CALIFORNIA ENERGY COMMISSION

DEMONSTRATION PROJECT REPORTS

Construction Process and Cost Evaluations

Occupant Response and Behavior

Monitoring Plan

Monitoring Reports

TECHNICAL REPORT

February 2004
P500-04-009-A3

DAVIS ENERGY GROUP INCORPORATED

STATE OF CALIFORNIA ENERGY COMMISSION

Arnold Schwarzenegger, *Governor*

Prepared By:
Davis Energy Group
Dave Springer
123 C Street
Davis, California 95616
Contract No. 500-98-024

Prepared For:

California Energy Commission

Phil Spartz
Project Manager

Nancy Jenkins
PIER Buildings Program Manager

Terry Surles
PIER Program Director

Robert L. Therkelsen
Executive Director

DISCLAIMER

This report was prepared as the result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Energy Systems Integration

What follows is an attachment to the final report for the Alternatives to Compressor Cooling Phase V project, Contract Number 500-98-024, conducted by Davis Energy Group. This project contributes to the PIER Building End-Use Energy Efficiency program.

This attachment, "Demonstration Project Reports" (Attachment A-3), provides supplemental information to the project's final report and includes the following reports:

- *Construction Process and Cost Evaluations*
- *Occupant Response and Behavior*
- *Monitoring Plan*

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Abstract

This "Demonstration Project Reports" attachment is a set of documents produced by the Alternatives to Compressor Cooling Phase V project, funded by the California Energy Commission's Public Interest Energy Research (PIER) Program.

The multi-year Alternatives to Compressor Cooling Phase V (ACC) Project has the goal of reducing residential peak load in California by using nighttime ventilation to cool houses that are designed for optimal summer performance and that potentially eliminate the need for air conditioning in transition climates.

This attachment, "NightBreeze Product and Test Information" (Attachment A-3), provides supplemental information to the project's final report and includes the following reports:

Construction Process and Cost Evaluations
Provides construction costs and builder feedback from the two demonstration homes constructed by Centex and Clarum Homes as part of the ACC project.

Occupant Response and Behavior
Summarizes owner feedback on comfort, ease of operation, and general satisfaction from the owners of the demonstration homes.

Monitoring Plan
Presents the general strategy and methodology for monitoring both demonstration sites.

Monitoring Reports
Outlines results from monitoring the two demonstration homes.

Demonstration Project Reports

Alternatives to Compressor Cooling
Contract No. 500-98-024

Issued: **February 17, 2004**

Presented To: **California Energy Commission**
1516 Ninth Street
Sacramento, CA 95814

Prepared By: **Davis Energy Group, Inc.**
123 C Street
Davis, CA 95616

© Copyright, 2004, Davis Energy Group, Inc. All rights reserved.

Foreword

This document is a compilation of multiple reports submitted to the California Energy Commission as deliverables under Phase 5, Task 2.4, of the Alternatives to Compressor Cooling (ACC) project. These reports describe the construction process of the two demonstration homes built under the ACC project, provide results of builder and owner interviews, and describe monitoring methods and results.

CONSTRUCTION PROCESS AND COST EVALUATIONS

Subtask 2.4.7

1 Centex Homes, Livermore

1.1 Background

In June of 2001 Centex Homes' Northern California division agreed to participate in the Alternatives to Compressor Cooling Project demonstration. During initial meetings with Centex staff, the Los Olivos Plan 2, a two-story 3450 ft² home, was selected to serve as the demonstration house. Through subsequent meetings with Centex and the mechanical contractor it was determined that installation of the dampers and outside air ducting would be difficult given the vaulted ceilings and minimal attic space, and Plan 1 was chosen instead. Plan 1 is a 3080 ft² one-story home. The site for the house is Lot 78, which is on the east side of Bertolli Drive. Construction began in October 2001 and was completed in July of 2002.

Shortly after the plan was selected an agreement was reached between Centex Homes and Davis Energy Group that the house would also serve as a pilot project for the Zero Energy Homes project being conducted by DEG for the National Renewable Energy Laboratory. Designs were completed for the installation of a 3.6 kW PV system and a solar water heating system. The house also became a model under the Alameda County Waste Management Authority green building program, which led to the installation of cellulose wall insulation and several other green building measures.

1.2 Construction Process

Design and Equipment

Under the Alternatives to Compressor Cooling project participation agreement Centex agreed to implement several changes to the building design. These included:

- Slab perimeter insulation
- Spectrally selective windows
- Exterior shading of east and south windows (trellis)
- Radiant barrier roof sheathing
- 50% exposed floor surface (wood over concrete)
- 5/8" drywall throughout the house
- NightBreeze mechanical system

With the donation of a Rinnai instantaneous gas water heater, the Polaris water heater that was specified in the original design was replaced by a Rinnai Model 2532FFU. In addition, a hot water recirculation system controlled by motion sensors was specified to minimize pipe heat loss and pumping energy. Designs were also modified to provide for the solar storage tank, which preheats domestic hot water that is delivered to the Rinnai.

The HVAC system was sized using ACCA Manual J, and the duct design was completed using ACCA Manual D. The house was divided into living and sleeping zones, with separate systems serving each zone[1]. A location for the outside air intake was selected on the north gable. Enviromaster International supplied the two NightBreeze systems consisting of hot water air handlers and controls. Dampers were obtained directly from ZTECH. Cut-outs for connections to the outside air intake and air handler connections were made, the barometric dampers were

[1] Other Plan 1 homes utilize single furnaces and air conditioners with zone dampers.

installed[2], and the dampers were tested prior to delivery to the site. Labels in English and Spanish were also added to the damper blades to warn against moving the damper manually.

Construction
Prior to the initiation of construction a meeting was held with mechanical, plumbing, electrical, and roofing contractors to review design drawings, discuss construction schedules, allocate responsibilities, and answer questions. During the course of construction additional on-site support was provided by DEG.

Features and equipment were installed exactly as shown in the final drawings. Minor problems were noted during commissioning. Subcontractors completed all installations except for the of the slab edge insulation, which was completed by Jeff Jacobs (construction superintendent); the solar water heater, which was installed by Solahart; the PV system, installed by AstroPower; and the hot water recirculation system, installed by DEG. DEG also installed and connected the relays that operate the circulating pumps for the air handlers.

Though dampers were conspicuously labeled with signs warning that manual operation of the damper blade would damage the damper motor drive gears, gears on one of the motors were stripped and the motor had to be replaced. Installing temporary fasteners to secure the damper blades during construction should resolve this problem in the future.

In general, the mechanical and electrical contractors had little or no difficulty implementing the design changes. The plumbing contractor required the most support and required assistance with interpreting the plans that were provided. DEG marked the exact locations of piping stub-outs prior to drywall, and provided guidance while piping connections between the solar storage tank, water heater, and pumps were made.

After all work was completed we received a call that the water heater was spouting water into the side yard. Micah Stevens, the construction superintendent at the time, and the plumber concluded the problem was with the water heater, and the plumber indicated that since he did not supply it, it was not his responsibility. A review of monitoring data showed that the problem was with the pressure relief valve that the plumber installed. Replacing the valve resolved the problem, but in the process, the plumber inadvertently drained the glycol solution from the solar hot water loop. DEG purchased a positive displacement pump to recharge the system, which proved superior to the original charging method and resulted in an improved flow rate.

The problems described are an expected consequence of incorporating technologies with which construction personnel are not familiar. Implementation of these technologies on a larger scale would likely result in less difficulty because of a better familiarity with the equipment and designs.

1.3 Builder Interview

Jeff Jacobs, who was supervised the construction from start to finish was interviewed to identify construction issues. Questions and paraphrased answers follow:

Q. In your observation, were there any differences between the house as designed and what was built?
A. No. Dampers were relocated from the hallway for aesthetic reasons. No other changes were made. There were some issues with the trusses that were not related to the energy design.
Q. Did you have any difficulty interpreting the design?
A. The level of difficulty was typical of any new house design.

[2] This work is normally done by the installing contractor, but our intention was to minimize the risk of improper installation.

Q. What is your current opinion of the design? Are there features that stand out and that you would tend to replicate?
A. The TechShield roof sheathing was easy to introduce at the right point of the process, and didn't require coordination. Also liked the hot water recirculation system and the NightBreeze. The "take rate" for high efficiency equipment is normally low.
Q. What is your view of ventilation cooling? Would you recommend it to your peers or use it again?
A. That will depend on comfort level and data results. From a performance perspective it could be very positive, but it's difficult to judge without personal experience.
Q. Which features were most difficult to install or implement and why?
A. The PV system and solar water heating system were most challenging because they required the most subcontractor coordination. The cellulose insulation was also difficult because the garage wall had to be dry-walled to provide a backing, and it was difficult to work around. If a wall penetration was added it had to be removed and re-stuffed, but it is easier to achieve zero defects with cellulose.
Q. What measures could have been taken to make the process smoother? What would you do differently?
A. Probably would have used a different plumber, and/or provided better instructions.

Jeff provided additional valuable insights into the sales process, and suggestions to help with the sale of future houses. Buyers sign a sales contract before they decide on upgrades, which are added to their base contract. (Initial prices for houses are not based on construction cost, but on market value.) Jeff suggested that displays and literature should be provided at the Design Studio to assist with selling energy upgrades, and information should be provided that shows how energy savings "net out" the mortgage cash flow. There are actually three visits to the Design Studio[3]. Since big cost items such as cabinets and floor coverings are selected on the third visit, energy features should be presented at the first or second. Jeff also suggested including sales incentives in the price of options, to reward sales staff for selling energy upgrades, and to provide training. He said the Design Studio is moving into a new facility that is currently being designed, and his hope is that it will include an "energy center".

