Customer Advanced Technologies Presents:

GeoHeat Pump

Ground Loop Heat Exchangers

Directional Boring Test

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Energy Research & Development

Sacramento Municipal Utility District

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Report #

Acknowledgements

This report would not have been possible without the assistance of the very able project team. The team was composed of Lisa Meline, Nick Cabianca, Nick Mitchell, Kevin Oxley, David Grupp, David Maul, and Bruce Baccei. Each team member contributed significant information in a very positive, problem solving manner. The team functioned well together and it was a pleasure to work with all of them.

The project would not have been possible without the well founded thesis that since GeoHeat Pump systems work well in other parts of the United States, they might also work well in Sacramento. This report confirms that thesis. Bruce Baccei has been a steady voice of support for GeoHeat Pumps that enabled this test to be completed.

Finally, we cannot say enough about how wonderful the SMUD customers are who hosted this project. Steve and Becca Trumbly and their family are strong supporters of energy efficiency and wanted to have their home match their beliefs. They happily put up with the few inconveniences during the R&D and construction phases of this project, asked lots of questions, and welcomed us into their home. We feel very blessed to have worked with the Trumblys over this past year.

Table of Contents

Executive Summary

This GeoHeat Pump Ground Loop Heat Exchanger Directional Boring Test project evaluated a new approach to installing the ground loop heat exchanger. The purpose of the project was to determine if the new boring approach could significantly reduce the total cost of installation and operation for the highly energy efficient GeoHeat Pump technology. This approach has been used in Portland, Oregon successfully but has not been tested in Sacramento.

The project proposed to install a ground loop heat exchanger as a retrofit to an existing home in the SMUD service area, analyze the effectiveness of this installation, then monitor the performance and energy efficiency of the installed system for 1 year.

A home in the Pocket Area of southwest Sacramento was identified and an engineering analysis of the home's energy load was conducted. A GeoHeat Pump unit, manufactured by Water Furnace, was selected for this application and successfully installed. The Ground Loop Heat Exchanger using traditional high density polypropylene (HDPE) pipe was successfully installed. Sensors were installed to track the system's performance and data has been collected and analyzed.

This report discusses the project installation and initial data analysis. A subsequent monitoring report will be prepared after the system has been monitored for at least 1 year that will include more detailed energy efficiency calculations. This current report also analyzes the costs to install a Ground Loop Heat Exchanger. Current R&D installation costs and future installation costs in a more mature and competitive market are both detailed. These costs are close to what was estimated in an earlier internal SMUD report three years ago and make GeoHeat Pumps a competitive option for homeowners in Sacramento.

The project yielded valuable information about this promising GeoHeat Pump technology for the Sacramento area. The project met the initial project objectives, as described below, in determining that the new boring approach would significantly reduce installation costs for the Ground Loop Heat Exchanger portion of a GeoHeat Pump system. The project also provided additional information not originally anticipated. Most interesting was the high level of interest among the test homeowner's neighbors in GeoHeat Pumps and their requests to be notified when a SMUD incentive program would be available.

Introduction/Project Description/Goals

This project was designed to test the effectiveness and cost of a new GeoHeat Pump drilling system called directional boring. The directional boring approach promises to reduce costs from $20-30/ft to $10/ft or less for installation of the GeoHeat Pump Ground Loop Heat Exchanger. It is possible to achieve further cost reductions if the volume of drilling increases substantially. Such a cost decrease would significantly improve GeoHeat Pump system cost effectiveness for homeowners in SMUD's service territory.

A secondary goal is to develop a project approach that can be replicated in many homes and small to medium commercial sites in SMUD's service territory. The subject home is of a style and age (1988) that represents a large class of homes in Sacramento. The subject home is built on a slab foundation, not a raised foundation. A raised foundation home allows for piping to be easily placed under the home and out of the attic and allows for simplier connections to the exterior ground loop heat exchanger. A GeoHeat Pump system can installed easier and less expensively on a home with a raised foundation than on a home with a slab foundation. Therefore, if the Geo system can be successfully retrofitted on the test home, then it can be done on many other homes.

Project Site

The site selected for this project is a home owned and occupied by SMUD customers Steve and Becca Trumbly. The Trumbly home is located at 7504 Rio Mondego Dr, Sacramento, CA 95831. The home is in the "Pocket" area of southwest Sacramento near the Sacramento River. The home is on old river bottom soils. The site is identified in the aerial views in Attachment 1.

The home sits on a typical suburban lot and is 65' wide by 150' deep. It is bordered by similar homes on 3 sides. There is a front yard with lawn, shrubs, and driveway, and a backyard with lawn, shrubs, and a patio. These photos are also in Attachment 1.

The home was built in 1988 with a Trane air source heat pump (ASHP) for heating and cooling and a natural gas water heater. The water heater failed and the Trumblys had it replaced right before the SMUD test was conducted. The ASHP needed to be replaced according to the homeowner. The home is single story and approximately 2000 sq ft.

Project Plan

The research team proposed to conduct the following actions:

1. Review the Home Performance audit which was conducted recently and develop an energy analysis of the Trumbly home to determine the appropriate HVAC and ground loop heat exchanger sizing,
2. Boreholes starting in the front yard to create a ground loop heat exchanger using a directional drilling rig,
3. Install monitoring equipment on the Ground Loop Heat Exchanger supply and return lines and circulation pump,
4. Connect the individual boreholes to a manifold and connect that to the home via a directionally bored supply and return line; the lines would enter the home via a small opening cut out of the garage floor near the existing water heater,
5. Remove the existing air handler in the interior utility closet that is associated with the air source heat pump (ASHP) and replace it with a split unit up flow GeoHeat Pump System sized for the needs of the home[1],
6. Connect the Ground Loop Heat Exchanger supply/return lines to a circulating pump near the GeoHeat Pump unit in the back of the garage. Connect the refrigerant line sets between the GeoHeat Pump unity and the new air handler in the existing utility closet in the houset,
7. Install a new thermostat,
8. Install a new 50 gal water storage tank (traditional electric water heater that is not electrically connected) plumbed into and immediately upstream of the existing water heater; this storage tank will act as a preheater for the domestic water heater; route insulated supply/return lines from the GeoHeat Pump system's desuperheater and connect them to the new water storage tank,
9. Remove the existing outside Trane condenser unit and cap the refrigerant lines,
10. Install monitoring equipment on the desuperheater, GeoHeat Pump unit, air handler unit, and natural gas water heater to determine energy usage specific for energy consumption and savings of the desuperheater,
11. Repair all modifications and clean up so that the home is returned as close as possible to its current well-kept appearance,

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[1] The original plans called for a package GeoHeat Pump unit to be installed in the interior utility closet. During the engineering design phase, we determined that the closet was too small to accommodate the newer, more energy efficient package units without substantial modifications to the closet and adjacent hall. A split GeoHeat Pump unit was then specified and subsequently installed. The air handler is in the interior closet and the heat pump with desuperheater is in the garage next to the existing domestic water heater.

12. Monitor the system for 1 year,
13. Prepare analysis for SMUD on a quarterly basis and a final report at the end of the first year, or as needed.
14. Provide a report and communicate with the homeowners so they feel the test is a success and any issues are resolved quickly.

Project Team

This project was conducted by the following team:

1. Engineering Design: Meline Engineering; Lisa Meline; energy analysis; engineering design; ground loop heat exchanger design; project advice; contribute to reports;
2. Directional Boring: Geonomic Developments; Nick Cabianca and Nick Mitchell; Licensed drilling contractor; contribute to ground loop heat exchanger design; provide cost estimates for directional boring and conventional vertical boring; perform boring for ground loop heat exchanger; install supply/return lines from ground loop to garage and stubs out capped pipes 5' above garage floor; flush all piping systems and conduct pressure tests; obtain needed city/county permits; minimize all construction waste materials for erosion control and visual disruption; clean up after completion;
3. HVAC Installation: Geonomic Developments; Nick Cabianca and Nick Mitchell: Licensed HVAC Contractor; advise team on project; install HVAC equipment, new water storage tank for the desuperheater option, and associated plumbing and electrical;
4. GeoHeat Pump Manufacturer: Water Furnace; Equipment manufacturer; Kevin Oxley; provide GeoHeat Pump equipment.
5. Energy Monitoring: UC Davis Western Cooling Efficiency Center (WCEC): David Grupp; advise project team on modifications needed to project design to accommodate monitoring equipment; develop monitoring plan with equipment specifications; purchase and install monitoring equipment; participates in analysis of project and presentations to client;
6. Project Coordination: Maul Energy Advisors (MEA); David Maul; Project Leader; responsible for developing project proposal; establishs project team and conduct team meetings; prepare project reports to SMUD and Homeowner; lead project briefings for SMUD and Homeowner; resolve issues as they arise; provide frequent communication with Project Team and SMUD.

Project Capital Budget

The cost estimate to design, install, and operate this project is broken out below by team member. The costs include all equipment, labor, travel, and overhead:

1. Engineering Design: Meline Engineering; Lisa Meline:	$7500.
2. Directional Boring: Geonomic Developments; Nick Cabianca/Nick Mitchell:	$26,000.
3. HVAC Installation: Geonomic; Nick Cabianca and Nick Mitchell:	$5450.
4. Desuperheater Installation: Nick Cabianca and Nick Mitchell;	$1650.
5. GeoHeat Pump Manufacturer: Water Furnace; Kevin Oxley (billed through Geonomic Developments):	$3038.
6. Landscaping Repair: Tau Lolohea	$300.
7. Project Coordination: MEA; David Maul:	$15,000.
Total Project Capital Budget with Desuperheater:	**$59,938.**
Less Homeowner (Trumbly) Contribution[2]:	-$3,500.
Total SMUD Project Capital Budget with Desuperheater:	**$55,438.**

Project Monitoring Budget for 1 Year

1**.** WCEC: David Grupp (costs included in a separate contract)	$46,586.

Project Analysis

The goal of this project is to determine if a new directional boring approach now being used to install the Ground Loop Heat Exchangers for GeoHeat Pump systems is significantly more cost effective than vertical HDPE drilling for the same GeoHeat Pump system in the Sacramento area.

