 14 06 04:16p Rob Starr 9097950252 p.1

Test Data Collection Form

Rater Name: Rob Starr Date: 8-14-06
 Builder: CLARUM Plan: _____
 Project: BARRIO SIENAS Phase: _____ Loc: _____ Square Feet: 2040
 Address: 742 DI GIORGIO Number of Floors: 1
 Stage of Construction (circle one): ROUGH/FINAD House faces: N (5) E W

Blower Door

Depressurize Target: 50 pascals Target Infiltration (SLA): 1.5 - 3.8 Pass Fail
 Small Fan, ring size: (0) 1 2 3 House Pressure: 34 True Fan Flow (CFM): 1342 Carpet Y N Y N Holes
 Large Fan, ring size: 0 A B C Fan Pressure: _____ Measured Infiltration (SLA): 3.2 Weather-strip Y N #1 F place
 Mechanical Ventilation off Y N open

Static Pressure

System: 1 2 3 Scaled

FAU Mfr: <u>NUGASBREEZE</u>	FAU Seams	Y	N
Model: <u>NB10-Z-120A</u>	FAU Door	Y	N
AFUE: _____	Output BTU: _____	Y	N
AC Mfr: <u>FREUS</u>	Duct Collars	Y	N
Model: <u>10M02-36</u>	Dry Wall	Y	N
SEER: _____	Tons: _____	Y	N
Coil Mfr: <u>AMANA</u>	Can Seams	Y	N
Model: <u>CAF-60T</u>	M Dampers	Y	N
Equipment Sizing Matches Design: <u>Y</u> <u>N</u>	P-Trap	Y	N
Air Conditioner on: <u>Y</u> <u>N</u>	TXV	Y	N
Sheetmetal Insulated		Y	N

Supply side measured: BEFORE or AFTER coil
 Supply vs. Attic: _____
 Return vs. Attic: _____
 Supply vs. Return: _____
 Static Pressure (TWC): _____

Duct Blaster

System: 1 2 3 Upstairs / Downstairs

Ring: 0 1 2 (3) 0 1 2 3 Target CFM at 6%: _____
 At 25 Pascals: _____ Tonage: 33
 Duct Pressure: 25 Floor Area: _____
 Fan Pressure: _____ BTU: _____
 Flow (CFM): 54 Fan Flow: _____
 Leakage %: 4.5
 Target leakage below 5% (Pass) Fail
 Ring: 0 1 2 3 0 1 2 3 Notes: _____
 At 50 Pascals: _____
 Duct Pressure: 50
 Fan Pressure: _____
 Flow (CFM): _____
 Leakage %: _____

Room by Room Air Flow

Room	Design CFM	Actual CFM
KIT		296
DIN		346
LIV		454
M BED		116
1/2 BATH		122
MWC		57
MRA		62
BED 1		54
OFF / BED 2		163
		183

Return	Design CFM	Actual CFM
A		1412

Ceiling Insulation

Ball Blown-in Fiberglass Cellulose Using Radiant Barrier Y N
 Target Insulation R- _____ Observed R-Value _____ Depth blown in: _____ Uniform depth Y N Pass Fail
 Duct Insulation Target R- _____ Observed R- _____ Pass Fail

Water Heater

Target Size: _____ Observed Size: _____ Blanket required: Yes No Blanket present: Yes No
 Target Energy Factor: EF _____ Observed: EF _____ Target Recovery Efficiency: RE _____ Observed: RE _____
 W H Mfr: _____ Model: _____
 Recirculation System Y N If so, Type _____ Hot Water Main Pipe Insulation Verified at rough Y N
 Solar Water Heating Y N If so, Temperature Gauge Present: Y N

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East Star Road

Aug 14 06 04:17p

Rob Starr

9097950252

p.2

Test Data Collection Form

Rater Name: Rob Starr Date: 8-14-06
 Builder: CLAWN Plan: _____
 Project: BOKEGO SPRINGS Phase: _____ Lot: 322 Square Feet: 2000
 Address: 3224 EAST STAR ROAD Number of Floors: 1
 Stage of Construction (circle one): ROUGH FINISH House faces: N S E W