Jeff said they are not promoting a solar option package for Los Olivos, primarily because of the poor market conditions. He noted that none of the subcontractors were willing to take responsibility for securing the PV modules to the roof. He prefers a "one call" contractor who can install the modules to the added complexity of having to call the roofing contractor twice, once for the composition roofing under the modules and again for the tile roofing.

Jeff's overall reaction to the project is that it was a definite positive in terms of publicity and goodwill, but a negative in terms of production reality. He said he can do anything one time, but it is more difficult to incorporate specialized features in a production scenario. Many of the measures are difficult to include as buyer options.

1.4 Sub-contractor Feedback

Subcontractors were asked their impressions of the systems they were installing during the course of construction. The HVAC contractor, Four Seasons Heating & Air Conditioning, showed mild interested in the NightBreeze system, and was primarily concerned with who would be responsible for warranty service and long-term maintenance. They did not find the NightBreeze system difficult to install, but are not particularly interested in marketing it to other builders. The plumbing contractor, Marina Plumbing, was also primarily concerned with repercussions associated with installing something new, and had little interest in understanding how the systems

[3] A Centex-maintained facility that allows buyers to view and select options and upgrades.

worked, only how it should be installed. They struggled to understand the piping configuration, which was complicated both by the solar water heater and the need for flowmeters and temperature sensors for monitoring. The electrical contractor, Crockett Electric, took a more active interest in the systems, particularly the photovoltaics, and appeared to appreciate that experience gained on this project could yield future benefits.

1.5 Incremental Costs

The net incremental cost for implementing the "ACC" changes listed in Section 2 is estimated at $17,500. Other features added to the house, the failure of subcontractors to maintain exact records, and other factors complicated the determination of incremental costs. Rather than use figures provided by the mechanical and plumbing contractors, incremental costs were estimated using RS Means 2002 Residential Cost Data. Local cost factors were applied to reflect the higher bay area construction costs. Other cost data were provided by Jeff Jacobs; a spreadsheet detailing Centex costs for all items is provided in Table 4.

Original mechanical specifications for Plan 1 called for two air conditioners, a 3 ton and a 4 ton. Instead the contractor used one 5 ton unit and one furnace with two zones as the standard system for Plan 1. The demonstration house was equipped with two 2-ton units. Consequently, incremental costs are based on the assumption that the baseline house has separate 2 and 3 ton condensing units and two furnaces. Given the actual demonstration house cooling load, a single 3-ton air conditioner with two zones could have been used, reducing the size by two tons. Table 1 shows the breakdown of incremental costs for the HVAC system.

Table 1: Mechanical Subcontract Estimated Incremental Costs

Change		Price	Qty	Total
Eliminate furnace		$390	-2	<$780>
Add NightBreeze		$1250	2	$3970
Substitute 2-2 ton AC for 2 & 3 ton		$1213	-1	<$1213>
	Subtotal			$1978
	Location factor at 20%			$396
	Total			$2374

The plumbing subcontractor has failed to respond to requests for cost data, so estimates from RS Means were used. These ignored the addition of the solar water heater but accounted for the substitution of the instantaneous for the storage water heater, the elimination of gas piping to the attic, and added costs for the insulated piping to the air hander. Plumbing cost details are shown in Table 2.

Table 2: Plumbing Subcontract Estimated Incremental Costs

Change		Price	Qty	Total
Eliminate storage gas water heater		505	-1	<$505>
Add Rinnai V2532FFU		1110	1	$1110
Add piping to air handlers		10.23	160	$1637
Eliminate gas pipe to furnace		6.75	-30	<$203>
	Subtotal			$2039
	Location factor at 20%			$408
	Total			$2447

Total incremental costs are summarized in Table 3. The exterior window shading was the greatest single cost item. Proper building orientation and application of overhangs could reduce or eliminate this cost. Some of the features add value beyond what they contribute to summer energy savings. For example the 5/8" drywall has a 1-hour fire rating and reduces noise transmission. The trellis provides outdoor shade, which will make the backyard space more useable in the summer. The NightBreeze system provides fresh air ventilation; a dedicated ventilation system could add $500 or more to the house cost. The instantaneous water heater provides a continuous supply of hot water in addition to reducing annual water heating costs by more than 30%.

Table 3: Total Incremental Costs

Item	Incremental Cost	Notes
Slab perimeter insulation	$2570	Labor & materials for subcontracts.
Radiant barrier roof sheathing	$846	
Upgrade drywall from 1/2" to 5/8"	$400	The contractor did not charge extra for the 5/8" drywall; Jeff Jacobs' estimated the cost at $400.
Upgrade windows from vinyl double pane to spectrally selective	$0	Spectrally selective windows are standard in all Los Olivos models.
Plumbing Subcontract: Replace storage water heater with instantaneous, provide piping to air handler, eliminate gas piping to furnaces	$2447	The water heater was donated and the plumbing contract included piping for the solar water heater. The incremental cost was estimated from equipment cost differences and cost estimates for the additional piping to the air handlers (see Table 2). The plumbing contractor has not responded with a figure.
HVAC Subcontract: Replace two furnaces with air handlers; replace one 3-ton AC with one 2-ton	$2374	NightBreeze system components were donated but the net cost includes $3970 for two NightBreeze systems. The contractor actually charged an additional $3977 in labor, which is difficult to justify.
Trellis shade structures	$8830	Including $1000 for painting.
Total Incremental Cost	**$17 ,467**	

Table 4: Added Cost Breakdown

Item	Type	Subcontractor	Cost	Warranty	Notes
Frame	**Labor**	Beardsley	495.00	**N/A**	**1.** Remove door at entry hall to accommodate "night breeze" return in plenum. **2.** Siding labor to remove & re-install gable vents in workable location.
Architect	**Labor**	Hezmalhalch	2,140.00	**N/A**	Exhibits for Energy Model Home/Electical standsrds/Exhibits
HVAC Labor	**Labor**	4 Seasons	3,977.00	**N/A**	Extra labor & material for installing specified materials for Davis Energy House
Electrical (photovoltaics)	**Labor**	Crockett Electric	1,750.24	**N/A**	Additional electrical for photovoltaic system and solar controls
Roofing	**Labor**	Peterson Dean	642.00	**N/A**	Net Cost with Credit for Roof Tile
Plumbing	**Labor**	Marina	3,000.00	**N/A**	Jeff's guesstimate (waiting for est. from Marina)
Painting	**Labor**	Peterson Painting	1,000.00	**N/A**	Trellis
Doors	**Labor**	Pac Door	350.00	**N/A**	Jeff's Guesstimate (Waiting for Pac Door estimate)
Siding	**Labor**	Beardsley	500.00	**N/A**	Gable Vents
Concrete	**Labor**		1,285.00	**N/A**	To allow for foam insulation at Porch
		Labor Total	**15,139.24**		
Insulation (perimeter)	**Systems / Products**	Janco	1,284.55	**N/A**	Labor & materials to accommodate 1" Perimeter Insulation at Front Porch
Insulation (cellulose)	**Systems / Products**	Cal Coastal	1,048.00	**N/A**	2800 cost less1752 normal cost
Night Breeze System	**Systems / Products**	Davis Energy	-14,000.00	**Through March 2004 (Letter to come)**	Received Grant.
Techshield	**Systems / Products**	No. Cal Lumber	846.00	**N/A**	Differential cost between Techshield/Standard roof sheet
Photovoltaic Panels	**Systems / Products**	AstroPower	11,608.00	**10 Year (Enclosed)**	Net Cost. 25,000 paid to AstroPower. 13,392.00 Buydown credit coming.
Solar Water Heating	**Systems / Products**	Solahart	0.00	**Requested**	Donated Unit - estimated valve of $2,072.
Landscape Structures	**Systems / Products**	Coastal Lumber	7,830.00	**N/A**	Jeff's Guesstimate
Light Fixtures	**Systems / Products**	Crockett Electric	800.00	**N/A**	Jeff's Guesstimate based on 40 Fluorescent lights @ $20 each
		Systems/Products Total:	**9,416.55**		
		Grand Total:	**24,555.79**		

2 Clarum Homes, Watsonville

2.1 Background

Clarum Homes volunteered a demonstration site for the Alternatives to Compressor Cooling Project in May of 2001. The home is one of two models in the Watsonville "Cherry Blossom" development, which includes a total of 31 1611 ft² two-story units. Except for minor floor plan variations and orientation differences, all units are identical. The unit selected for the demonstration is located on Lot 18 and fronts on Loma Prieta Avenue. The front of the house faces southeast. All units in the development are equipped with photovoltaic systems. Construction was completed in September 2001, but the house was not sold and occupied until May 2002.

2.2 Construction Process

Design and Equipment

Under the Alternatives to Compressor Cooling project participation agreement Centex agreed to implement several changes to the building design. These included:

- Spectrally selective windows
- Radiant barrier roof sheathing
- 50% exposed floor surface
- 5/8" drywall throughout the house
- NightBreeze mechanical system

Given the mild climate, exterior window shading and slab perimeter insulation applied to the Livermore house were not needed. A Polaris water heater was installed to provide heat for domestic use and space conditioning.