The data gathered allowed the team to determine the energy efficiency of a retrofit GeoHeat Pump HVAC system. The data gathered also allowed the team to estimate potential reductions in installation costs for future projects using the new directional boring approach compared to the more prevalent vertical drilling approach. The

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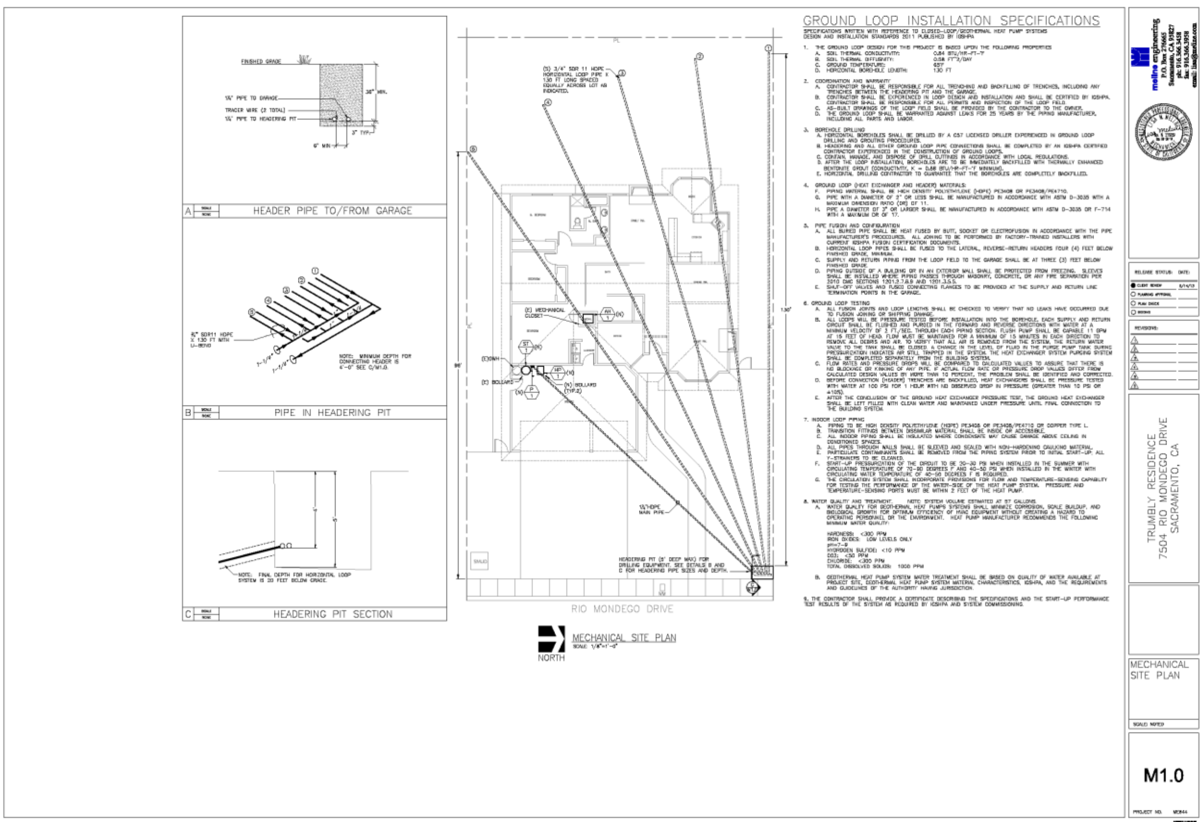
[2] The homeowner, Steve and Becca Trumbly, agreed to partially fund this project with a contribution of $3500 since they were receiving a new highly energy efficient HVAC system.

GeoHeat Pump system installation costs are compared to a traditional Air Source Heat Pump replacement system.

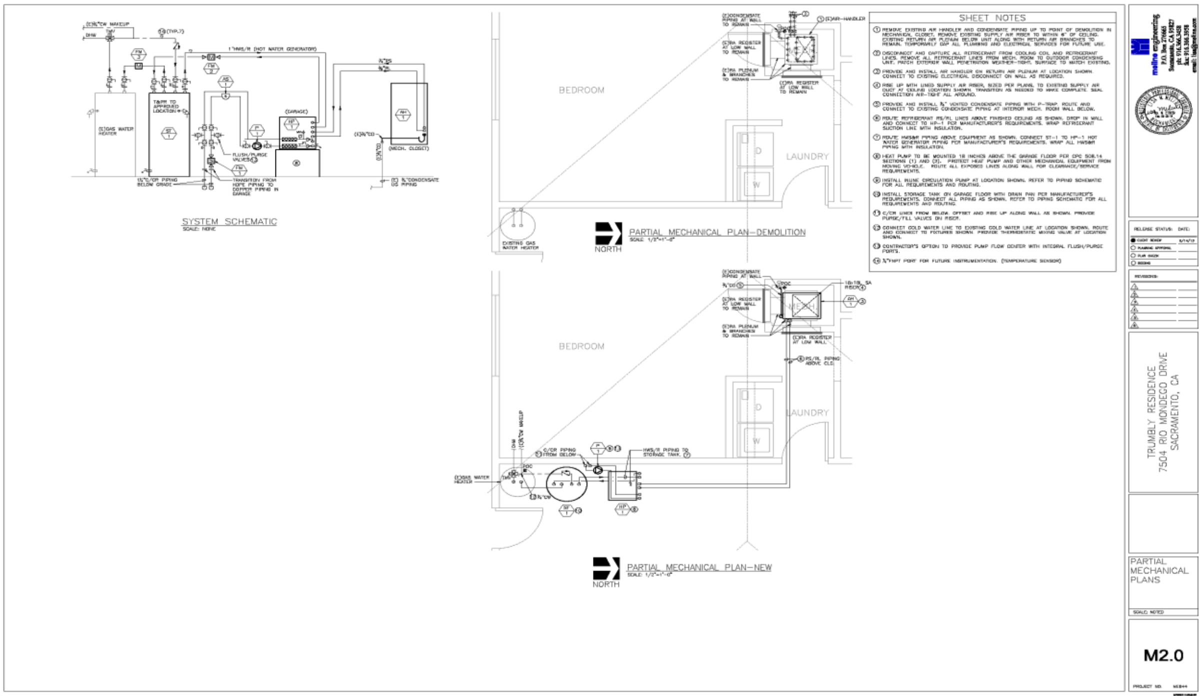
Engineering Analysis

The project engineering analysis was conducted by Meline Engineering, a Sacramento firm with extensive experience with GeoHeat Pump systems. The engineering analysis included an analysis of the project test site, a determination of the building's heating and cooling loads, the determination of the Ground Loop Heat Exchanger engineering details, and the determination of the borehole length.

Ground Loop Heat Exchanger Site Plan



Garage Floor Detail and Mechanical



The floor plan above was prepared by Meline Engineering after an onsite inspection and measurement.

Based on the building's heating and cooling loads and the assumed soil characteristics at the project site, the borehole lengths and flow requirements were determined.

The project initially assumed that the home would need approximately 600 feet of borehole underground. This assumption was based on general guidelines from GeoHeat Pump manufacturers using the more prevalent vertical hole approach and a review of a previous SMUD sponsored Home Energy Audit.

The engineering analysis showed that the home actually needed 650 feet of borehole underground for the Ground Loop Heat Exchanger. It also showed that the old 3 ½ ton HVAC air source heat pump (ASHP) unit was correctly sized. Therefore, a new 3 ½ ton Geo Heat Pump unit was initially specified to match both the home's needs and the Ground Loop Heat Exchanger capacity to deliver energy to the HVAC unit. However, the GeoHeat Pump manufacturer participating in this test project did not carry a 3 ½ ton unit in the configuration needed, so a slightly larger unit as specified. The unit installed had a 4 ton cooling capacity rating.

Project Analysis: Energy (kWh) Usage

Meline Engineering conducted several model runs of the existing home and its ASHP HVAC unit and the home with the proposed new GeoHeat Pump unit. This analysis documents the impact of the GeoHeat Pump on home energy usage. The model runs provide detailed information on run hours and power consumption in both the cooling mode and heating mode. The detailed tables are in Attachment 4. A summary of this information is below:

Summary of Heating and Cooling Hours for Trumbly Home

	ASHP Cooling	**GHP Cooling**	**Difference In Hours**	**% Difference**
Run Hours	**390**	**354**	**36**	**-9%**
Energy Consumed in kW-hrs	**3398**	**2512**	**886**	**-26%**

	ASHP Heating	**GHP Heating**	**Difference In Hours**	**% Difference**
Run Hours	**1826**	**1330**	**496**	**-27%**
Energy Consumed in kW-hrs	**9036**	**6267**	**2769**	**-31%**

The SMUD charges for electricity vary by season and by quantity of usage. Their standard residential summer rate for the Base usage quantities of between 0 and 765 kWh/month is $0.1033/kWh. SMUD charges $0.1836/kWh for all electricity consumed above 765 kWh in a month (called Base Plus) during the summer (June 1 to Sept 30). Their standard residential winter rates for Base usage quantities of between 0 and 1280 kWh in a month is $0.0955/kWh. SMUD charges $0.1771/kWh for all electricity consumed above 1280 kWh in a month (called Base Plus) during the winter, spring and fall. These rates are charged for all electricity consumed in the home, including HVAC, lighting, appliances, and “plug loads”.

If we assume that the lighting, appliance, and plug load electricity consumption uses up all the Base allocation, then the HVAC usage would all be in the Base Plus allocation at the higher rate. During the summer, the model runs above show that the ASHP consumed approximately 3398 kWh in the 4 month summer period, or an average of 849 kWh/summer-month. This level of consumption clearly puts much of HVAC cooling load electricity into the Base Plus allocation and rate level. Peak months would be higher and shoulder months would be lower, but this simple assumption allows us to make a rough comparison of the potential savings if the more energy efficient GeoHeat Pump system is used.

Applying the SMUD Base Plus Summer rate of $0.1836/kWh to the difference in electricity consumption of 886 kWh gives us a savings of $162.67 during the summer period each year.

During the winter heating season, we can make the same assumptions but apply the winter rates to the difference in the quantity of electricity consumed between the ASHP system and the GeoHeat Pump system. The model runs show that the home consumed 9036 kWh for heating during the 4 month heating season, or approximately 2259 kWh/winter-month, also well above the Base allocation. Thus, applying the Base Plus Winter rate of $0.1771/kWh to the 2769 kWh difference between the two systems yields a savings of $490.39 during the winter period each year.

Combined, the GeoHeat Pump system is expected to save the customer $653/year.

The combined energy savings for both heating and cooling is 3655 kW-hr or 29.4% of their HVAC energy. This is a significant savings to both the customer and to SMUD.

Project Analysis: Energy Demand (kw)

The older ASHP HVAC equipment was not only less energy efficient than the new GeoHeat Pump system but it also had a higher electricity draw during peak times. The older equipment is rated at a peak capacity electrical draw of 5.12 kW in the cooling mode when the outside temperature is 110 degrees F. This same unit is rated at a peak electrical draw of 6.13 kW in the heating mode when the outside temperature is 29 degrees F.

The new GeoHeat Pump system is rated for a peak electrical draw of 3.89 kW in the heating mode during the winter, and at 4.12 kW in the cooling mode during the summer, regardless of outside air temperature. For SMUD, the summer peak is more critical so it is used as the basis for analysis.

During the summer air conditioning season when the GeoHeat Pump is operating in cooling mode, the new unit is reducing the home's peak electrical demand by 1.00 kW. This is very significant and saves SMUD from purchasing peak capacity during the most expensive times of the year. The new unit also reduces peak electrical demand during the winter by an even greater amount of 2.24 kW, but during this time of year SMUD has sufficient peak capacity so the unit does not save SMUD as much money.

Project Analysis: Drilling/Boring Cost Comparison

The GeoHeat Pump industry normally estimates project costs for potential clients based on a drilling or boring cost/foot basis after calculating the building's heating and cooling load. For example, a residential building in the Sacramento area would normally need about 200 feet of vertical borehole installed using the prevalent HDPE vertical ground loop heat exchanger systems for each ton of cooling capacity.[3] A project site located on dry soils would need more and one located on wet soils or with lateral underground water movement would need less. Therefore, a 3 ½ ton cooling load would require about 700 vertical feet of borehole. If the boring cost is $20/vertical foot, the estimated boring cost would be $14,000, plus fixed costs (set up/break down, permits, etc.). Some drillers charge more since the same equipment can be used for water wells at that cost.

The new directional boring approach which has recently been developed could potentially reduce these costs significantly. This newer directional boring approach uses equipment with lower capital and operational costs. This equipment pushes a drilling pipe stem with a spade shaped blade into the soil instead of using a rotary drilling rig to grind its way into the soil or rock. The boring equipment creates a borehole by shoving the soil aside instead of grinding the soil or rock and bringing ground particles back to the surface with drilling muds. While water is used as a lubricant to help the boring stem shove its way through the soil, very little of this water returns to the surface. Further, harsh chemicals are not used so any "drilling muds" or liquids do not normally need to be disposed of in a controlled waste facility[4]. The

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[3] The cooling demand stresses the Ground Loop Heat Exchanger the most and a system sized for the maximum cooling load will be able to handle the winter time heating load.