Blower Door Depressurize Target: 50 pascals Target Infiltration (SLA): 1.5 - 3.8 Pass Fail
 Small Fan, ring size: 0 1 2 3 House Pressure: 26 True Fan Flow (CFM): 1389 Carpet: Y N Y N Holes: _____
 Large Fan, ring size: 0 A B C Fan Pressure: _____ Measured Infiltration (SLA): 4.0 Weather-strip: Y N # 1 F. place: _____
 Mechanical Ventilation off: Y N even C close

Static Pressure System: 1 2 3 Scaled _____
 F.A.U. Mfr: LENNEX FAU Seams: Y N
 Model: LBK32-MV-036 FAU Door: Y N
 AFUE: _____ Output BTU: _____ Coil Seams: Y N
 AC Mfr: LENNEX Duct Collars: Y N
 Model: KC21-036 Dry Wall: Y N
 SEER: _____ Tons: _____ Cao Seams: Y N
 Coil Mfr: _____ M Dampers: Y N
 Model: _____ P-Trap: Y N
 Equipment Sizing Matches Design: Y N TCV: Y N
 Air Conditions on: Y N Sheetmetal Insulated: Y N
 Supply side measured: BEFORE or AFTER coil
 Supply vs. Attic: _____
 Return vs. Attic: _____
 Supply vs. Return: _____
 Static Pressure (IWC): _____

Room by Room Air Flow System: 1 2 3 Upstairs / Downstairs _____

Room	Design CFM	Actual CFM
MBA		90
MRED		105
1 1/2 BA		43
LIV		267
DIN		335
KIT		143
LAV		67
BA 2		94
BED 1		295
BED 2		226

Return	Design CFM	Actual CFM
A		1276

Duct Blaster Total, Supply & Return
 System: 1 2 3 Upstairs / Downstairs _____
 Ring: 0 1 2 3 Target CFM at 6": _____
 At 25 Pascals: _____ Tenage: 3
 Duct Pressure: 25 Floor Area: _____
 Fan Pressure: _____ BTU: _____
 Flow (CFM): 24 Fan Flow: _____
 Leakage %: 2%
 Target leakage: below 6% Pass Fail
 Ring: 0 1 2 3 Notes: _____
 At 50 Pascals: _____
 Duct Pressure: 50
 Fan Pressure: _____
 Flow (CFM): _____
 Leakage %: _____

Ceiling Insulation Bat Blown in Fiberglass Cellulose _____ Using Radiant Barrier: Y N
 Target Insulation R-Value: _____ Observed R-Value: _____ Depth blown in: _____ Uniform depth: Y N Pass Fail
 Target R-Value: _____ Observed R-Value: _____ Pass Fail

Duct Insulation Target R-Value: _____ Observed R-Value: _____ Pass Fail

Water Heater Target Size: _____ Observed Size: _____ Blanket required: Yes No Blanket present: Yes No
 Target Energy Factor: EF _____ Observed EF: _____ Tank Recovery Efficiency: RE _____ Observed RE: _____
 W.H.Mfr: _____ Model: _____
 Recirculation System: Y N If so, Type: _____ Hot Water Main Pipe Insulation Verified at rough: Y N
 Solar Water Heating: Y N If so, Temperature Gauge Present: Y N

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2/7/02

Broken Arrow Road

Aug 14 06 04:17p Rob Starr 9097950252 p.3

Test Data Collection Form

Rater Name: Rob Starr Date: 8-14-06
 Builder: Clarem Plan: _____
 Project: BORRERO SPRINGS Phase: _____ Lot: 73 Square Feet: 1940
 Address: 3234 BROKEN ARROW RD Number of Floors: 1
 Stage of Construction (circle one): ROUGH FINISH House facts: N S ☒ W

Blower Door Depressurize Target: 50 pascals Target Infiltration (SLA): 1.5 - 3.8 Pass Fail Pass
 Small Fan, ring size: 0 1 2 3 House Pressure: 33 True Fan Flow (CFM): 1351 Carpet: Y ☒ N ☒ Holes: _____
 Large Fan, ring size: 0 A B C Fan Pressure: _____ Measured Infiltration (SLA): 3.4 Weather-strip: Y ☒ N ☒ # 1 F. place: _____
 Mechanical Ventilation off: Y ☒ N ☒ open Close