The HVAC system was sized using ACCA Manual J, and the duct design was completed using ACCA Manual D. The outside air intake was located on the roof and was covered by a custom-fabricated vent cap that also contains the outdoor temperature sensor. Enviromaster International supplied the NightBreeze system. As with the Livermore site, dampers were prepared and tested in advance of delivery.

Construction

Since construction was already underway when the builder agreed to participate, all coordination with subcontractors occurred on site while they were engaged in their work.

Features and equipment were installed exactly as shown in the final drawings. Minor problems were noted during commissioning. Subcontractors completed all work except for control wiring, which was completed by DEG. The tight construction schedule required that DEG personnel complete some of the work that would normally have been completed by subcontractors.

As was done for the dampers at the Livermore site, the damper was conspicuously labeled with signs warning that manual operation of the damper blade would damage the damper motor drive gears. As with the Livermore project the signs were ignored, the damper drive gears were stripped, and the motor had to be replaced.

In general, the mechanical and electrical contractors had little or no difficulty implementing the design changes. Again, the plumbing contractor required the most guidance.

2.3 Builder Interview

John Suppes, Clarum Homes Vice President, had little involvement in the construction in the home. His superintendent, Bud Wilkes, similarly had little involvement in the changes that were made to the house, and after construction was completed Mr. Wilkes became involved in another development and was unavailable for interview. Although Mr. Suppes initially expressed some interest in using ventilation cooling on other homes, he did not respond to follow-up phone calls.

2.4 Sub-contractor Feedback

Subcontractors were not interviewed, but contact with both the HVAC and plumbing subcontractors during construction indicated that they were generally comfortable with the installation of the NightBreeze system. Their primary concerns related to who would be responsible for maintenance.

2.5 Incremental Costs

The total incremental cost to adapt the Clarum Homes house to the summer comfort design was $6820. Costs per measure are detailed in the table below. Though not required for Title 24 compliance, the builder installed low-E windows and attic radiant barriers as standard features on all houses in the Cherry Blossom development. Subtracting the cost for these items lowers the true incremental cost to $5899.

The largest single cost item was the Polaris condensing water heater, which improves heating and water heating efficiency but is not a required component of the system. The wholesale cost of the water heater is about $2000. The incremental cost would likely have been lower if summer comfort features had been installed as standard equipment on all models, due to volume purchasing and labor savings.

Table 1: Incremental Costs

Item	Standard Cost	Improvement Cost	Incremental Cost
Radiant barrier roof sheathing			$520
Upgrade drywall from 1/2" to 5/8"			$600
Upgrade windows from vinyl double pane to vinyl double pane Low-E (U<0.4, SHGC<0.4)			$401
Plumbing improvements: upgrade water heater from minimum standard to Polaris, provide water heater venting & condensate drain, provide piping to air handler			$4140
HVAC improvements:			
Standard furnace	$330		
NightBreeze system		$612	
Damper		$345	
Outside air vent cover		$257	
Labor to install damper & outside air intake		$275	
Incremental cost			$1159
Total Incremental Cost			$6820

3 Conclusions

Mild California climates offer the opportunity for "tunneling through" cost barriers by applying design strategies that completely eliminate air conditioning, thereby resulting in incremental costs that are equivalent to or below baseline costs. For climates such as Livermore, where air conditioning is needed to weather extreme heat storms, it is more important to assess whether measures are individually cost-effective. Future projects should start with measures that are easy for the builder to implement and have little cost impact, such as radiant barrier sheathing, thicker drywall and spectrally selective windows. More aggressive, costly, measures that would more greatly disrupt the construction process should be evaluated individually for what they contribute.

The Watsonville climate proved to be too mild to serve as a good demonstration of ventilation cooling, perhaps explaining the lack of interest by Clarum Homes in making wider use of this technology. The lack of visibility of ventilation cooling, relative to photovoltaics, may have also played a role.

Marketing efforts, such as those suggested by Jeff Jacobs, are needed to stimulate the construction of a sufficiently high volume of homes with energy upgrades to provide economy-of-scale cost reductions and to justify the effort of offering them. Alternatively, builders must be convinced that the addition of these measures as standard features will allow them to market their homes as higher quality than the competition, thereby providing the improved market positioning all builders seek. Since the measures that improve summer performance are interdependent, they must be offered as an upgrade package that can be sold based on its numerous benefits.

At the Livermore site, HVAC system incremental costs were impacted by the need for two NightBreeze systems instead of the single two-zone furnace used in the baseline house. Adding zoning capability would allow the NightBreeze system to be more competitive with furnaces in homes where zoning is needed. Also, packaging of the hydronic components would improve the comfort level of the plumbing contractor and reduce field labor cost.

OCCUPANT RESPONSE AND BEHAVIOR

Sub-task 2.4.8

1 Objective

Since the overall objective of the Alternatives to Compressor Cooling project is to develop technology and designs that reduce peak load while maintaining comfort, it is important to obtain owner feedback on comfort, as well as ease of operation and general satisfaction. This report summarizes the results of interviews and other contact with the owners of the two demonstration homes.

2 Survey Background

2.1 Survey Questions

With assistance from Bruce Hackett, DEG developed a list of survey questions to determine the owners' understandings of house performance and technologies, comfort levels, familiarity with the control interface, and other concerns[4]. A copy of the list of questions is attached.

2.1 Owner Profiles

The buyers of the Watsonville demonstration house are a working couple with two children. We had no contact with the husband, who was not present during any of our visits. "Rita", who we interviewed, works in a medical facility nearby. An older Spanish-only speaking person, perhaps a grandfather, watches the house during the day. We found it difficult to schedule appointments, probably due to their working schedules. Rita appeared to be very intelligent and literate, and to the interviewer appeared to be the head of the household. She had no questions about the house and how it works.

The buyers of the Livermore demonstration house are a working couple without children. "Tony" is an airline pilot and is away for several days at a time. "Tina" works part-time and spends most of the day at home. Both seem to be intelligent and inquisitive, and our interactions with them make it clear they are interested in how the house performs.

2.2 Interview Process

Both interviews were conducted by David Springer in the owners' homes. Rita's interview was cut very short by another appointment she had scheduled, and it was necessary to complete it by telephone. The survey questions were used as a guide in both cases, but were not followed precisely in order to allow the owners the opportunity to express themselves freely. Both interviews were reviewed by Bruce Hackett.

2.3 Monitored System Use

To put the owners' responses in context, it is useful to review how the monitoring data indicated the houses were operated. The owners of the Watsonville house moved in during the spring of 2002, so ample monitoring data is available to identify how the heating and cooling systems were used. The ventilation cooling system was used sporadically during the summer of 2002. Ventilation fan energy did not exceed 4 kWh during any month, and totaled only 12 kWh during the months of June through September, 2002. The maximum indoor temperature recorded was 80°F (in the 2nd floor master bedroom); this occurred on a day when the outdoor temperature reached 93°, and the NightBreeze system was turned off. Except for a short period of time during

[4] Names have been changed to protect priviacy.

which Rita was shown how to operate the heating system, she left if off for the entire winter of 2002-2003.

The owners of the Livermore house moved in during October 2002. The data show they used the heating system fairly routinely, setting the temperature back between about midnight and 8 AM, and again between noon and 6 PM. At the time of the interview they were still using the heating system and had not switched to cooling. Summer data collected subsequently show that the ventilation cooling system was only turned on during a five-day hot spell with three consecutive days exceeding 100°F. The air conditioner was run only briefly, according to Tony, to verify that it worked. The highest indoor temperature during this period was 79°F.

3 Watsonville Interview

3.1 Background

This interview was held partly at the owners' home on May 28, and by telephone on June 23, 2003. The personal interview was cut short by her need to run an errand, and difficulty in reaching her by phone resulted in the 3-week delay between the initial interview and the follow-up. Rita's responses to questions were brief, in part because most of the interview was conducted by telephone. She volunteered little information and the interview followed the format of the survey fairly closely.

Rita said she did not operate her heating system during the winter because she was concerned about energy costs, so her satisfaction with the heating system was limited by her very brief experience with it when she was shown how to operate it. She used the ventilation cooling system more, but still did not use it consistently. Since the house does not have air conditioning, she had no experience with it.

3.2 Understanding of the House and Heating/Cooling Systems

Rita said she understands how the ventilation cooling system is supposed to work, explaining that it cools by bringing in outdoor air. She indicated the system seems to work as intended, and finds the house more comfortable than the townhouse she lived in previously. She attributes some of the improved comfort to better house design, such as good windows. She said she doesn't have to use the heating or cooling systems much to stay comfortable. She believes the house and the mechanical system are saving energy and is very satisfied with their performance. When asked if she would request the same system heating and cooling system if she were buying another house, she responded that she would.

When asked about her understanding of how the heating system worked she said she thought it obtained heat from the water heater. I asked her why she didn't use the heating system during the previous winter and she said she was concerned about high bills, but she would have liked the house to be kept warmer and will probably use it next winter. She said when she did turn it on that it heated the house in a very short time, which is one reason why she was worried about her energy bill. I asked if she thought the heating system was cheaper to operate than a furnace. She replied that it is better than a furnace and that there is nothing she would change about it. She said she would want the same system again if she were buying another house.