[4] Regulations for disposal of any waste products or material from boring and drilling will vary by local jurisdiction, so local regulations need to be checked before the project is initiated.

equipment used for directional boring is much smaller and much less expensive than larger equipment used for drilling vertical boreholes.

The additional advantage of directional boring is the orientation of the borehole. A vertical drilling machine creates a vertical borehole that goes deep, usually 200' to 300'. These vertical boreholes, if not properly completed, may allow surface contamination to enter underground drinking water aquifers or allow cross aquifer contamination. This risk can be eliminated with the use of Bentonite grout to seal the borehole. The directional boring machine starts a borehole at an angle to the surface, usually 45 degrees or less. Once the borehole is started, the directional boring machine can direct the tip of the boring stem in any direction, making a gradual arc. Directional boring introduces less risk to aquifers since they do not go as deep. Any potential risk can also be eliminated by sealing the borehole with Bentonite grout.

For this current project, the team designed a GeoHeat Pump Ground Loop Heat Exchanger that initiated each borehole at 30 degrees, continued the borehole until it reached a little less than 20' below the surface, then made an arc to horizontal, continuing for the length needed at 19' below the surface.

This approach is much cleaner than more prevalent methods of drilling since creates fewer potential pathways for surface contaminants to reach drinking water aquifers. The newer, lower cost boring equipment and approach also provides more flexibility in its applications and reduced site impacts. This approach is currently being used in Portland, Oregon, an area similar to Sacramento in regards to soils and home lot sizes. This new approach could reduce future variable boring costs to $10/ft or below resulting in a project variable boring costs in the $6500 range plus fixed costs for a 3 ½ ton system.

The boring costs proposed in this project represented a significant reduction in the costs experienced by some other projects in Northern California. Geonomic Developments, the boring contractor, proposed a budget for this R&D project that included variable costs, fixed site costs, and project R&D costs. The variable costs include the operation of the boring machine to create the borehole, pipe installed in the borehole, and grout used to seal the pipe in the borehole. The fixed costs include the excavation for and installation of the ground loop heat exchanger manifold, the lateral lines to the home, permits from Sacramento County and the City of Sacramento, concrete cutting and repair, and sales tax. The R&D costs include the travel and lodging for the team during installation and participation in the R&D review and report preparation.

Geonomic Developments made an initial estimate for the variable costs based on an assumed design. The final costs were corrected based on the actual project design.

The variable costs initially assumed for the boring operation were $10.25/ft bored and for materials were $4.80/ft bored, for a total variable cost of $15/ft bored. They had assumed a borehole design with each borehole arcing down and back up to the surface at the end of the borehole, allowing for easy insertion of the HDPE pipe.

The final design for the ground loop heat exchanger called for 650 feet of borehole, which requires 1300 feet of HDPE pipe, but with buried borehole ends requiring the installation of end anchors. This is more expensive to install than they assumed. Actual variable costs for this project came to:

Variable Ground Loop Heat Exchanger Boring Costs:

1. boring: $6,800 ($10.46ft of borehole)

2. grouting/mobilization: $2,000 ($3.08/ft of borehole)

2. 3/4" GHEX piping: $1,800 (1300' used; $2.77/ft of borehole)

Subtotal for Ground Loop Heat Exchanger Variable Boring Costs: $10,600

Cost/foot of borehole (650 total feet bore): $16.31

Fixed Costs for Ground Loop Heat Exchanger System

1. supply return lines: $2,000

2. 1-1/4" supply line piping: $800

3. excavation: $800

4. manifold: $1900

5. Permit: $1,200

Subtotal for Fixed Installation Costs: $6,700

Total Boring and Ground Loop Heat Exchanger Installation Costs: $17,300

This R&D project was a learning experience for all involved since it was a new approach used for the first time in a documented case in Sacramento. The $10.46/ft of bored hole is a significant reduction from expected costs. Even when the variable Ground Loop Heat Exchanger costs are added, the variable cost at $16.31 is still less than vertical borehole systems.

If the same team were to conduct another project in Sacramento, the costs would be lower due to experience and increased efficiency. The cost reduction due to increased operational efficiencies is about $2-3/foot. Geonomic Developments also estimated that increasing GeoHeat Pump project activity and volume in the future to be able to support a dedicated boring crew and equipment in Sacramento would lower their variable costs by at least another $2.00/ft. Additional competition among qualified contractors as the market matures, should lower the variable costs another $2/foot based on what we have seen in other parts of the country.

If all these efficiencies are realized, then future boring and variable Ground Loop Heat Exchanger costs could drop total variable costs by $6/foot to $10/foot or less of bored hole and reduce the variable borehole installation costs to below $7,000 for a similar sized home, lot, and soil conditions. Obviously, costs will vary considerably based on different lot characteristics and home sizes.

Based on the team discussion, we estimate that future fixed boring costs would also be reduced and closer to $4600 instead of the $6,700 encountered by this project. This lower cost is due to lower sales taxes and lower excavation and manifold costs as drillers become more proficient.

A customer's installed costs would include these fixed and variable costs, but not the R&D costs incurred by this project. The fixed costs will be lower in the future since this project encountered several unusual aspects that delayed the installation and increased costs simply because the technology is new to Sacramento and the permitting and approval process was unclear. This topic is discussed in more detailed under Issues.

Without the R&D costs, with more competition among contractors, and with lower fixed costs, a future homeowner with the similar site conditions and home performance as the test home should be able to get Ground Loop Heat Exchanger installed quotes for less than $11,000.

The budget for this R&D project also included a labor and materials component for an HVAC contractor (Geonomic Developments) to install the GeoHeat Pump with a desuperheater and a separate line item to clean the existing HVAC ducts. The desuperheater portion involves a new water storage tank (next to and just upstream of the homeowner's existing domestic water heater), plumbing connections to the domestic water heater, and plumbing connections to GeoHeat Pump. The desuperheater is an additional heat exchange coil that is wrapped around the refrigerant return line right before it enters the compressor. This heat exchange coil extracts remaining heat that the upstream main heat exchanger cannot extract. This remaining heat is then transferred to the water storage tank and reduces the amount of energy that the domestic water needs to provide to bring the city water supply up to the desired homeowner temperature. A very small circulation pump moves the water in the desuperheater line between the GeoHeat Pump heat exchanger coil and the water storage tank. This circulation pump consumes a small amount of electricity when it operates. This circulation pump operates only when the mail GeoHeat Pump operates and when the desuperheater option is selected.

During the summer time, the desuperheater makes the GeoHeat Pump much more energy efficient by removing additional heat energy from the refrigerant line. During the winter, the desuperheater makes the GeoHeat Pump slightly less energy efficient as a space heater since it also removes additional heat that would have otherwise gone into heating the home. However, warm water from the desuperheater displaces natural gas that would have otherwise been required to heat the water for domestic use. On balance, the desuperheater increases the home's overall energy efficiency. This R&D project was designed to help quantify the net energy saved and compare it to the installation cost to determine if this option is cost effective and should be considered for future homes.

Geonomic Developments provided a cost bid for just the desuperheater portion of the project and completed this desuperheater work for $1650. With the monitoring installed on the various components of this project and the operation of the desuperheater we should be able to determine if it is a cost effective option for future installations. The desuperheater cost effectiveness won't be determined until after the first full year's data are analyzed.

Net Cost to the Consumer

This report analyzes the R&D project sponsored by SMUD at the customer's home. There were many costs incurred in this project that are unique to an R&D project and would not be incurred in the normal course of business. However, from this project team's experience, we can extrapolate what the cost to the customer would have been if this had not been an R&D project.

As stated in the previous section the upfront or gross costs to the customer for the Ground Loop Heat Exchanger portion of a project this size would have been approximately $11,000 in a mature, competitive market with multiple borehole contractors vying for the customer's business. The GeoHeat Pump equipment was an additional cost of $8488 (equipment cost plus installation). Together, the cost of the complete total GeoHeat Pump system was $19,488. At the start of this project, SMUD obtained a cost quote for a traditional air source heat pump, a typical replacement similar to the customer's existing unit. The cost for this traditional unit was approximately $7,000, or $12,488 less than the GeoHeat Pump system.

The GeoHeat Pump system is much more energy efficient and qualifies for cost support in two significant ways. First, currently the federal government offers customers who install a GeoHeat Pump system an income tax credit equal to 30% of the entire cost of the project. For this project, that tax credit would be equal to $5,846, reducing the customer's net after tax cost to $13,642.

Second, many utilities offer an incentive to customers who install GeoHeat Pump systems since it qualifies as an energy efficiency measure and it also reduces the peak electric load on the utility's system during the utility's most expensive time period. In an earlier internal paper for SMUD, the value of this benefit to SMUD was estimated at over $4,000. If SMUD were to establish a GeoHeat Pump system incentive program and offer an incentive of this level, then the net net cost to the customer would drop to $9,642 for the Geo system. This cost is a bit more than the cost of a traditional air source heat pump system. However, the customer should have lower bills for the next 25+ years since the GeoHeat Pump system can provide the same level of heating and cooling as a traditional HVAC system but with less energy consumed.

Project Installation Procedures

This project was initiated with SMUD securing the approval of the Trumblys to serve as hosts for the project site. Once they agreed, Meline Engineering visited the site to conduct a site inspection and take measurements for their engineering analysis, as documented above. The initial plans were prepared, in collaboration with Geonomic Developments and the project team. After the equipment was selected and the schedule was set, the project team canvassed the neighborhood to alert the neighbors that there was going to be a construction project in their neighborhood. The project team prepared an informational flyer (Attachment 5) to assist in this process.

The project team was very surprised that most of the neighbors were familiar with GeoHeat Pump systems and were very interested in the technology. Almost a third of the neighbors stated that they wanted a GeoHeat Pump system for their home if SMUD developed an incentive program for them. This neighborhood is a very good candidate for a community approach to GeoHeat pump development consistent with SMUD's other community energy efficiency programs, if SMUD desires to go that route.

Geonomic Developments brought all the materials and equipment on site to start the project in late June 2013. The Ground Loop Heat Exchanger was installed with a directional boring machine in three days. Attachment 6 shows pictures of this machine and its operation. The GeoHeat Pump unit and interior air handler were installed in 1 ½ days. The Ground Loop Heat Exchanger was flushed and pressure tested and the remaining project was tested to ensure it operated well, all on the fifth day. The entire work was completed in 5 days. A landscaping contractor worked for a half day the following week to ensure the lawn was repaired to its previous status. Attachment 6 also includes a picture of the lawn looking nice four weeks after all the work was completed.

Project Analysis: Monitoring (accurate through December 2013)

Climatic and Ground Conditions

The GeoHeat Pump system was installed right before the peak summer temperatures of the year were experienced. The monitoring system started collecting data just after an extended time period of high temperatures. Figure 1 shows the daily high and low temperatures for outside air as solid lines. The ground loop temperatures are indicated by dashed lines, with makers. Areas in which markers are absent indicate days when the GeoHeat Pump system did not operate at all. The maximum and minimum ground loop temperatures are recorded. During cooling season the minimum loop temperature is recorded by the GEO_EWT sensor, and during the heating season the GEO_LWT will record the minimum temperature. The average ground loop temperature is the average of the GEO_EWT and GEO_LWT temperature data points taken throughout the day.