Static Pressure System: 1 2 3 Sealed _____
 F.A.U. Mfr: Carrier F.A.U. Seams: Y N
 Model: 36TCA036-30 F.A.U. Door: Y N
 AFUE: _____ Output BTU: _____ Coil Seams: Y N
 AC Mfr: Carrier FCR-036 Duct Collars: Y N
 Model: _____ Dry Wall: Y N
 SEER: _____ Tons: _____ Can Seams: Y N
 Coil Mfr: _____ M. Dampers: Y N
 Model: _____ P-Trap: Y N
 Equipment Sizing Method Design: Y N TXV: Y N
 Air Conditioner on: Y N Sheetrock Insulated: Y N
 Supply side measured: BEFORE or AFTER coil
 Supply vs. Airside: _____
 Return vs. Airside: _____
 Supply vs. Return: _____
 Static Pressure (TWC): _____

Duct Blaster Total, Supply & Return
 System: 1 2 3 Upstairs / Downstairs _____
 Rings: 0 1 2 3 0 1 2 3 Target CFM at 6%: _____
 At 25 Pascals: _____ Tons: 3
 Duct Pressure: 25 Floor Area: _____
 Fan Pressure: _____ BTU: _____
 Flow (CFM): 54 Fan Flow: _____
 Leakage %: 4.5
 Target leakage: below 6% (Pass) Fail Pass
 Rings: 0 1 2 3 0 1 2 3 Notes: _____
 At 50 Pascals: _____
 Duct Pressure: 50
 Fan Pressure: _____
 Flow (CFM): _____
 Leakage %: _____

Ceiling Insulation Batt Blown-in Fiberglass Cellulose Using Radiant Barrier: Y N
 Target Insulation R-Value: _____ Observed R-Value: _____ Depth (down in): _____ Uniform depth: Y N Pass Fail Pass

Duct Insulation Target R-Value: _____ Observed R-Value: _____ Pass Fail Pass

Water Heater Target Size: _____ Observed Size: _____ Blanket required: Yes No Blanket present: Yes No
 Target Energy Factor: EF _____ Observed: EF _____ Target Recovery Efficiency: RE _____ Observed: RE _____
 W. H. Mfr: _____ Model: _____ Pass Fail Pass
 Recirculation System: Y N If so, Type: _____ Hot Water Main Pipe Insulation Verified at rough: Y N
 Solar Water Heating: Y N If so, Temperature Gauge Present: Y N

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Appendix B: Prototype Home vs. Benchmark

(Note: the estimated costs included in the preliminary analyses in Appendix A do not include HVAC system costs.)

Di Giorgio House

Clarum Homes		TMASS				
Borrego Springs - DiGiorgio		1,920 Sqft				
Floor Area =						
Borrego Springs, CA - CZ 15						
Energy and Cost Analysis for Base Case and BA Prototype Houses						
	Base Case / BA Benchmark House (kBtu/sf-yr)	Base Case / BA Benchmark House (kBtu/yr)	Prototype House - Energy Savings Features (kBtu/sf-yr)	Prototype House - Energy Savings Features (kBtu/yr)	Reduction in Energy Use (kBtu/yr)	Estimated Incr. Cost: Base to Prototype House (Energy Savings Level)
Heating	2.71	5,203	1.36	2,611		
Cooling	78.47	150,662	26.52	50,918		
Water Heating	12.66	24,307	7.96	15,283		
Total	93.84	180173	35.84	68813	61.8%	
Lighting		23,969		7,191		
Total (Heat, Cool, WH and Lighting)		204,142		76,004	63%	
Other Uses		59,213		58,643		
Total (Heat, Cool, WH, Lighting & Other Uses)		263,355		134,646	49%	
Site Generation (2.4kW PV)				(38,703)		
Overall Total Energy Savings		263,355		95,943	64%	
ENVELOPE: (Insulation U-Values or R-Values)						
Roof (attic)	R-22		R-38 (U-value = 0.025)			\$192
Roof (at furnace)	R-22		R-19 (U-value = 0.047)			
Wall (Exterior)	U-value = 0.085		R-28			\$1,065
Wall (Kneewall)	U-value = 0.088		R-13			
Floor (above garage)	N/A		N/A			
Floor (cantilever)	N/A		N/A			
Attic Radiant Barrier	No		Yes			\$461
Low Air Infiltration	No		Yes			
GLAZING:						
			Dual Pane Vinyl Frame Windows w/ Spectrally Selective Glass			
U-Factor						
Slider (horz)*	0.790		0.35			
Fixed*	0.790		0.35			
Patio*	0.790		0.35			
SHGC						
Slider (horz)*	0.790		0.35			
Fixed*	0.790		0.35			
Patio*	0.790		0.35			
HVAC SYSTEM: (Oasys Evap Cooler by Davis Energy Group)						
Furnace: AFUE	0.78		0.84 equivalent			TBD
A/C: SEER	10 SEER		19.0			TBD
Duct Insulation / Location	5.0/Attic		R-4.2 buried in insulation			
Duct Testing	No		Yes			
ACCA Manual D	No		Yes			
WATER HEATING:						
Water Heater Size	40 gal		Tankless System			\$750
Energy Factor	0.54		0.80			
Distribution Type	Standard		Pipe Insulation			\$75
External Wrap	R-12		None			
3rd Party Inspections and Testing (In ComfortWise Program)	No		Yes			\$490
Gas dryer stub	No		Yes			\$75
Fluorescent lighting (screw-in lamps)	No		All fluorescent			\$250
Pv System	No		Kyocera			\$16,500
Total Estimated Incremental Cost						\$19,858