3.3 Comfort

When asked about temperature preferences, Rita said she and her family "tend to be cold people, which is why the house works well for them." However, she did find it a little too cold last winter because she didn't use the heating system. In summer she doesn't mind the house being cooler at night. The house stays comfortable most of the time, which she attributes to the high quality windows and good insulation. She had no suggestions on how comfort might be improved.

When asked about noise from the heating/cooling system she said that noise from the street is much greater than noise from the system. I asked if she noticed any difference in dust accumulation between this house and her previous one, and she said that dust is noticeable. I mentioned that the filter should catch most of the dust if she uses the ventilation cooling system. She said she might try using the fan instead of windows, now that she understands that outside air is filtered.

3.4 Use of Controls

Rita feels she has a good understanding of how to use the thermostat, and she finds it easier to use than others. She said she didn't know how to use the thermostat at her previous house. When asked what she didn't like about this thermostat, she said "With this one you have to set it to either heating or cooling", implying that it should automatically switch from one mode to the other. (All residential thermostats must be manually switched between heating and cooling.) I explained that "vacation mode" can be used to accomplish automatic mode changes if she desires that capability. Asked if she had any suggestions for improvements to the thermostat she said "no".

4 Livermore Interview

4.1 Background

This interview was conducted in the owners' home on April 9, 2003. The owners had been in the house since October 2002, and so had ample winter experience with the house but virtually no experience of what the house would be like in summer. Both Tina and Tony were present for most of the interview, though Tony had to leave for a haircut appointment before we had finished.

Upon receiving their first utility bill for over $600 Tina contacted me to ask why it was so high. Most of the cost was gas usage. I provided a comparison of monitored (space heating and water heating) gas usage to what was listed on the PG&E bills and found that less than half the gas usage recorded on their bill, which covered three months, was for space heating and water heating. Tina likes to run one of the three gas fireplaces most of the day and evening, but gas consumption still appeared to be higher than expected. PG&E charged them nothing for gas use in the subsequent two bills, suggesting there may have been a meter reading or billing error on their part. Subsequently, Tony and Tina have been very pleased with their utility bills, both electric and gas.

4.2 Understanding of the House and Heating/Cooling Systems

When asked what they understood about how the heating/cooling system works, they said they understand the concept of ventilation cooling but since they moved in last October, have not had an opportunity to use it. Both Tina and Tony said when the house is heated up it holds the temperature for a long time. Tina has also been using the gas fireplace for long periods of time. She said it looks like a real fire and she likes to sit by it. There are three gas fireplaces in the house, but she mainly uses the one in the living room (a Heatolator brand with a standing pilot, no convective vents, and no fan). Now that she is aware that the largest part of their gas bill was from the fireplace, she will use it less and use the heating system more. I suggested she try using higher thermostat settings in order to decrease dependence on the fireplace. She said she also likes to use the fireplace for visual effect.

4.3 Comfort

Tina commented that the house "feels like a cave", in that the temperature doesn't change very rapidly. They acknowledged that this characteristic would be more of a benefit in the summer. Recently when outdoor temperatures were pleasant it felt too cool inside the house and they opened windows to warm it up.

I asked if they noticed any difference between this house and previous houses, specifically with respect to noise and dust. Tina said the heating system was quiet, except for when the fan was running at full speed (due to a control problem that was remedied). Tony remarked that there is a noise similar to a pump running that he hears above the master bedroom when it is quiet at night, but he could not hear it during the day. He didn't think it comes from the heating/cooling system. Tina said there is a lot of dust accumulating on the hardwood floors, but suspects it is lint from the new carpets. She said she hasn't vacuumed the house yet, and that might help.

They don't expect to use the air conditioner very much, since they rarely used it in their prior house. Tony likes it cooler than Tina. Tony briefly expressed his feelings about how the government should be spending money on solar instead of going after foreign oil.

4.4 Use of Controls

Tina said she was not completely comfortable with the use of the thermostat, mentioning specifically the "Vacation" mode, which she has not seen on other thermostats. She finds it complicated, but said the thermostat in her previous house was also difficult to use. For winter, they programmed the thermostats to maintain 70°F between 5 PM and 11 PM, and 60°F the remainder of the time. Tina is home most of the time, and manually raises the thermostat setting when she feels cold, but usually only for periods of 30 minutes.

4.5 Other Comments

Gas use is a big issue for them. Tina said she interprets "zero energy" literally. They thought that their electrical savings should be applied to their gas costs. They were billed for 688 therms for October through February at a cost of about $677. February through March they were billed for an additional 42 therms. They understand that most of the gas use was from the fireplace. They expressed they would not have spent the extra $30,000 for the zero energy features if they knew they would still be paying the utility bills they have. However, since they essentially did not pay more for the solar and energy efficiency features (it is their impression the builder absorbed these costs), they still feel like they got their money's worth.

Tina asked if she could accompany me to her neighbor's house at 3090 Lusitana Drive, which we are monitoring as a base case (this house has an identical floor plan and nearly identical orientation). She wanted to compare notes with them on utility bills. She had a conversation with the owners (much of which I didn't hear because I was occupied with downloading data), and afterward seemed satisfied that she was paying no more than they for gas; they probably use their fireplaces less. The owners indicated they would provide copies of their utility bills for our analysis. We are monitoring indoor temperatures at each thermostat and air conditioner power, of which there had been none since the house was first occupied in October.

Tony asked what would happen if something went wrong with the system after our contract was over. I indicated we would replace any of the control components without charging for hardware, but would charge for labor after 2004. This appeared to satisfy their concern. They have no objection to leaving the monitoring equipment installed for as long as we need it.

5 Conclusions

5.1 Watsonville House

In retrospect the Watsonville house has proven to be less than an ideal demonstration, because of the mild climate, the owner's broad tolerance of high and low temperatures, concern about energy costs, and resulting minimal use of the mechanical ventilation cooling and heating systems. However, the owner's behavior highlights the value of the "summer comfort" improvements made to the building envelope. The best possible outcome was realized by completely eliminating both heating and cooling energy use.

5.1 Livermore House

Shortly after buying the home the owners of the Livermore house indicated their nervousness about the complexity of the mechanical systems. The fact that they were able to program the thermostats without contacting us, and Tina's frequent use of the thermostat "short term" setting feature suggests that the perceived complication does not inhibit her ability to use it properly to obtain comfort. Their comment that the house feels like a cave suggests they perceive the effects of the added thermal mass (tiled concrete floor and 5/8" drywall), which has proven to provide good summer comfort and virtually no air conditioning use through June 2003. Tina's habit of raising the thermostat setting just when she feels cool, instead of setting it and leaving it alone probably compromises winter comfort because the mass doesn't have time to warm up, and therefore the operative temperature may be lower than it should be for proper comfort. Recent feedback from the owners about not having to use the air conditioner through a five-day hot spell indicates they appreciate the value of the design.

The following conclusions can be drawn from these demonstrations and interviews:

- Both houses can be operated without air conditioning to the satisfaction of the current owners through typical summer "heat storm" conditions.
- Owners of both houses seem to grasp the concept of ventilation cooling.
- Temperature tolerances of both families are probably not restricted to the ASHRAE "predicted mean vote" comfort boundaries.
- Both owners find thermostats confusing in general, but find the NightBreeze thermostat less so.
- No improvements to the houses and systems were identified by either of the owners, suggesting the NightBreeze system and other summer comfort home features are reasonably market-acceptable.

SURVEY QUESTIONS

Understanding Of House Performance And Its Technologies

Ventilation Cooling

What is your understanding of how the ventilation cooling system is supposed to work?
Does it seem to you to work the way it is intended?
What are your dissatisfactions with it, if any? (compare to earlier house, if applicable)
Do you think it is saving energy? Does it reduce AC use?
Do you notice any other benefits or problems?
Do you think you would request the same system if you were buying another house?
What reactions to it from others, e.g. spouse, friends, neighbors?

Heating

What is your understanding of how the space heating system is supposed to work?
And does it seem to work the way it is intended?
Do you think it is cheaper to operate than a furnace? Is it better than, not as good as, or the same as a furnace?
What would you change about it?
Would you use it again?

Comfort Levels And Specific Periods/Sources Of Discomfort

What indoor temperatures do you prefer in summer & winter?
Do you like it cooler at night or the same temperature as during the day in summer?
Was the house comfortable last summer/winter, or uncomfortable at any particular time of day or during any particular type of weather?
What about it was comfortable/uncomfortable?
Do you have ideas about why it was more/less comfortable?
Do you have any thoughts on what could be done to improve comfort?
Was the system noisier or quieter than systems in other homes you have lived in?
Did you notice any difference in dust allergies compared to other houses?

Use And Evaluation of the Thermostat (User Interface)

Do you feel that you have a full understanding of how to operate the thermostat?
What about the thermostat is difficult to understand?
What features do you like, if any, or to you <u>not</u> like, or have some trouble with?
Do you have any suggestions for improvements?

MONITORING PLAN

Sub-task 2.4.3

1 Background & Objectives

In prior project phases it was determined that air conditioning loads can be substantially reduced, and in some climates, eliminated, by designing merchant housing for optimal summer performance and by providing mechanical systems that provide nighttime ventilation. Computer simulations have demonstrated the potential for significant air conditioner capacity reductions when houses are optimized for summer performance and cooled by flushing them with cool nighttime air.