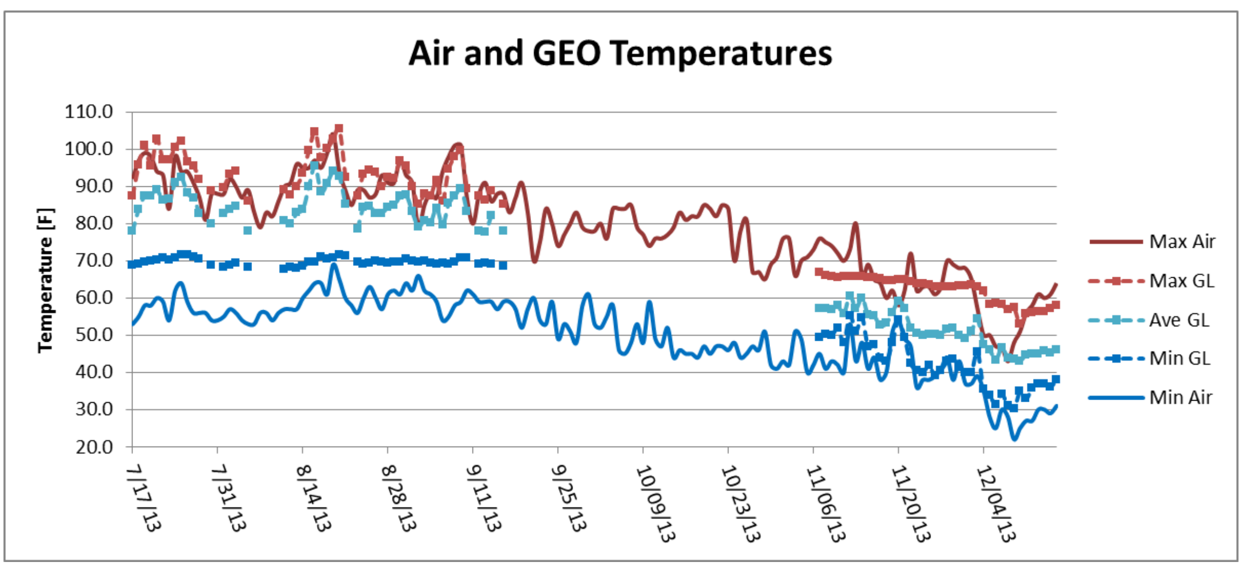


Figure 1

Calculations were made for the thermal energy delivered to the home, as well as a metric for heating degree days (HDD) and cooling degree days (CDD). HDD and CDD were calculated using the sine wave approximation method. The base temperature was adjusted so that good correlation could be made between the degree day calculation and Q_del to the building and may not match other sources for tabulations of HDD and CDD**.**

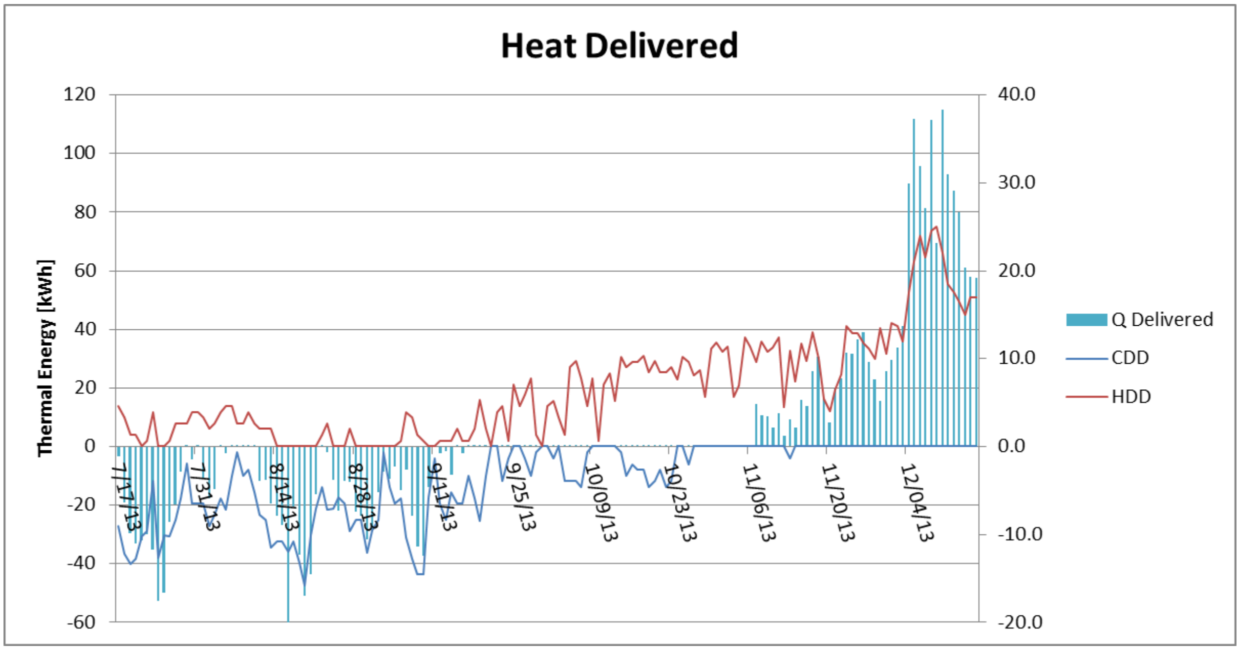


Figure 2

A visualization of the amount of heat delivered to the space and the calculated degree days was produced in **Error! Reference source not found.**. It was found that a fairly good correlation could be obtained if the thermal energy was plotted against the quantity [HDD – CDD].

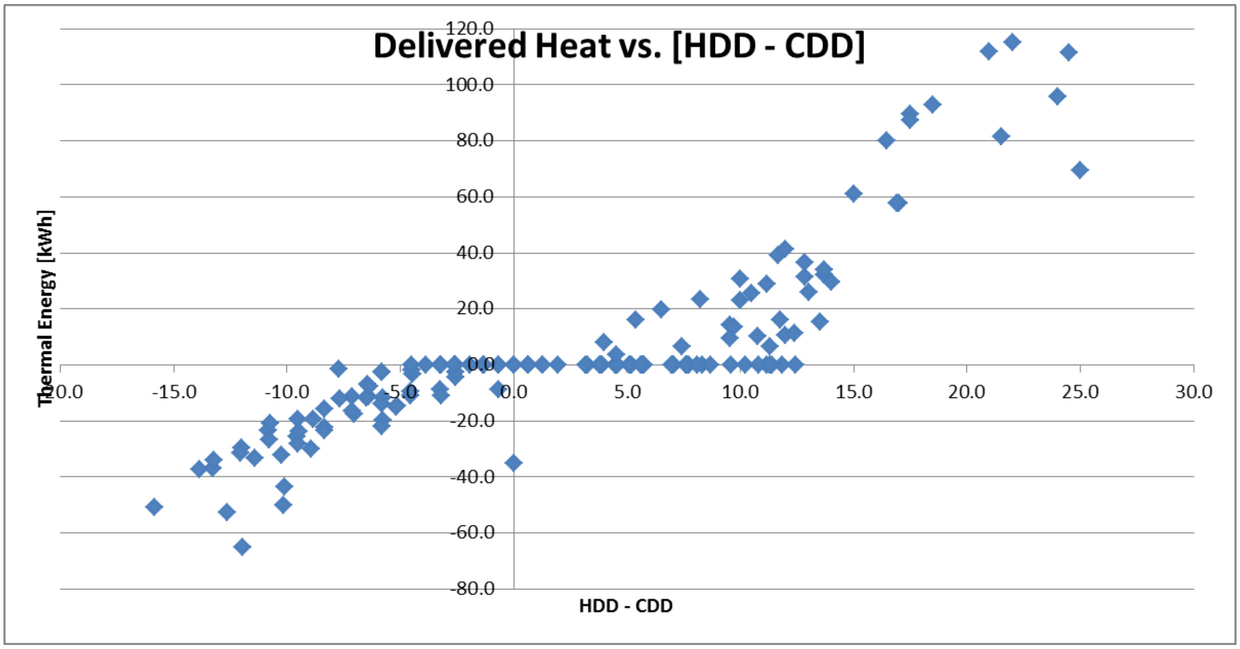


Figure 3

The fraction of heat added at the hot water heater tank (Q_HWH) and the preheat tank (Q_DSH) was calculated. The sum of these two values indicates the amount of hot water delivered. It should be noted that these values indicate the heat content of the hot water produced, and not the heat input to the two tanks to produce this water. **Error! Reference source not found.** can be interpreted to show the amount of "useful" energy contributed by each of the devices.

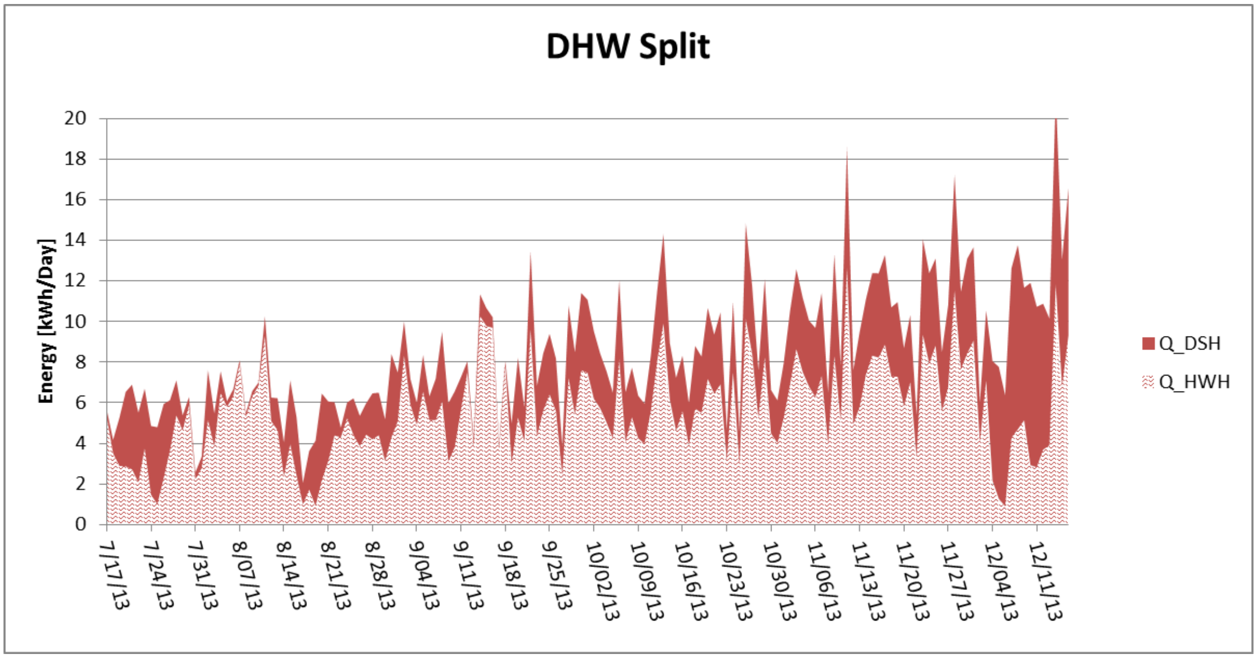


Figure 4

Electrical Input Energy and System Efficiency

Heat pump input energy was evaluated in two different ways. Figure 3 shows a plot with input energy split out by component for Fan, Ground Loop Pump, and Compressor.