Table 10: Borrego Springs Di Giorgio vs. BA Prototype House Energy and Cost Analysis

DiGiorgio			3 Bedrooms			
Comparison of Total Energy Use						
TMASS Wall System	Base Case / BA Benchmark House			BA Prototype House - Energy Savings (Upgraded Features, Fluorescent, Gas Dryer Stub, and Tankless Hot Water)		
	\		Dollars	Energy Use		Dollars
	Therms	kWh	\$	Therms	kWh	\$
	Energy Code Related					
	Space Heating	52	\$ 52.03	26		\$ 26.11
	Space Cooling		\$ 1,912.89		4,973	\$ 646.49
	Water Heating	243	\$ 243.07	153		\$ 152.83
	Other Uses					
	cooking	78	\$ 78.00	78		\$ 78.00
	clothes washer		\$ 13.65		105	\$ 13.65
	dishwasher		\$ 26.77		206	\$ 26.77
	electric or gas dryer		\$ 108.55	72	76	\$ 81.89
	refrigerator		\$ 86.97		669	\$ 86.97
Miscellaneous (Appliances + Plug)		\$ 416.83		2,469	\$ 320.96	
Lighting		\$ 304.33		702	\$ 91.30	
reduce kWh by solar contribution		n/a		(3,780)	\$ (491.40)	
Total use	373	\$ 3,243.10	329	5,420	1,033.57	
Total Annual Energy Use			263,355	kBtu/yr	88,392 kBtu/yr	
Reduction in Energy Use				12%	75% 68%	
Total for Column in kBtu/yr			37,310	226,045	32,894 55,498	
Total kBtu/yr for BA Benchmark House			263,355	kBtu/yr		
Total kBtu/yr for Prototype House			88,392	kBtu/yr		
Percent End Use Energy Savings			66%			
Estimated Montly Energy Bill			\$ 270.26	/mo	\$ 86.13 /mo	
Reduction in Energy Cost					32%	
price of gas/therm			\$1.00			
price of electricity/kWh			\$0.13000			