Work under the current phase is to develop, install, and test an integrated heating, ventilation and cooling system. Laboratory testing has been completed on mechanical system hardware, and field tests are to be completed in two homes built to project specifications. Builders with developments located in Climate Zones 3 and 12 have been selected for participation in these demonstrations.

This monitoring plan presents a general strategy and methodology for the monitoring of both demonstration sites. Monitoring data collected will help satisfy the following objectives:

- Validate electrical demand reduction and energy savings estimates developed using building simulations.
- Develop indoor temperature profiles due to the use of ventilation cooling.
- Verify proper system and control operation.
- Identify behavioral issues with respect to use of the house and systems, and comfort expectations and experiences.

2 Strategy

2.1 Approaches to Estimating Energy and Demand Savings

There are three strategies that can be employed to estimate energy savings resulting from the implementation of specific energy measures. These include (1) side-by-side tests of buildings that are identical in every respect except for the energy measure, (2) monitoring the same house with and without the energy measure in operation, and (3) using monitoring data to calibrate a computer model of the house and using the calibrated model to predict energy savings. Each approach has limitations that are described below.

2.1.1 Side-by-Side Testing

Side-by-side testing requires that two houses having the same orientation be available for testing, which may be a limiting factor. This approach is highly limited by differences in occupant behavior, and is only statistically valid if a large sample is tested.

2.1.2 Operating the Same House with and without the Energy Measures Active

The “summer performance house” design includes integral design features such as enhanced thermal mass and high performance windows that cannot be removed and replaced at will. This approach could be effective for determining the impact that just the mechanical ventilation component has on comfort and energy savings, but the extent to which the owners use windows for ventilation will have a significant effect on the outcome of such testing.

2.1.3 Simulations Using Calibrated Models

Previous efforts to calibrate computer models against monitored performance have met with limited success, are expensive, and may require intrusion by testers. The Short-term Energy Monitoring, or STEM method, attempts to normalize building response to air temperatures, solar heat gains, thermal mass interactions, and building infiltration. STEM testing requires about one week of co-heating tests and extensive data analysis to develop model inputs. Long term calibration approaches simply attempt to match seasonal simulated and monitored building loads. Both methods are subject to a great deal of arbitrary "art" in making adjustments to computer inputs. For optimal accuracy, monitoring data must include direct beam and diffuse solar radiation, wind speed, and outdoor temperature so that weather files specific to the site can be generated.

2.1.4 Proposed Strategies

Given the small sample and other project constraints, results of monitoring to determine energy impacts of the summer performance designs cannot be obtained with scientific accuracy. However, trends determined from monitoring can help support the probability that results of computer simulations completed using earlier calibrations are accurate[5].

Side-by-side testing will be completed if "base case" houses with similar orientations and occupancies are available for testing, and if developers are willing to sign access agreements for both the demonstration house[6] and a "base case" house. In any case, efforts will be made to obtain utility bills from houses with similar orientations and occupancies for making general comparisons. Demonstration houses will be operated with and without mechanical ventilation cooling on a two-week cycle through the summer in an effort to identify its impact.

2.2 Key Monitoring Parameters

Key parameters required for evaluating impacts and verifying operation include:

- Total building space conditioning load (heating and cooling)
- Ventilation system cooling output
- Air conditioning system cooling output (Livermore site only)
- Fan and pump electrical energy use
- Compressor energy use (Livermore site only)
- Indoor and outdoor temperatures
- System status

Specific monitoring data points necessary to define the key parameters include:

- *Temperature*: Supply and return air; indoor and outdoor air
- *Insolation*: Solar insolation measured by a pyranometer.
- *System States*: The state of the damper, heater and A/C signals.
- *Air Flow*: One time measurement of total supply air flow using a flow hood (and coincident blower power)
- *Electrical Energy*: Compressor, blower motor, and pump for heater.

---

[5] The DOE-2 model developed for this project was calibrated using small test buildings located at Pala, California, and is described in Meldem and Winkelmann (1995).
[6] Because the Watsonville demonstration house will be used as a sales office for the duration of monitoring, side-by-side testing is precluded due to substantial differences in occupancy. Opportunities for monitoring a "base case" house at the Livermore site are under investigation.

- *Fan RPM*: Motor RPM will be used to calculate air flow rates from fan test data to be provided by the equipment manufacturer

2.3 Data Acquisition Approach

Individual monitoring systems will be installed at each site to obtain, store, and transfer data. Monitoring systems will consist of dataloggers, multiple sensors, and a modem for communicating data via existing telephone lines. Other test equipment will be used for one-time measurements. Detailed hardware specifications are provided in Section 3. Monitoring and test equipment in general include:

- Dataloggers for temperature, power, and solar insolation measurement
- On-site modems for downloading data to the host monitoring computer
- Solid state or RTD temperature sensors for indoor, outdoor, and duct temperatures
- A Pyranometer for solar insolation measurements.
- 24V relays for state monitoring
- Power monitors for measuring true RMS power of fan, pump, and compressor
- Powered flow hood for one-time air flow measurement calibration

All sensors will be scanned every 15 seconds, and data will be summed or averaged (as appropriate) and stored in datalogger memory every 15 minutes. The dataloggers will also compute energy transfers at 15 second intervals by multiplying flow rates by temperature differences.

Datalogger memory will be sufficient to store at least four days of data, so that loss of communications will not interrupt the stream of data. Dataloggers will be powered by low voltage power supplies with battery backup to protect against data loss during power outages.

Data, in comma-delimited ASCII format, will be regularly downloaded to a central computer and screened using software to review data ranges. Out-of-range data will be reported and investigated to determine whether a sensor or monitoring error exists or equipment has failed.

2.4 Monitoring Period

The current project schedule provides for installation of monitoring equipment by August 1, 2001. Formal monitoring will commence when the monitoring system has been commissioned and calibrated, and will continue for at least one year, terminating not later than August 30, 2002.

2.5 Evaluation Approach

Full-year performance simulations for base case and nighttime ventilation systems will be completed using validated models. Models will be developed using the following steps:

- Develop DOE-2 building shell inputs from plans and/or site audits
- Survey occupants on occupancy patterns, use of auxiliary heating (wood stoves, etc.) and thermostat setpoints and develop "typical" occupancy and internal gain profiles, and thermostat schedules
- Develop nighttime ventilation performance algorithms from monitoring data and configure DOE-2 heating/cooling system models
- Utilize "best available local" weather data or *typical meteorological year* (TMY) data to complete DOE-2 simulations
- "Benchmark" models to monitoring data by varying building load inputs to achieve reasonable correspondence between modeled and monitored building energy use

Validated models will be used to simulate annual performance for base case and vent cooling systems for each site.

3 Monitoring System Design

3.1 Datapoints

Datapoints vary by system type, and are designated in the specific site monitoring plans to be developed once sites are selected. Potential system types to be monitored in this study are listed in Table 1, which also shows the number of datalogger inputs for each system type. Dataloggers will calculate values from inputs, including space heating and cooling energy, the fresh air vent load during heating, and the total "economized" cooling delivered (where outside air is cooler than return air so the damper is open).

In addition to the datapoints shown in the site monitoring plans, one-time measurements will be made of system air flow rates for use in determining heating and cooling energy delivery.

Table 1: Sites to be Monitored

	Number of Datapoints			
System Type/Description	Analog	Digital	Counter	Total
Clarum, Watsonville, No A/C	7	2	3	12
Centex, Livermore, A/C	7	4	3	14

3.2 Datalogger Specifications

Data Electronics DT-50 dataloggers will be used for this project. Input specifications are listed in Table 2; detailed specifications are provided in the appendix. Analog inputs are single-ended type (all referenced to ground). Digital inputs will be used for power monitors and signal states; high speed counter inputs will be used with power monitors and to determine fan speed. The dataloggers are provided with an RS232 communications interface and battery backup.

Table 2: Datalogger Input Specifications

Model	Analog	Digital	Counter
Datataker 50	10	5	3

3.3 Sensor Types and Specifications

Table 3 lists the types of sensors to be used for the various monitoring points and their performance specifications. Sensor selection was based on functionality, accuracy, cost, reliability, and durability. Specific model numbers are listed as examples; similar models by other manufacturers may be used. Signal ranges for temperature sensors correspond approximately to listed spans. Detailed manufacturers' specifications are provided in the appendix.

Table 3: Sensor Specifications

Type	Application	Mfg/Model	Signal	Span	Accuracy
LM34	indoor temp.	Basys TS 1100	~0-2 V	.01V per °F	±1% (70°F)
RTD	outdoor temp.	RM Young 41342LF	4-20 mA	-30 - 130°F	±1.6%
RTD	duct temp.	ACI TTM 100-7-D	4-20 mA	40 - 130°F	±1.5%
Pyranometer	solar insolation	Li-Cor LI-200SA			±3%
Type T	water temp.	Gordon 20CTOUH	~0-3 mV	~0-160°F	±0.4%
power monitor	elect. energy	CSS-WNA-1P-240-P	pulse	4 pulse/Wh	±0.5%
24V Relay	signal state		digital		

3.4 Modem Specifications

The Datataker COMS port will be set to a minimum of 2400 baud. The modem shall be Hayes compatible, MNP2-5, V.42, V.42bis, Everex 24E+ or equivalent. Modem settings shall be established using the following commands:

E0	Commands not echoed
Q1	Quiet mode on
L0	Low ring volume
&D0	DTR ignored
&R0	CTS tracks RTS when modem is on-line
&S0	Forces DSR signal high
S0=1	Auto answer mode, one ring
\N2	Reliable mode only
&W0	Saves active profile 0

A 9-to-25 pin RS232 cable (modem - DCE) with connections as shown on Page 13 of the Datataker Manual (Version 3.1) will be used to connect the modem to the Datataker.