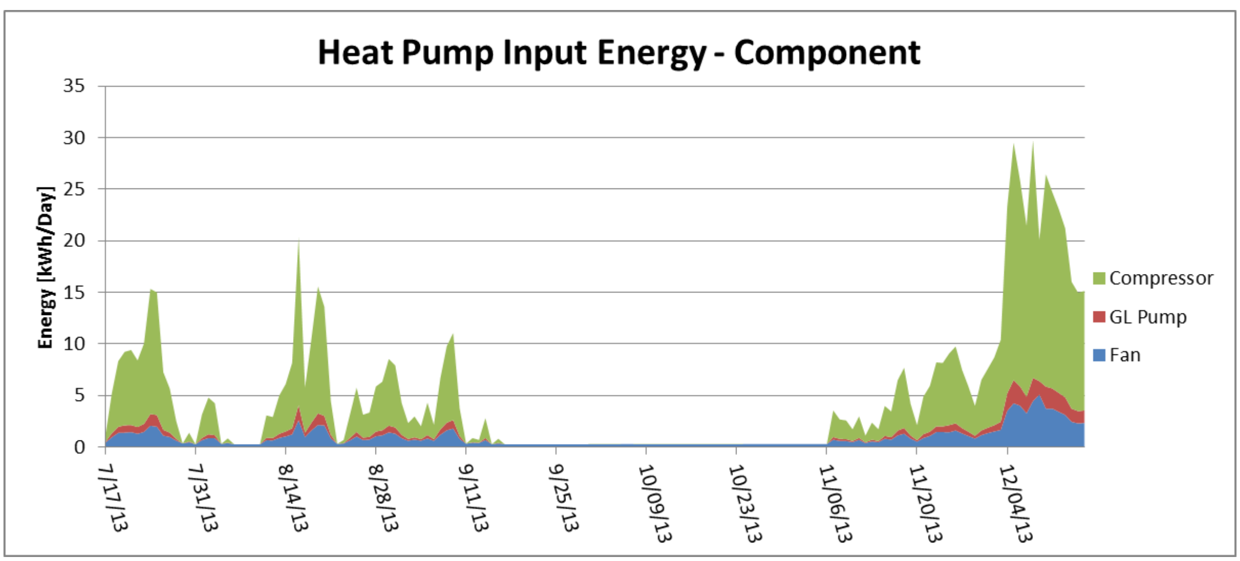


Figure 3

The heat pump energy was also split out by operating mode.

Figure 4 shows the same energy split out of the total by mode and condenser and AHU. The condenser unit represents the energy used by the compressors and water pump, while fan power is the power consumed by the indoor air handling unit.

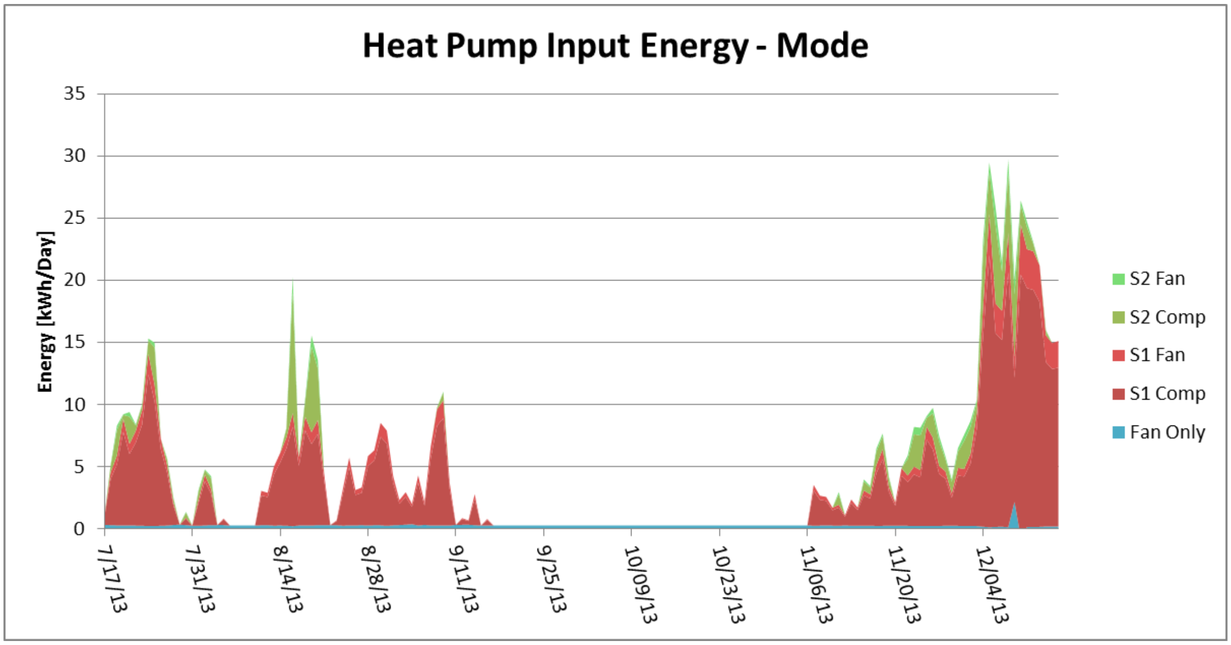


Figure 4

The data was analyzed to determine the performance of the heat pump system with regards to average condenser side temperatures. Figure 5 shows the calculated efficiency for the heat pump by average condenser side temperature. Efficiency ranges from 10 – 17 EER for cooling operation, and from 3.5 – 4.8 COP for heating. As expected, stage one operation shows higher efficiency than for stage two operation.

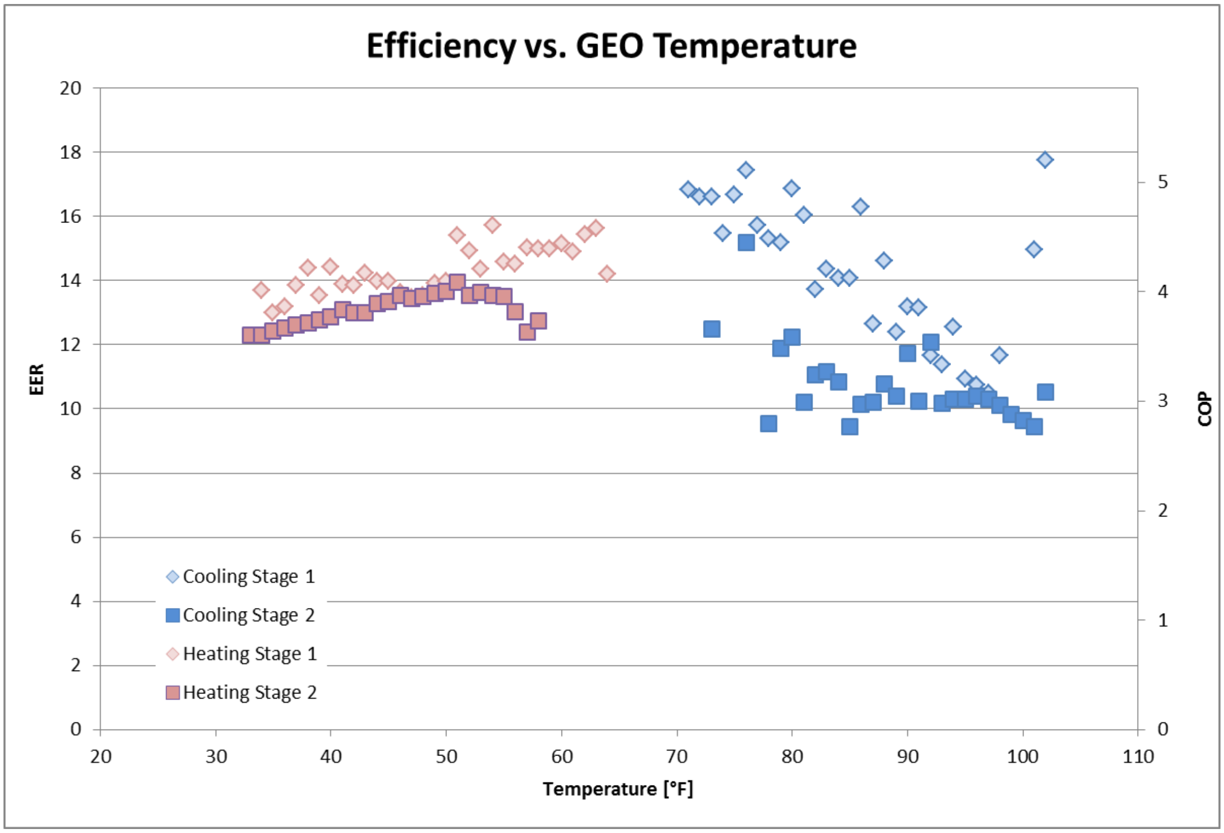

Efficiency vs. GEO Temperature
EER
COP
Temperature [°F]
Cooling Stage 1
Cooling Stage 2
Heating Stage 1
Heating Stage 2
0
2
4
6
8
10
12
14
16
18
20
1
3
5
30
40
50
60
70
80
90
100
110

Figure 5

Data Terms

T_hi
Daily high air temperature measured at KSAC Airport. Value was retrieved from WUnderground.com, in turn from Sacramento Executive Airport. Measured in degrees Fahrenheit.

T_lo
Daily low air temperature measured at KSAC Airport. Value was retrieved from WUnderground.com, in turn from Sacramento Executive Airport. Measured in degrees Fahrenheit.

HDD
Heating Degree Days. Calculated by the sine wave approximation method using high and low temperatures

Where T_S = (Building Temperature), T_C = the daily low temp. (T_lo), and T_H = the daily high temp. (T_hi)

$$HDD = \begin{bmatrix} if\ T_C > T_S\ , & 0 \\ if\ T_C < T_S < T_H\ , & \left(\dfrac{(T_H - T_C) * \sqrt{1 - \left(\frac{T_H + T_C - 2T_S}{T_H - T_C}\right)^2}}{2 * \cos^{-1}\left(\frac{T_H + T_C - 2T_S}{T_H - T_C}\right)} \right) - \left(\dfrac{T_H + T_C - 2T_S}{2}\right) \\ if\ T_S > T_H\ , & T_S - \dfrac{T_H + T_C}{2} \end{bmatrix}$$

CDD
Cooling Degree Days. Calculated by the sine wave approximation method using high and low temperatures

Where T_S = (Building Temperature), T_C = the daily low temp. (T_lo), and T_H = the daily high temp. (T_hi)

$$CDD = \begin{bmatrix} if\ T_S > T_H\ , & 0 \\ if\ T_H > T_S > T_C\ , & \left(\dfrac{(T_H - T_C) * \sqrt{1 - \left(\dfrac{2T_S - T_H - T_C}{T_H - T_C}\right)^2}}{2 * \cos^{-1}(\dfrac{2T_S - T_H - T_C}{T_H - T_C})} \right) - \left(\dfrac{2T_S - T_H - T_{C_S}}{2} \right) \\ if\ T_C > T_S\ , & \dfrac{T_H + T_C}{2} - T_S \end{bmatrix}$$

Q_GEO
Daily energy transferred into ground via ground loop. It is calculated using the difference in the ground loop temperatures (GEO_EWT and GEO_LWT), the ground loop flow rate (GEO_Flow), and the constants for water density and C_P according to the equation $Q=mC_P\Delta T$.

Q_Geo = GEO_Flow * 8.35 * 3.18E-04 * 1 * (GEO_LWT - GEO_EWT)

T_GEO_lo
Daily low geo water temperature. The lowest temperature measurement from geo entering or leaving water temperature measurements that day (GEO_EWT or GEO_LWT), while the ground loop flow rate (GEO_Flow_tot) was non-zero. Both entering and leaving are included because the average high and low temperatures could be either depending on whether the system is heating or cooling.

T_GEO_ave
Daily average geo water temperature. The overall average temperature measurement from geo entering or leaving water temperature measurements that day (GEO_EWT and GEO_LWT), while the ground loop flow rate [GEO_Flow_tot] was non-zero. Both entering and leaving are included because the average high and low temperatures could be either depending on whether the system is heating or cooling.