Table 11: Borrego Springs Di Giorgio Comparison of Total Energy Use

Country Club House

Clarum Homes		TMASS				
Borrego Springs - Country Club/Lot 96		1,920 Sqft				
Floor Area =						
Borrego Springs, CA - CZ 15						
Energy and Cost Analysis for Base Case and BA Prototype Houses						
	Base Case / BA Benchmark House (kBtu/sf-yr)	Base Case / BA Benchmark House (kBtu/yr)	Prototype House - Energy Savings Features (kBtu/sf-yr)	Prototype House - Energy Savings Features (kBtu/yr)	Reduction in Energy Use (kBtu/yr)	Estimated Incr. Cost: Base to Prototype House (Energy Savings Level)
Heating	2.78	5,338	1.57	3,014		
Cooling	82.43	158,266	26.48	50,842		
Water Heating	12.99	24,941	7.96	15,283		
Total	98.20	188544	36.01	69139	63.3%	
Lighting		23,969		7,191		
Total (Heat, Cool, WH and Lighting)		212,513		76,330	64%	
Other Uses		59,213		58,643		
Total (Heat, Cool, WH, Lighting & Other Uses)		271,727		134,973	50%	
Site Generation (2.4kW PV)				(38,703)		
Overall Total Energy Savings		271,727		96,269	65%	
ENVELOPE: (Insulation U-Values or R-Values)						
Roof (attic)	R-22		R-38 (U-value = 0.025)			\$192
Roof (at furnace)	R-22		R-19 (U-value = 0.047)			
Wall (Exterior)	U-value = 0.085		R-28			\$1,065
Wall (Kneewall)	U-value = 0.088		R-13			
Floor (above garage)	N/A		N/A			
Floor (cantilever)	N/A		N/A			
Attic Radiant Barrier	No		Yes			\$461
Low Air Infiltration	No		Yes			
GLAZING:						
			Dual Pane Vinyl Frame Windows w/ Spectrally Selective Glass			
U-Factor						
Slider (horz)*	0.790		0.35			
Fixed*	0.790		0.35			
Patio*	0.790		0.35			
SHGC						
Slider (horz)*	0.790		0.35			
Fixed*	0.790		0.35			
Patio*	0.790		0.35			
HVAC SYSTEM: (Oasys Evap Cooler by Davis Energy Group)						
Furnace: AFUE	0.78		0.84 equivalent			TBD
A/C: SEER	10 SEER		14.0			TBD
Duct Insulation / Location	5.0/Attic		R-4.2 buried in insulation			
Duct Testing	No		Yes			
ACCA Manual D	No		Yes			
WATER HEATING:						
Water Heater Size	40 gal		Tankless System			\$750
Energy Factor	0.54		0.80			
Distribution Type	Standard		Pipe Insulation			\$75
External Wrap	R-12		None			
3rd Party Inspections and Testing (In ComfortWise Program)	No		Yes			\$490
Gas dryer stub	No		Yes			\$75
Fluorescent lighting (screw-in lamps)	No		All fluorescent			\$250
Pv System	No		Kyocera			\$16,500
Total Estimated Incremental Cost						\$19,858

Table 12: Borrego Springs Country Club vs. BA Benchmark Energy and Cost Analysis

Country Club/Lot96			3 Bedrooms			
Comparison of Total Energy Use						
TMASS Wall System	Base Case / BA Benchmark House			BA Prototype House - Energy Savings (Upgraded Features, Fluorescent, Gas Dryer Stub, and Tankless Hot Water)		
	\		Dollars	Energy Use		Dollars
	Therms	kWh	\$	Therms	kWh	\$
	Energy Code Related					
	Space Heating	53	\$ 53.38	30		\$ 30.14
	Space Cooling	15,457	\$ 2,009.43		4,965	\$ 645.51
	Water Heating	249	\$ 249.41	153		\$ 152.83
	Other Uses					
	cooking	78	\$ 78.00	78		\$ 78.00
	clothes washer		\$ 13.65		105	\$ 13.65
	dishwasher		\$ 26.77		206	\$ 26.77
	electric or gas dryer		\$ 108.55	72	76	\$ 81.89
	refrigerator		\$ 86.97		669	\$ 86.97
Miscellaneous (Appliances + Plug)		\$ 416.83		2,469	\$ 320.96	
Lighting		\$ 304.33		702	\$ 91.30	
reduce kWh by solar contribution		n/a		(3,780)	\$ (491.40)	
Total use	381	\$ 3,347.31	333		1,036.63	
Total Annual Energy Use	271,727	kBtu/yr		88,718	kBtu/yr	
Reduction in Energy Use			13%	76%	69%	
Total for Column in kBtu/yr	38,078	233,648	33,298	55,421		
Total kBtu/yr for BA Benchmark House	271,727	kBtu/yr				
Total kBtu/yr for Prototype House	88,718	kBtu/yr				
Percent End Use Energy Savings	67%					
Estimated Montly Energy Bill		\$ 278.94 /mo		\$ 86.39 /mo		
Reduction in Energy Cost				31%		
price of gas/therm	\$1.00					
price of electricity/kWh	\$0.13000					

Table 13: Borrego Springs Country Club Comparison of Total Energy Use