3.5 Equipment Panel

The datalogger with battery backup, modem, and shunt resistors for 4-20mA circuits will be securely mounted in a locking metal enclosure, Circle AW 12244TCS. Shunt resistors and low voltage power supply terminals will be prewired. Power supplies for the datalogger, modem, and 4-20mA sensors will be plugged into a power strip located inside the equipment panel.

3.6 Wiring

Wiring shall be Belden 22 gauge shielded communications cable or equal, #8761 single pair, #8771 3-conductor, and #8723 two pair. Thermocouple wire shall be Gordon T20-5-510 or equal.

4 Monitoring System Installation

4.1 Site Monitoring Plans

Brief site-specific monitoring plans will be prepared for each site, and will include:

- Site audit form including the site location, owners name, and building
- Datapoint list specific to the site and system type
- Description of sensor location
- Datalogger and sensor wiring diagrams and cable schedules
- Datalogger program
- Planned monitoring schedule

A sample site specific plan is included in the appendix.

4.2 Datalogger Installation

Dataloggers will be installed in locations agreeable to owner/occupants, accessible for servicing, and protected from moisture and temperature extremes. Equipment panels will be mounted to drywall or wood surfaces using appropriate fasteners. Power connections will be secured and/or labeled to prevent inadvertent disconnection. Equipment panel covers will be marked with a contact and phone number to call in the event of problems.

4.3 Sensor and Wiring Installation

Sensors and wiring will be securely installed, but in a manner as to minimize damage to existing surfaces/materials and reduce repairs needed during decommissioning. Wiring will be labeled at both ends using designations listed in the site monitoring plan. All sensor locations will be reviewed with building owners prior to installation. The following procedures will be followed for installation of the various sensor types:

Indoor Temperature Sensor. Install at or near thermostat height. Wiring may be run inside wall up to attic or down to crawlspace. If a closet or utility room is located on the reverse side of the wall, wiring may be run inside the adjacent space if approved by the owner.

Outdoor Temperature Sensor. Install under the roof overhang or inside intake vent on the north exposure of the building, or other location which is shaded from direct sunlight at all times. Thermal influences from adjacent roofs, blacktop surfaces, and vents will be avoided.

Supply and Return Air Temperature Sensors. Holes (1-1/4") will be drilled in supply and return plenums for mounting of sensors. Sensors will be located as far from heating/cooling coils as possible, but prior to any duct branches. Sensor boxes will be secured using sheet metal screws. For decommissioning, duct penetrations will be sealed with aluminum-backed butyl tape.

Power Monitors. Verify that power is disconnected during power monitor installation. Install current transformers (CTs) with proper orientation to line and load, and connect to power monitors in accordance with manufacturers instructions. Locate power monitors close to CTs, preferably inside equipment. If exposed, mount power monitor boxes using sheet metal screws or double-stick tape. Observe that CTs and power monitors do not present an electrical hazard.

Wiring. Route wiring as inconspicuously as possible between the datalogger and sensors, minimizing hole drilling and other penetrations of existing building materials. Label wiring at both ends with sensor abbreviation using 3M 11954 label dispenser. Secure wire to drywall surfaces using plastic wire tie anchors where wire is exposed to view or subject to snagging. Secure anchors to drywall and wood surfaces using drywall screws. Use tape-backed anchors for sheet metal surfaces. Where visible, run wire in corners, and orthogonal to surfaces. Provide strain relief's at points of connection, including the datalogger panel and sensor boxes. Bundle multiple wire runs neatly using plastic wire ties, and clip wire tie ends.

Communications. Install standard telephone wire from main telephone box or owner-supplied jack to modem. Use crimp-on RJ11 jacks to connect to modem. Verify that connections do not interfere with owner's telephone service. Phone switching devices or alternate line sharing technologies will be used if no additional phone lines are available.

4.4 Installation Documentation

An installation documentation form will be completed to document any changes to equipment or sensor locations, the date of installation, and communications line telephone number.

4.5 Commissioning and Calibration

A commissioning log will be completed for each site to record sensor calibrations, air flows, and other data. On completion of equipment installation, a laptop computer will be connected to the datalogger for reading real time data, and the following calibrations and verifications will be completed:

Air Temperature. Using calibrated temperature sensor, record monitored and calibrated temperatures for each sensor. Do not record readings until temperatures have stabilized. Duct sensors may be removed, or calibrated prior to mounting in ducts.

Power. Activate vent cooling system and verify power measurement. Reverse polarity of CT, voltage, and datalogger connections as needed to correct for lack of readings. Repeat for A/C power and heating power measurements.

Air Flow. Set up the datalogger to record fan power and use a flow hood to measure air flow at all supply grilles. Record air flow rates and fan power in the commissioning log. Record flow and power measurements at each discrete speed. A least-squares fit of these data will be used to program the datalogger to compute air flow from fan power.

Communications. Dial the datalogger modem from a remote computer and verify all communications.

Permanent Programming. Enter offsets and other program variables determined during commissioning into the site datalogger program, and upload the program. After one day of operation, download and verify all readings.

On completion of commissioning, the site monitoring plan will be updated to document equipment installed, serial numbers, calibration adjustments, and any comments.

4.6 Building Access Procedures

To insure good relations with building owners/occupants, the following procedures will be followed:

- The DEG representative will contact the homeowner to schedule the installation at least one week prior to the monitoring installation.
- The installer will confirm with the owner at least 24 hours prior to beginning work.
- Before leaving the site, the installer will insure that the premises are clean, and that all power, heating/cooling operation, and telephone service are restored.
- If the owner is not present when the installer leaves, the installer will insure the premises are secure.
- The installer will safeguard against loss of pets by insuring doors and gates are closed at all times, as needed.
- The installer will not attempt access to the premises without the owner or utility representative being present, unless expressly allowed by the owner.

4.7 Owner Briefing

Upon the completion of the monitoring installation the owner will be briefed on the location of equipment, any safeguards needed to prevent data loss, and maintaining an operating log for recording any unusual occurrences such as equipment failure, loss of power, inadequate comfort, or other conditions.

5 Datalogger Programming

Dataloggers will be configured with monitoring programs specific to each site. Programs will scan individual channels at 15 second intervals and will store these data in temporary buffers and sum or average the values over a 15 minute logging interval. The 15 second scanning interval provides high data resolution on parameters which may change during the logging interval and allows for more accurate calculation of energy transfers. In addition, the 15 second interval allows for filtering of temperature data to provide representative supply and return water/air temperatures only during system operation. All of the equations are very similar, with the exception of the temperatures used.

Sensible heating energy delivered by the hydronic heater will be computed by the datalogger program on 15 second intervals, using Equation 1.

Equation 1: Qair = CFM * (Tsupply - Treturn)*1.08

Where:
CFM = calibrated air flow (cubic feet per minute)
Tsupply = supply air temperature (°F)
Treturn = return air temperature (°F)

For the periods where the damper opens to bring in fresh air during heating, the following similar equation will be used:

Equation 2: Qair = CFM * (Tsupply - To)*1.08

Where: To = outside air

The fresh air vent load (favl) will also be calculated for the periods where the damper is open to bring in fresh air during heating. Equation 3 will be used for these calculations.

Equation 3: Qfavl = CFM * (Trelief - To)*1.08

where, Trelief = relief air temperature (°F)

The following equations are for A/C cooling for the houses that are equipped with A/C. Equations 4 and 5 are total cooling rates:

For normal A/C cooling (damper closed):

Equation 4: Qacn= CFM * (Treturn – Tsupply)*1.08

For econ A/C cooling (damper open, outside air cooler than return air)

Equation 5: Qace= CFM * (To – Tsupply)*1.08

For the econ A/C cooling load:

Equation 6: Qacel= CFM * (To – Trelief)*1.08

For vent cooling, the following equation was used:

Equation 7: Qvc= CFM * (Trelief – To)*1.08

6 Data Acquisition

6.1 Data Communications

Each datalogger will be configured with a modem for transferring data to a central computer. Most residential phone systems are equipped for two lines. The second line will be activated for data communications. If both lines are in use a third line will be added, or a line share switch (Teltone M-392-A&4 or equal) will be installed to enable one of the lines to be shared.

A central computer, located at DEG offices in Davis, will use an automated program to sequentially call each site every 24-48 hours. If an individual site does not respond, the program will retry for a specified period of time before proceeding to the next site. Each working day after data download, files for the previous day(s) will be checked for completeness. Efforts will be made to recover missing files by manually downloading data. To minimize data loss, communications problems will be responded to within 2 days. With the expected number of sensors, each datalogger will be able to store data for a minimum of 4 days before the memory overflows.

6.2 Screening, Range Checks, and Reporting

Software will be developed for each site to read in the "raw" data and verify that all readings are within expected values (e.g. indoor air temperature is between 40 and 90°F). If the range checking software reports that data are out of range, the suspect data will be visually examined to determine whether ranges should be modified, or a sensor is defective. If the review indicates sensor error a service call will be scheduled to repair or replace sensors. Upon detection of system failure, the owner will be notified immediately. Twice monthly all data from each site will be graphed in time-series format to insure that the data are physically consistent (e.g. if the unit starts operating in heating mode one should see an increase in the supply air temperature, pump energy consumption, and the heating signal should be high and A/C signal low).