T_GEO_hi
Daily high geo water temperature. The highest temperature measurement from geo entering or leaving water temperature measurements that day (GEO_EWT or GEO_LWT), while the ground loop flow rate (GEO_Flow_tot) was non-zero. Both entering and leaving are included because the average high and low temperatures could be either depending on whether the system is heating or cooling.

DHW_tot
Total Daily Flow of water from the water heater (DHW_Flow_tot), including flow noise.

Q_DHW_tot
Daily energy used by the whole system. It is calculated using the temperature difference between the entering cold water (DCW_EWT) and the exiting hot water (DHW_LWT), the domestic water flow rate (DHW_Flow_tot) including flow noise, and the constants for water density and C_P according to the equation $Q=mC_P\Delta T$.

Q_DHW_tot = DHW_Flow_tot * 8.35 * 3.18E-04 * 1 * (DHW_LWT - DCW_EWT)

DHW_dem
Total daily flow of water from the water heater (DHW_Flow_dem), excluding flow noise.

Q_DHW_dem
Daily energy used by the whole system. It is calculated using the temperature difference between the entering cold water (DCW_EWT) and the exiting hot water (DHW_LWT), the domestic water flow rate (DHW_Flow_tot) excluding flow noise, and the constants for water density and C_P according to the equation $Q=mC_P\Delta T$.

Q_DHW_dem = DHW_Flow_dem * 8.35 * 3.18E-04 * 1 * (DHW_LWT - DCW_EWT)

COP_HW
Coefficient of performance of the domestic hot water system. It is measured by dividing the energy received by the water (Q_DHW) by the energy put in by the hot water heater gas burner (Q_HWH_B).

COP_HW = Q_DHW / Q_HWH_B

Q_DSH_dem
Daily energy used by the desuperheater. It is calculated using the difference in the desuperheater entry ((DSH_EWT) and exit temperatures (DSH_LWT), the desuperheater flow rate (DSH_Flow_tot) including flow noise, and the constants for water density and C_P according to the equation $Q=mC_P\Delta T$.

Q_DSH = DSH_Flow_tot * 8.35 * 3.18E-04 * 1 * (DSH_LWT - DSH_EWT)

Q_DSH_useful
The daily energy contributed by the ground source heat pump desuperheater to the DHW. It is calculated by subtracting the water heater gas burner energy supplied (Q_HWH_B) from the total DHW energy supplied (Q_DHW_dem).

$$Q\_DSH\_Useful = Q\_DHW\_dem – Q\_HWH\_B$$

Q_HWH_dem

Daily energy used by the water heater. It is calculated using the difference between the hot water entry (DHW_EWT) and exit temperatures (DHW_LWT), the domestic water flow rate (DHW_Flow_tot) excluding flow noise, and the constants for water density and C_P according to the equation $Q=mC_P\Delta T$.

$$Q\_HWH = DHW\_Flo\_tot * 8.35 * 3.18E-04 * 1 * (DHW\_LWT - DHW\_EWT)$$

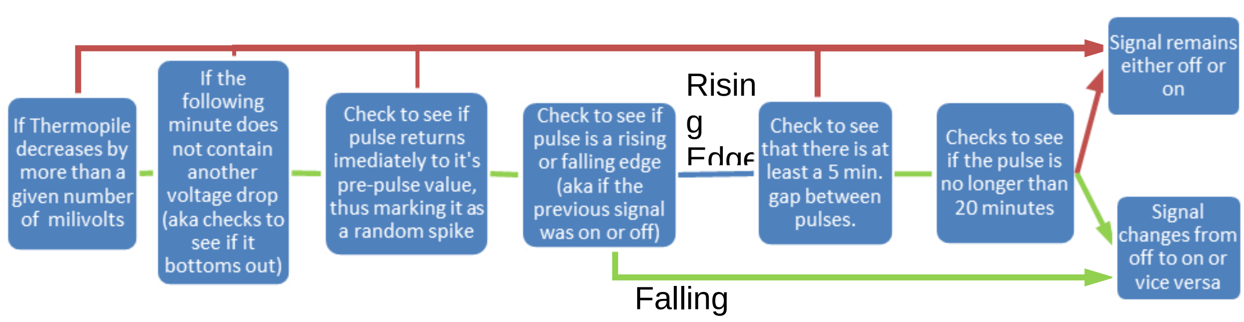
Q_HWH_B

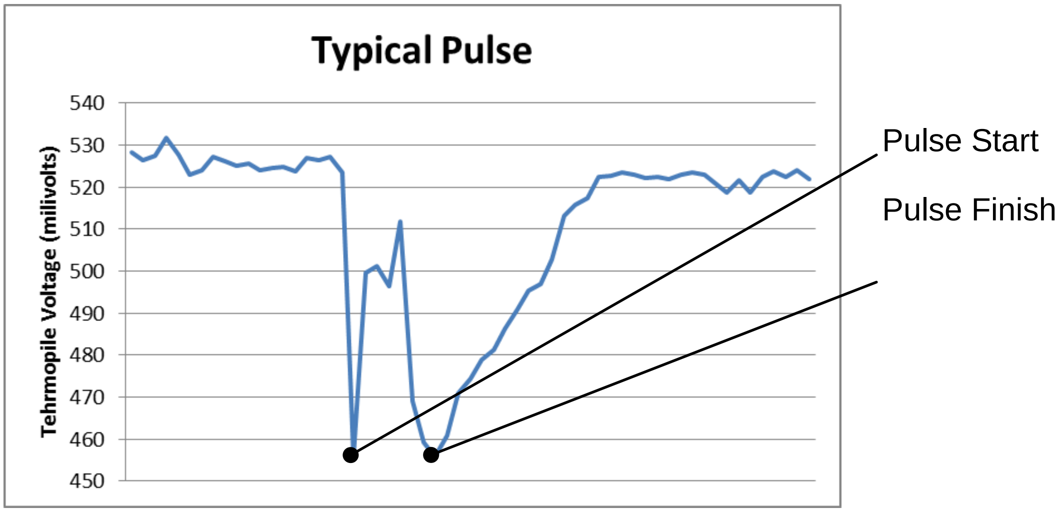
Daily energy usage of the water heater gas burner. This is measured by multiplying the duration the burner is on each day (HWH_Active) by burner capacity and a conversion factor from BTU to kWh.(HWH_prod), and a hot water heater efficiency factor (HWH_eff).

$$Q\_HWH\_B = HWH\_Active * 0.1954 * 0.8$$

HWH_Active

Number of minutes per day the water heater burner is active as measured by the hot water heater thermopile. By using the following flowchart, the edges of intervals when the hot water heater turns on or off can be found, and correspondingly the total active time can be found by totaling the intervals in between the edges. The detection is dependent on four variables, the minimum voltage drop in the thermopile, the minimum time interval between pulses, the maximum length of an individual pulse, and the minimum change in net voltage between to rule out a random spike. These were arbitrarily assigned to fit the data, and can be changed from either the “Constants” or “Calcs” worksheets.





E_AHU
Daily energy usage of the indoor air handler unit. This value is the calculated kilowatt-hours used by the unit. The kWh value is calculated by subtracting the maximum (HP_AHUPow) value from the minimum (HP_AHUPow) value for the day in order to get the daily net energy difference.

E_Cond
Daily energy usage of the condenser. This value is the calculated kilowatt-hours used by the unit. The kWh value is calculated by subtracting the maximum (HP_CompPow) value from the minimum (HP_CompPow) value for the day in order to get the daily net energy difference.

E_GPP
Daily energy usage of the ground pump. This value is the calculated kilowatt-hours used by the unit. The kWh value is calculated by subtracting the maximum (GEO_PumpPow) value from the minimum (GEO_PumpPow) value for the day in order to get the daily net energy difference.

Q_Del
The total thermal energy delivered by the system to the interior space. It is calculated by taking the inverse of the thermal energy delivered to the ground (Q_Geo) and then adding pump energy (E_GPP) multiplied by a heat transfer factor (Pump Eff) and the compressor energy (E_Comp) multiplied by a heat transfer factor (Comp Eff). Note that a positive number here indicates thermal energy delivered to the space, a negative number indicates thermal energy extracted from the space.

$$Q\_Del = -Q\_Geo + E\_GPP * 0.9 + E\_Comp * 0.95$$

COP_GSHP
The Coefficient of Performance of the system. It is calculated by dividing the total thermal energy delivered by the system (Q_Del) by the electrical energy supplied to the system (E_AHU) plus (E_Cond).

$$\text{COP\_GSHP} = \text{Q\_Del} / (\text{E\_AHU} + \text{E\_Cond})$$

EER_tot
The energy efficiency ratio of the total system including thermal energy added to the DHW system. It is calculated by multiplying the thermal energy delivered (Q_Del) by the conversion factor (3.412).

$$\text{EER\_tot} = \text{Q\_Del} * 3.412$$

EER_hvac
The energy efficiency ratio of the cooling system neglecting thermal energy added to the DHW system. It is calculated by multiplying the coefficient of performance (COP_GSHP) by the conversion factor (3.412).

$$\text{EER\_hvac} = \text{COP\_GSHP} * 3.412$$

GSHP_DC_S1
The duty cycle for Stage 1 of the conditioning unit. It is calculated by dividing the sum of the intervals when the difference in the compressor (HP_CompPow) is under a minimum threshold by the number of recording minutes in that day.

$$\text{GSHP\_DC\_S1} = \text{CountIF(Range: (HP\_CompPow), Criteria: } 0 < x < 0.04\text{) / Count(HP\_CompPow)}$$

E_GSHP_S1
The daily energy used during Stage 2 cooling. It is calculated by summing all the differences in kWh during the intervals when the difference in the compressor (HP_CompPow) is below a minimum threshold.

$$\text{E\_GSHP\_S1} = \text{SumIF(Range: (HP\_CompPow), Criteria: } x < 0.04\text{)}$$

GSHP_Duty_S2
The duty cycle for Stage 2 of the conditioning unit. It is calculated by dividing the sum of the intervals when the difference in the compressor (HP_CompPow) exceeds a minimum threshold by the number of recording minutes in that day.

GSHP_DC_S1 = CountIF(Range: (HP_CompPow), Criteria: 0.04 < x) / Count(HP_CompPow)

E_GSHP_S2

The daily energy used during stage 2 cooling. It is calculated by summing all the differences in kWh during the intervals when the difference in the compressor (HP_CompPow) exceeds a minimum threshold.

E_GSHP_S2 = SumIf(Range: (HP_CompPow), Criteria: 0.04 < x)

E_Comp

The daily energy used by the compressor. It is calculated by subtracting the daily condenser energy (E_Cond) from the daily GGP energy (E_GPP).

E_Comp = (E_Cond) – (E_GPP)

HWH_Rat_tot

A comparison of the water heater energy calculated by dividing the thermal energy absorbed by the water including noise (Q_HWH_tot) by the burner energy put into the water (Q_HWH_B).

HWH_Rat_tot = (Q_HWH_tot) / (Q_HWH_B)

HWH Rat_Dem

A comparison of the water heater energy calculated by dividing the thermal energy absorbed by the water, including noise, (Q_HWH_dem) by the burner energy put into the water (Q_HWH_B).

HWH_Rat_dem = (Q_HWH_dem) / (Q_HWH_B)

E_AHU_S1

The daily energy usage of the fan unit while the compressor is operating at Stage 1. It is calculated by adding power intervals (HP_AHUPow) while the compressor (Comp On?) is on, but stage 2 (Stage 2 kWh) is 0.

E_AHU_S1 = SumIfs(SumRange: (HP_AHUPow), CriteriaRange1: (Comp On?), Criteria: “=True”, Criteria Range2: (Stage 2 kWh), Criteria: “=0”) - SumIfs(SumRange: (HP_AHUPow).OffsetUpOneRow, CriteriaRange1: (Comp On?), Criteria: “=True”, Criteria Range2: (Stage 2 kWh), Criteria: “=0”)

E_AHU_S2
The daily energy usage of the fan unit while the compressor is operating at stage 2. It is calculated by adding power intervals (HP_AHUPow) while the stage 2 (Stage 2 kWh) is greater than 0.