Reporting software will be developed specific to each site to summarize performance data, including low, high, and mean temperatures, A/C, pump, and blower energy use, and other information. Individual site data performance reports will be provided with monthly project progress reports due by the 5th business day of each month.

6.3 Data Format and Storage

Data will be stored in comma-delimited ASCII format in files named by site and date in the format S#MMYY (where S# stands for site number). For example, the July 2001 file for Site 1 would be named "010701.DAT". A header list will be developed for use in identifying columnar data for each site. All files will be stored on a DEG computer and files will be archived on a monthly basis. Direct access to the data may be made by special arrangement.

MONITORING REPORTS

Sub-task 2.4.5

1 Introduction

Interim monitoring reports were prepared in accordance with the Task 2.4.5 schedule, and these reports are repeated in Sections 2 and 3. The Livermore site report covers the period through October 2002 and the Watsonville report covers the period through April 2002. However, monitoring of the Livermore site continued through December 2003, and the Watsonville monitoring system was decommissioned at the end of March, 2003. The owners of the Watsonville house rarely utilized the cooling system during the entire monitoring period, and there is no significant additional information to report beyond what is presented in Section 3. The interim monitoring report for the Livermore house covers the period up to October 2002, the same month that the owners took occupancy. Consequently there is significantly more data of interest that was collected after the end of the interim monitoring reported in Section 2. These additional results are briefly described in section 3.

2 Livermore Demonstration Site

2.1 Overview

This report presents the results of the first four months of monitoring of the Livermore demonstration site located in Centex Homes' Los Olivos development at 3050 Bertolli Drive. The house is one story and has 3080 ft² of conditioned floor area. It is located in Climate Zone 12. The house was completed in July 2002 and sold in September, but has yet to be occupied. The cooling system was operated from the time of completion. A refrigerator and lighting that was kept on while the house was being shown contributed to internal heat gains. The house was open to tours by potential buyers on a daily basis prior to being sold. Since the house is also a demonstration under the Zero Energy Home program, PV generation and total house power are being monitored in addition to mechanical systems supplied under this project. Monitoring data are available for viewing on line at the Florida Solar Energy Center website:

http://www.fsec.ucf.edu/bldg/active/zeh/livermore/data.htm

2.2 Monitoring History

The table below chronicles the installation of the monitoring equipment, problems encountered, and changes that may affect the monitoring data.

2/6/02	Installed pre-wiring for sensors
7/2/02	Installed sensors & dataloggers
7/18/02	Preliminary commissioning, began logging data
7/26/02	Completed commissioning of monitoring system
8/9/02	Replaced defective damper motor and control board, unit #2
9/26/02	Repaired connection to enable remote mode switching; replaced defective flowmeter on solar loop
10/16/02	Revised power monitoring to correct discrepancy between total and sub-metered loads, recharged solar loop

The monitoring plan called for the HVAC system to be operated in "NightBreeze" mode and "standard" mode on alternating two-week intervals. Standard mode disables night ventilation cooling and variable speed fan operation (in heating mode). Due to the late completion of the house and a wiring problem with the relay that controls mode switching, monitoring was only completed using NightBreeze mode.

Two problems were encountered with the NightBreeze systems. When one of the dampers was installed the damper blade was apparently forced, causing the drive gears to strip. This was not detected until late July, and a replacement damper motor was installed in August. Although the fan on this unit was continuing to use energy, no outside air was being delivered through July into the first week of August. The second problem was that the unit #2 fan motor was not obeying the control signal, and was operating at its highest speed, using more than 1 kW. Replacing the control board rectified this problem. Both malfunctions contributed to diminished performance.

2.3 Data Review

Data summaries for the months of July through October are attached to this report. Tabular reports for each month list each measured and calculated value, and totals, averages, maximums and minimums, and times of occurrence of the maximums and minimums. The reports include descriptions of each data point, including those that are being monitored to evaluate the home's solar performance. Following each tabular report are graphs for each week of monitoring that plot indoor and outdoor temperatures and fan power and air conditioner power. Indoor temperatures measured at the Master Bedroom and Living Room were averaged and power values for the two systems were totaled to make the graphs easier to read. Thermostats were set at 76° during most of the monitoring period to keep the house comfortable during tours.

July

July 19th was the first day of monitoring, so the month was missing 420 hours of data. One or both of the air conditioners ran on July 20, 27, 28, and 31, though indoor temperatures during most of these periods were below 75°F. A total of 0.6 hours of air conditioning was recorded. The maximum recorded indoor temperature was 78.6°F and the average was 72°F for the month. The EER's for night ventilation cooling (total sensible cooling from outdoor air divided by total fan energy) was 259 and 61 for fan units 1 and 2 respectively. The lower EER for unit 2 was due to a control problem that was not resolved until September 26.

August

One air conditioner was operated briefly during August 2 & 3, probably because it was manually turned on (indoor temperature was less than 75°F). However, the week of the 8th had five consecutive days over 100°F, and the air conditioners ran six of those days to maintain the 76°F setting. The total full-load run time was 1.8 hours. For the four days that temperatures exceeded 102°F (the 10th – 13th), the average air conditioner demand between 4 PM and 6 PM was 1.68, 1.47, 1.87, and 0.54 kW. Only about 35% of the installed 4-ton air conditioner capacity was needed to maintain the 76°F setpoint during this period. Ventilation cooling fan EER's were 104 and 40 for the two units. There were 6 hours of missing data in August, due to house power being shut down by workers.

September

Though outdoor temperatures reached or exceeded 100°F on six days in September, air conditioning was not needed to maintain the 76°F thermostat settings. Total ventilation fan energy exceeded 1 kW on 19 days and EER's of 41 and 23 were calculated. On the hottest days, fan operation did not begin until well after the end of the 12-6 PM peak period. Only 45 minutes of data were lost due to power shut-downs.

October

Outdoor temperatures only exceeded 90°F on four days during October. There was no air conditioner operation. Combined ventilation fan energy never exceeded 400 Watts. Due to the lower fan speeds cooling EER's were 78 and 56 for units 1 and 2 respectively. There was no data loss during this period.

Summary

Energy consumed by fans and air conditioners over the monitoring period is tabulated below (in kWh). Total energy use for cooling was 454 kWh for the four months. The total fan energy use of 411 kWh far exceeded the air conditioner energy use of 42 kWh and all of the fan usage was during off-peak periods. Had the unit #2 control been operating properly, fan energy for unit #2 would have been similar to that for unit #1, reducing the total usage to about 250 kWh.

Month	A/C 1	A/C 2	Fan 1	Fan 2	Total
July (12 days)	3	4	7	14	28
August	20	15	49	65	149
September	0	0	38	217	255
October	0	0	10	11	22
All Months	23	19	104	307	454

DOE-2 simulations completed on the 1860 ft^2 "Summer Comfort Home" design predicted a peak load of 1.6 kW (0.86 W per ft^2) and annual air conditioning energy use of 417 kWh (0.22 kWh per ft^2). For the shortened summer, the 3080 ft^2 Livermore house used 454 kWh. If it had been monitored for the entire summer it would probably have used less than 700 kWh, which is very close to the 0.22 kWh per ft^2 predicted by DOE-2. Extrapolating from the DOE-2 energy demand predictions, the Livermore house would be expected to have a peak demand of about 2.6 kW. The measured highest demand on the third day of the August heat storm of 1.87 kW compares favorably to the predicted value.

Particularly given the low (76°F) thermostat setting and the malfunctioning fan control and damper, the performance of the night ventilation cooling system met or exceeded expectations. Future hardware problems can be mitigated by testing control boards before they are installed, and by securing the damper blades until after installation is completed. Monitoring under the Zero Energy Home Program will continue through the summer of 2003, providing an opportunity to obtain a full summer of performance data with the systems operating optimally.

3 Watsonville Demonstration Site

3.1 Overview

This report presents the results of the first six months of monitoring of the Watsonville demonstration site located in Clarum Homes' Cherry Blossom development at 19 Loma Prieta Avenue. The house is two stories and has 1611 ft^2 of conditioned floor area. It is located in Climate Zone 3. The house has served as a sales office for the development since its completion in October 2001, and has been unoccupied other than by sales staff. The house is scheduled to be sold and occupied by the beginning of July 2002.

3.2 Monitoring History

The table below chronicles the installation of the monitoring equipment, problems encountered, and changes that may affect the monitoring data.

9/12/01	Monitoring equipment installed
10/2/01	Modem problems corrected, air handler fan motor programmed with current EMI program
10/3/01	Lightening storm caused datalogger & modem failure
10/10/01	Datalogger and modem replaced
12/19/01	Replaced original ZCNR control board with prototype NightBreeze control. A locking cover was installed on the thermostat because the fan had been manually turned on and was left running.
1/4/02	Problem with water heater control corrected (no heating between 12/28/01 and 1/4/02)
4/5/02	The wall that the monitoring panel was installed on was removed to prepare the home for sale, resulting in data loss when the datalogger was disconnected by the contractor.
4/9/02	Restored datalogger operation; installed NightBreeze Rev. B control board with capability to cycle the system between "NightBreeze" and "Typical" operating mode. Control set in Vacation mode to enable automatic switching between heating and cooling. Faulty return air sensor noted.
4/25/02	Corrected return air sensor wiring problem stemming from events on 4/5/02. Set control to Cooling mode. "Low" temperature setting 65°F, "High" temperature setting 80°F.