E_AHU_S2 = SumIfs(SumRange: (HP_AHUPow), CriteriaRange: (Stage 2 kWh), Criteria: “>0”) - SumIfs(SumRange: (HP_AHUPow).OffsetUpOneRow, CriteriaRange: (Stage 2 kWh), Criteria: “>0”)

E_AHU_None
The daily energy usage of the fan unit while the compressor is off. It is calculated by adding power intervals (HP_AHUPow) while the compressor (Comp On?) is off.

E_AHU_S1 = SumIfs(SumRange: (HP_AHUPow), CriteriaRange: (Comp On?), Criteria: “=False) - SumIfs(SumRange: (HP_AHUPow).OffsetUpOneRow, CriteriaRange: (Comp On?), Criteria: “=False”)

Note: For all values, “dem” denotes that the value was calculated without including the effects of very low flow readings in the flow meter (aka noise); “tot” includes these readings.

Project Energy Efficiency

(This section will be completed by WCEC once twelve months of data has been collected and analyzed.)

Findings

Best Practices

If SMUD chooses to support further GeoHeat Pump development, the project team believes that a system can be developed to quickly screen a SMUD customer to determine if they are an appropriate candidate for further evaluation. The project team developed the following check list for SMUD’s use in this screening process.

Checklist of Best Practices in SMUD Service Territory : Initial Site Review

1. Visit the project site to obtain, or review a copy of, a site survey or plan that contains, the following information:

- Plot dimension and orientation (north arrow)

- Easements
- Location of underground utilities
- Location of all above ground structures
- Location of irrigation system pipes and sprinkler heads

2. Determine access for boring equipment (overhead, roadways, etc) and potential to use mats to minimize damage to lawn/garden areas.

3. Review boring and drilling permit requirements by Sacramento County for type of ground heat exchanger proposed at:
   http://www.emd.saccounty.net/envcomp/WP/Wells.html

   Locate existing water wells (if applicable)
   Locate existing septic system (if applicable)
   Locate existing sewer laterals to City street as applicable
   Determine whether or not there is existing soil contamination at the site which may require special instructions by the County for boring.

4. Determine local water quality either by collecting a sample, requiring it of the installing contractor, or by contacting the local water agency. Ensure water that is provided in the closed-loop ground heat exchanger is compliant with the pH and water quality requirements of the GeoHeat Pump manufacturer. Consider using distilled water.

5. Quickly examine neighboring lots to determine if any issues might arise from boring design or installation.

Checklist of Best Practices in SMUD Service Territory: Design

1. Conduct site survey (see above).
2. Calculate building peak heating and cooling loads.
3. Estimate ground heat exchanger size based on local soil thermal properties. The following properties may be assumed for most locations in SMUD Territory.
   - Deep Earth Temperature: 64-67 deg F
   - Conductivity: 0.80-0.87 Btu/hr-ft-deg F**
   - Diffusivity: 0.49-0.58 ft2/day**

**Note: Thermal properties may be better above the Sacramento Valley floor. It is recommended that an experienced driller be consulted to ascertain local boring and drilling conditions (cobble, sand, etc). Installed ground heat exchangers in project locations with high water tables, such as near the American and Sacramento Rivers, may recover more quickly due to ground water movement.

4. Select design temperatures. For SMUD territory it is recommended to use 45 deg F minimum entering water temperature for heating and 90 deg F maximum entering water temperature for cooling. At these design conditions no anti-freeze or auxiliary heat (strip heat) is required.
5. Correct heat pump performance at rated conditions to actual conditions.
6. Select heat pump(s) to meet heating and cooling loads. Ensure equipment is specified for geothermal heat pump applications which are constructed as 'extended-range' water source heat pumps.
7. Arrange heat pump and ground loop circuit(s) to minimize system costs, pump energy, and electrical demand.
8. Iterate optimum ground heat exchanger dimensions, grouting material, spacing, configuration to fit site and to serve building. Compute head loss for 'outdoor' components. It is recommended that thermally enhanced grout be specified with a conductivity k=0.88 Btu/hr-ft-F or better. Ensure driller has capability of pumping grout specified.

Note: During the construction process for residential projects it is recommended that a sample of the grout mixture (by engineer or mechanical contractor), in a clean container, and sent to an appropriate testing laboratory (or grout manufacturer) to verify that grout provided meets specified conductivity. A larger project (e.g., an office building or school) would require 3 random samples at different times during the grouting operation.

9. Layout interior piping to serve heat pump(s) and compute head loss.
10. Select ground loop circulation pump to meet total head loss of ground loop, interior piping and pressure drop through heat pump(s). Determine the system efficiency. If the system cooling EER is less than 12 btu/W-hr or the system heating COP is less than 3.5 W/W, then consider modifying the system design. Best practices is to reduce the pump demand to be less than 8% of the system total demand and air distribution fan demand to be less than 12% of the system total demand.

Also reference **ASHRAE HVAC Applications Handbook Chapter 34**, 12-step process (page 34.13 in 2011 edition)

Remaining Issues

During the course of this project several interesting issues arose. Many were resolved successfully to keep the project on track. However, several issues faced by the project team need to be raised in this report for further action. These issues need to be resolved to ensure future GeoHeat Pump projects can be accomplished more easily and still meet SMUD's, their customers', and Sacramento County/City expectations. These issues are:

1. Drilling/Boring County Permit Clarification

The County of Sacramento claims jurisdiction over the drilling of water wells, including Ground Loop Heat Exchange boreholes. Their adopted regulations are based on a draft set of State of California proposed guidelines discussing Geothermal Heat Exchange Wells. The State guidelines are currently being revised.

This project used a directional boring technology that kept the Ground Loop Heat Exchanger boreholes above 20'. However, the older State guidelines do not specifically address directional boring but address vertical drilling. As discussed above, vertical drilling and directional boring are different technologies that pose different risks to public health and safety.

In the initial conversations between Geonomic Developments and Sacramento County, there was some confusion between the project development team and Sacramento County as to the appropriate set of guidelines and their applicability to vertical drilling versus directional boring. As the project start date approached, the Geonomic Developments team again contacted the County regarding a permit and made the judgment call that a permit was not required since the project kept the field above 20'. The Geonomic Developments team did follow the Bentonite clay sealing/grouting procedure required for all drilling but the County was not available to conduct an onsite inspection during the grouting procedure.

The County later cited Geonomic Developments for failing to follow all the County procedures even though it is still unclear if this project should have needed a permit due to the confusion between the County and State regulations/guidelines on this. This issue is being discussed at the State and County levels for GeoHeat Pumps in general and we expect that a clear set of consistent guidelines will be published soon.

It is very important that any project that SMUD supports fully follow all applicable federal, state, and local permit requirements. It is important that both the appropriate regulations or guidelines be clarified for directional boring projects and the procedure for communicating with the appropriate parties. Future boring contractors need clear guidance in order to ensure they follow them. We recommend a meeting between SMUD representatives and the County on this issue to develop the appropriate guidelines and communication protocols.

2. Desuperheater Water Storage Tank City Permit Clarification

This project team included a test of the cost effectiveness of the Desuperheater option for this project. This option involves the installation of a water storage tank upstream of the homeowner's water heater and plumbing to connect both with the GeoHeat Pump. A stand-alone water storage tank is expensive, but an electric hot water tank can accomplish the same objective for most projects[5]. Its purpose is simply to hold water and keep it warm, not heat it.

The project team chose to use a much less expensive electric water heater with extra external insulation, and not connect the internal electric heating elements to an electricity supply source. This option helped control costs and accomplish the project objectives.

For this project, the GeoHeat Pump equipment (heat pump unit and inside air handler) installation and desuperheater equipment is regulated by the City of Sacramento, not the County. When the Geonomic Developments team approached the City to get a permit for this aspect of the project, the City did not know how to deal with a water storage tank in this type of an installation. The City had a “box to check” for water heaters and for thermal solar water heater storage tanks, but not one for a water storage tank. The City required the project team to electrically connect the water storage tank to a dedicated circuit at the electricity supply panel, adding expense and time to the project.

When the City of Sacramento inspector came to conduct an on-site inspection and sign off on the permit, he commented that while the project complied with the regulations, the regulations appeared to be inappropriate and should not have required the electrical connection.

We recommend that SMUD meet with the City to help them develop a set of guidelines and procedures for addressing Geo Heat Pump Desuperheater insulated water storage tanks, consistent with the City's overall health and safety requirements and other permitting procedures.

3. Thermostat Settings

After the GeoHeat Pump system was installed and started running, the Project team and the homeowners noticed an unusual operating characteristic of the unit. The

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[5] An electric water heater should not be used if the internal pressure might exceed the city water supply pressure.

GeoHeat Pump that was installed is highly energy efficient and includes a two stage compressor. The first stage comes on at a lower energy consumption level. This stage provides approximately 3/4 of the heating or cooling capacity but only uses approximately 1/2 of the energy. When the full capacity of the system is needed, the system activates the second stage. The second stage provides the full rated capacity of heating or cooling, and consumes power at the maximum rated level. The unit is designed to run more often in the first stage since it is more energy efficient than the second stage.

The first stage is activated when the thermostat in the house senses a difference between the ambient temperature and the temperature that the occupants have set as their desired temperature, called the “set point”. For example, if the occupants have selected the heating function and selected 68 degrees for the set point, the thermostat will activate the GeoHeat Pump for heating when the ambient temperature falls below 68 degrees.

The sensitivity of the set point can also be adjusted in the more detailed Technician Settings of the thermostat to determine how far the ambient temperature falls below the set point before the system is activated. For example, in the Technician Settings, the homeowner can select 0.5 degrees or 1.0 degrees as the sensitivity setting, so that the thermostat will not activate the system until the ambient temperature falls to 67.5 degrees or 67.0 degrees, respectively.

The second stage is activated when the ambient temperature deviates even farther from the set point. The amount of deviation from the first stage activation can also be adjusted before the second stage is activated. For example, in the Technician Settings, the homeowner can select 2.0 or 3.0 degrees as the additional temperature differential or stage two offset. In this example, stage two would activate when the ambient temperature falls below 66 degrees (2.0 degrees below the set point).

The documentation prepared by the manufacturer that accompanies the thermostat discusses the first stage operation and how the set point sensitivity can be adjusted in the Technician Settings section. However, the documentation does not address how the second stage deviation can be adjusted. The manufacturer does not provide a description of this in the online documentation either. The project team was able to discover how to adjust the second stage deviation by calling very experienced installers who had dealt with this issue earlier.

The project team also discovered that the manufacturer provided a default setting for the first stage set point and the second stage deviation that were too narrow. Thus, when the system was first installed, the GeoHeat Pump unit started in the first stage and quickly moved to the second stage, even though the first stage would have been able to handle the cooling load given a little more time. This resulted in the system running in its less energy efficient mode more often than required to provide the comfort level the occupants had selected.

Once the project team was able to diagnose and resolve this issue, they adjusted the first stage set point to 1.0 degree and the second stage deviation to 2.0 degrees. After that, the system ran in the most energy efficient mode for a greater percentage of the time, providing the optimum level of energy consumption to maintain the comfort level the occupants liked.

Recommendations

Based on the results of this project, the project team recommends the following:

1. SMUD should further support the development of GeoHeat Pumps in their Service Territory. The next step would be to conduct a Pilot Project limited to 100 customers. SMUD support for this Pilot Project should come with a Customer Incentive, with project implementation oversight by SMUD R&D.