Heating season data collected between October 10 and December 19, and between January 4 and April 4 reasonably reflect typical heating system performance for the system operating with the prototype control. When the new control was installed on April 9 it was set in Vacation mode so that it would automatically switch between heating and cooling modes to accommodate the variable weather. The data show daily switching between heating and cooling, suggesting that control adjustments may be needed to prevent this phenomenon.

3.3 Data Review

Data summaries for the months of October through April are attached to this report. Tabular reports for each month list each measured and calculated value, and totals, averages, maximums and minimums, and times of occurrence of the maximums and minimums. The reports include descriptions of each data point. Following each tabular report are graphs for each week of monitoring that plot indoor and outdoor temperatures and fan power. The two upstairs temperatures (TBR3 and TMB) were averaged to produce the single upstairs temperature graph[7].

As a reference point for indoor temperature data, the thermostat was programmed with the following temperature schedule:

Time Period	Temperature Setting
7 AM – 6 PM	68°F
6 PM – 7 AM	65°F

This temperature schedule was selected to correspond with sales office occupancy. Weekday and weekend schedules were identical. Settings for ventilation cooling were: 66°F "low" and 78°F "high".

[7] Line styles for indoor and outdoor temperatures are similar, but indoor (upstairs) and outdoor temperatures can be distinguished by their upper and lower extremes.

Further definition of QVENT and QFA is needed to understand the reported data. In cooling mode QVENT represents ventilation cooling energy. In heating mode, QVENT is energy removed from the house by the fan and damper to maintain indoor air quality when the heating system is not operating. QFA is the additional energy required to heat ventilation air when the heating system is operating. Therefore, the total heating season energy penalty for fresh air ventilation is the sum of QFA and QVENT.

October

There were 70 hours of missing data in October due to weather related datalogger failures, and power outages, but an additional 183 hours were excluded from the report because of apparent power outages and resulting lack of system operation during the first week. Since the water heater was not operational during the entire month of October (the gas meter was not installed), no heating use was recorded (sum of QHEAT = 0). However the fan operated as if heat were available. Manual operation of the fan by the occupants further complicated interpretation of the data. Solar heat gain was responsible for driving the indoor temperature above the 68° thermostat setting on many of the October days. Ventilation cooling was operative sporadically during the month, but the 71,643 kBtu of ventilation reported is not representative because of the manual fan operation. Due to the lack of heat, the lowest indoor temperature recorded was 63.1°F and the overall indoor average was 67°F. Average fan efficacy was 0.117 Watts per CFM.

November

The water heater, and hence the heating system, was not made operational until November 26th. Due to mild weather conditions the indoor temperature averaged 66.5°F. The minimum temperature reached 52°F (before the heating system was operational). There were 3.5 hours of missing data resulting from power outages, which are apparent from temperature drop-outs on November 9th, 24th, and 30th.

December

The second floor temperature was generally maintained above the 65°F minimum setpoint, with the downstairs area 2.3° cooler on average (the thermostat is on the second floor). The indoor temperature drifted over the 68°F setpoint as a result of solar gain. With the exception of periods when the thermostat was tampered with (see temperature plot for December 10th), the heating system did not operate above the 68°F setpoint. The fan used 6 kWh to deliver 2779 kBtu of heating, or 0.0028 Wh/Btu. This usage is 44% lower than the default fan energy value used in the Title 24 ACM Approval Manual standard value of 0.005 Wh/Btu. Data records for December were complete (no data loss).

January

Except for the loss of heating system operation between the first and the third of the month when the water heater was not functioning, January performance was similar to December. Fan energy use rose to 0.006 W/Btu due to the large amount of fan energy used during the first part of the month when the fan was running but no heat was being delivered. Not counting the first four days of January, fan energy use was only 0.002 Wh/Btu, or 60% less than the standard value.

February

A power loss on the 15th resulted in the loss of 45 minutes of data. Performance was again consistent with the previous months, with very low fan energy use (0.002 Wh/Btu).

The average difference between first and second floor temperatures was 2.4°F.

March

Loss of power on the 24th resulted in erroneous reporting of minimum air temperatures. Otherwise, system operation was representative of previous months. Fan energy use was 0.003 Wh/Btu.

April

The datalogger was removed by the contractor on the 5th to facilitate removal of a wall that partitioned the sales office from the mechanical room. The system was not restored until late on the 9th, resulting in the loss of 119 hours of data. Upon the restoration of the monitoring program, calculations were modified so that energy removed from the house by ventilation is reflected by a negative instead of a positive value. Therefore, values reported for QVENT and QFA are not correct for April. Though the system was switched to cooling mode on the 25th, temperatures were not warm enough to cause ventilation cooling.

3.4 Summary

In heating mode the system functioned properly to maintain indoor air temperatures above the setpoints, and the system supplied fresh air in accordance with the intended control function. Including the additional fan energy required for fresh air ventilation, fan energy consumption required to deliver heating was less than half of the standard value used in the Title 24 ACM manual for furnace fan energy.

Insufficient cooling season data were available during this period to adequately evaluate ventilation cooling performance. A brief test of the vacation mode control setting suggests that modifications to the control program to minimize alternate heating and ventilation cooling may be called for.

4 Epilog – Additional Performance Data from the Livermore Site

4.1 Additional Data from the Demonstration House

Data continued to be collected from the Livermore site through December 2003 on 15 minute intervals. The table below lists fan and air conditioner energy consumption (kWh), ventilation cooling "EER" (Btu/Wh), hours of air conditioner operation, maximum summer power demand (kW) indoor temperatures averages and maximums (°F), and outdoor temperature maximums (°F) recorded for the year beginning in October 2002 through September 2003.

Month	Fan Energy	A/C Energy	Vent EER	A/C Hours	Max. kW	Avg Indoor	Max Indoor	Max Outdoor
Oct-02	21	0	67	0		68.2	75.3	
Nov-02	25	1	52	0		66.1	72.1	
Dec-02	41	3	0	0		67.5	72.9	
Jan-03	78	2	0	0		69.2	74.2	
Feb-03	95	2	0	0		68.0	73.7	
Mar-03	98	0	12	0		69.0	73.8	
Apr-03	76	0	0	0		69.0	73.4	
May-03	20	0	76	0	1.14	71.0	77.2	99.4
Jun-03	24	2	49	0.9	2.23	72.3	78.7	103.8
Jul-03	57	16	50	7.4	4.17	76.1	81.2	106.7
Aug-03	25	5	75	0.4	1.7	75.1	79.9	101.5
Sep-03	18	4	44	0.1	1.5	75.5	79.5	101.2

Fan energy includes fan operation while the air conditioner or heating system were operating; winter fan energy is for heating. Less than 18% of cooling energy use (combined fan and air conditioner energy) occurred during on-peak hours, and air conditioner operation totaled 8.9 hours (both air conditioners). The highest peak demand of 4.17 kW occurred when both air conditioners were operating at the same time, although air conditioner duty cycle data indicate that only one two-ton air conditioner would have been sufficient to meet the cooling load.

Vent EER was calculated by dividing the cooling delivered by the ventilation system (based on indoor – return air temperatures and airflow) by the fan energy. Compared to air conditioning these values are very impressive, but since this cooling delivery does not coincide with peak cooling demand and is stored in the building mass at less than 100% efficiency, the EER values must be degraded by some amount[8].

Indoor temperatures were within the owners' comfort requirements. Ventilation cooling could have been used more extensively to provide lower nighttime and average daily temperatures, and this may have further reduced or eliminated air conditioner operation.

4.2 "Control" House

A house built to the identical plan as the Livermore demonstration house and located on Lot 55 of the Los Olivos development was equipped with portable dataloggers to measure indoor temperature, attic temperature, fan status, and air conditioner status. The HVAC system included a single 5-ton 10 SEER air conditioner. Ducting was divided into two zones. Although air conditioner power was not measured, it can be approximated from the status data using a 1 kW per ton assumption.

4.3 Performance Comparison

Side-by-side performance comparisons should not be taken too literally because of differences in occupant behavior. However, the differences shown in the figure below that compares the Lot 55 "control" house to the Lot 78 ACC demonstration house too great to explain by behavior. The figure below plots air conditioner power, indoor temperature, and outdoor temperature for the two houses for a typical summer day (7/25/03). The morning indoor temperature for the ACC house was about 4°F cooler, and the afternoon high was less than 1°F warmer than the Lot 55 control. At the same time the control house used 21.7 kWh of air conditioner energy to the ACC house's 4.1 kWh of fan energy (the air conditioner did not run). The frequent cycling of the air conditioner at the control house suggests the energy use was probably greater than estimated using the 1 kW per ton assumption.

In conclusion, the performance of the ACC house and ventilation cooling system more than met expectations for reducing peak load and minimizing or eliminating air conditioning use, while providing superior comfort.

[8] The degree of EER degradation is very difficult to assess, and would require a great deal of scientific study and analysis.

Comparison of the Livermore ACC House (Lot 78) and the Control House (Lot 55)