2. SMUD should meet with both the City of Sacramento and the County of Sacramento to review and potentially development clear summaries of the permitting requirements and communication protocols that are easy to understand for contractors in the GeoHeat Pump industry.

3. SMUD should continue monitoring of the current project site. Monitoring analysis should be conducted after a full 12 months has elapsed to examine any longer term issues and all four season issues.

4. Thermostat:

a. SMUD should urge GeoHeat Pump manufacturers to provide better documentation for their thermostats that addresses how to adjust the second stage deviation in the Technician Settings, and

b. SMUD should include in any future GeoHeat Pump Incentive Program an installer guideline that recommends a first stage set point of 1.0 degrees and second stage deviation value of 2.0 degrees.

Attachment 1: Initial Site Assessment

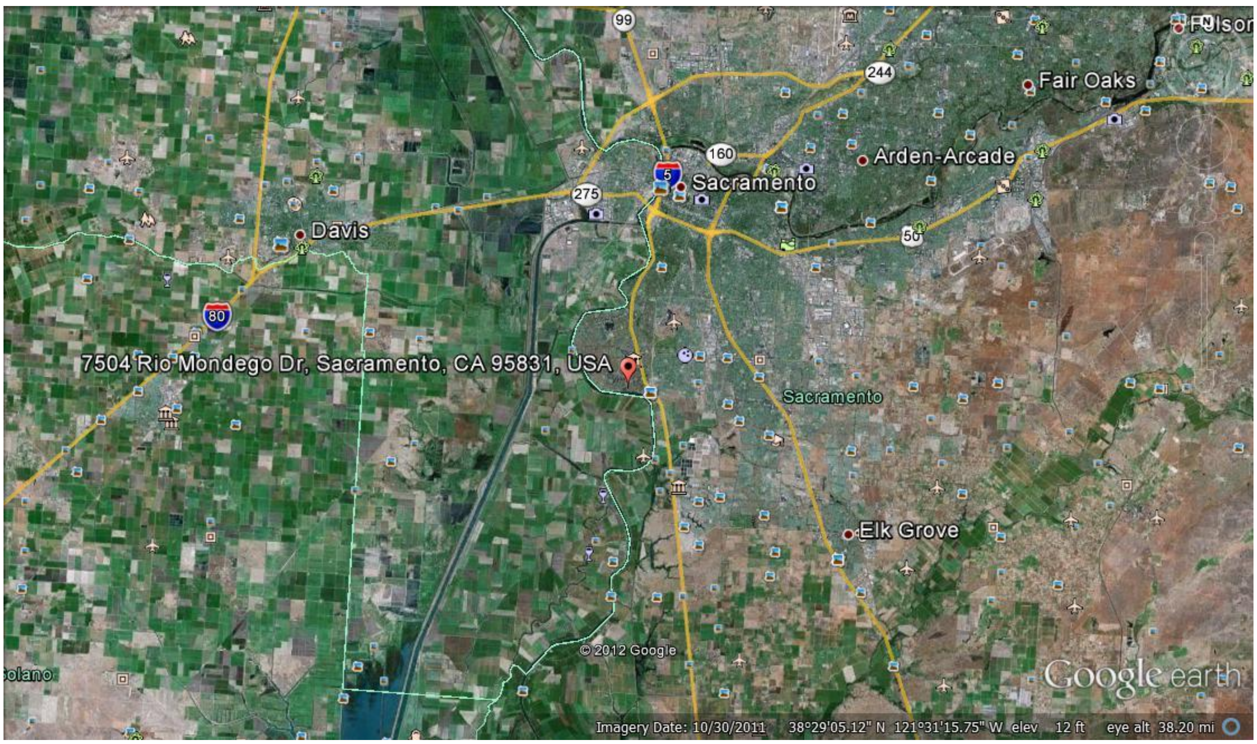
Site Characteristics

Location

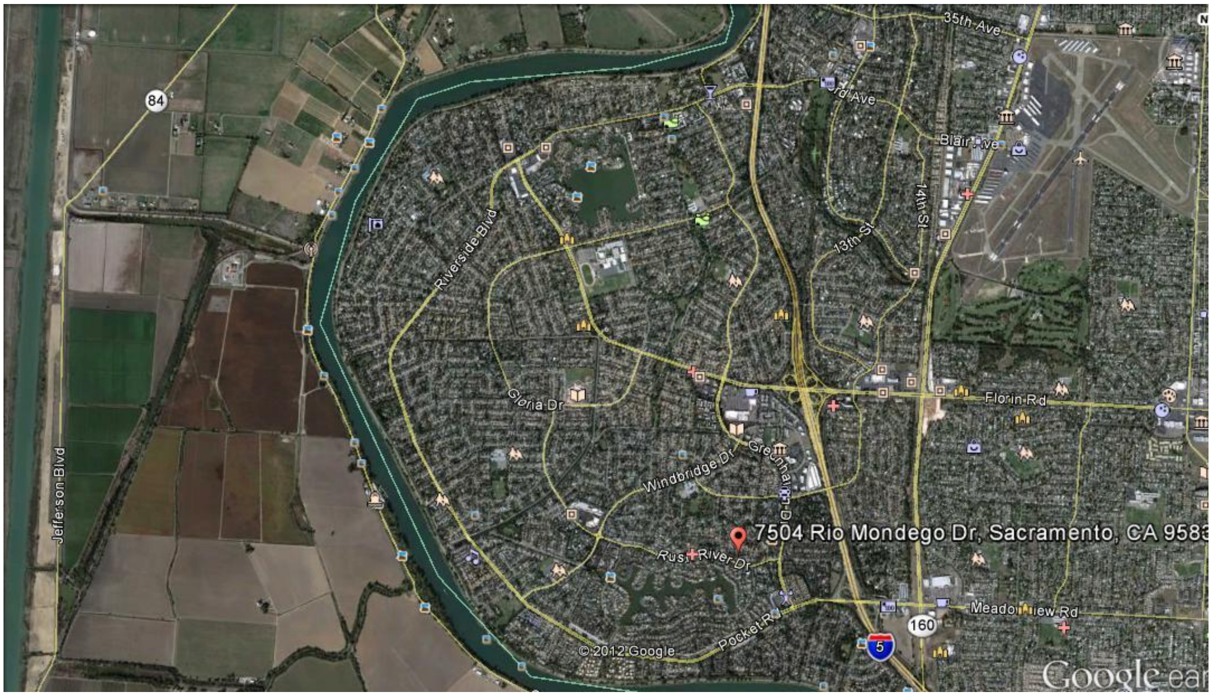
The site for the SMUD GeoHeat Pump Ground Loop Heat Exchange Directional Drilling R&D Project is a single family home in Sacramento. The home is located at 7504 Rio Mondego Drive, Sacramento, CA 95831. The home is located in the "Pocket" area of southwest Sacramento. The home is located a few blocks from the Sacramento River. The home is in the middle of a suburban area of similar homes. The home is currently owned by Steve and Becca Trumbly. They have been very cooperative with the initial investigation phase and are excited about the potential to have their home used for a SMUD demonstration site.

Site Maps

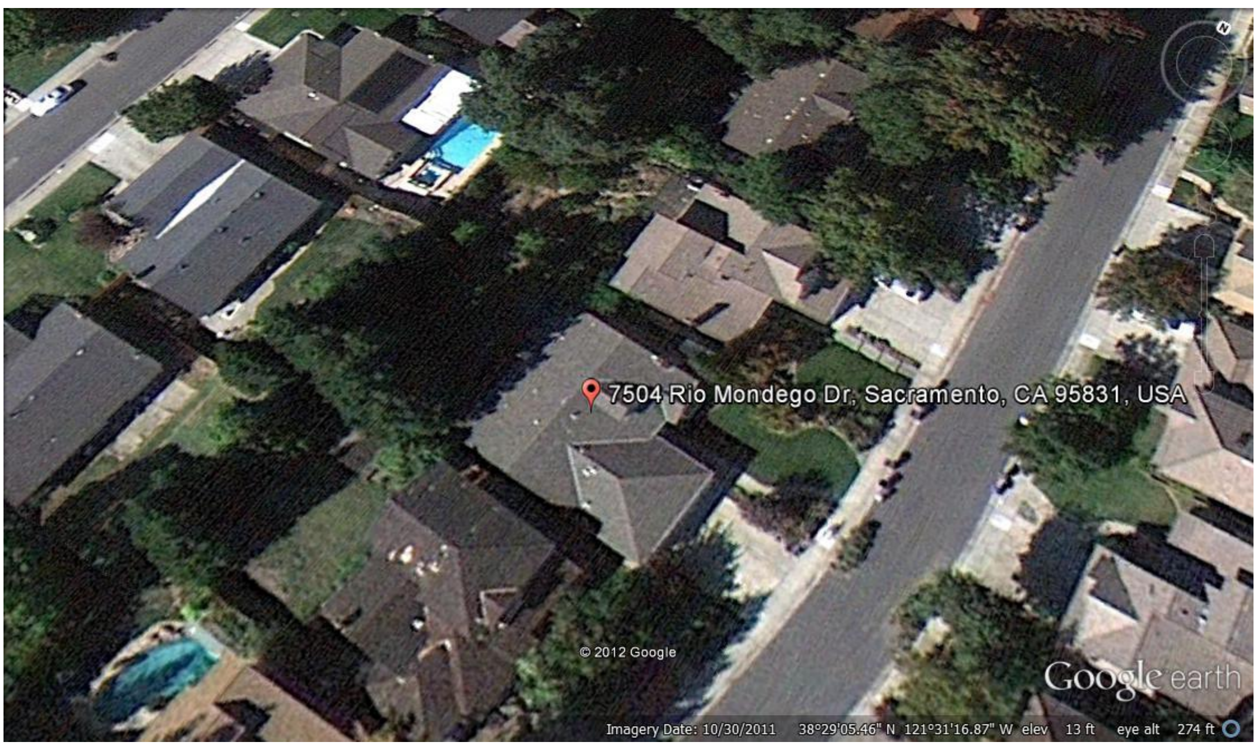
Regional View



Mid View



Neighborhood View



General Home Characteristics

The home is typical of many homes in the Sacramento area. It is a single story, stucco home built on a concrete slab foundation. The home was built about 1988, since the water heater has an installed date stamp for that date, making it about 24 years old. The home has an original ASHP for heating and cooling. The owners use a whole house fan for summer cooling during the nights. The home has an attached 2 car garage in the front. The domestic water heater is natural gas fired and located on a pedestal in the back left corner of the garage. The water heater shows many signs of leaking. The home also has gas service for cooking. The domestic water heater is approximately 19' on a straight line from the interior utility closet.

The owners report that their summer electric bills are approximately $130-140/month, their winter bills are approximately $140/month, and their offseason bills are approximately $90/month. They have a programmable thermostat which they set at 78 degrees in the summer late afternoon/evenings, off at night since they use the whole house fan, 66 degrees in the winter mornings and evenings, and 63 degrees in the winter nights and days. They would like to keep their home at a more comfortable temperature.

HVAC System

The HVAC unit is located in the interior of the home in a small utility closet with the outside unit located adjacent to the home in the back left corner. The utility closet has an opening of 27 ½ ". The heating and cooling is provided by a Trane ASHP. It is an upflow unit with the return air panel at the bottom and the conditioned air ducts going into the attic. The outside unit is a XE900, Model #TWB742A100A1. There is a 50 amp fuse box protecting the outside unit. The inside unit has a 60 amp service panel. The drain line for the inside unit drains directly down through the slap foundation.

Lot Characteristics

The lot is rectangular and approximately 65' wide and 150' deep. It is fenced on 3 sides. There are side yards on both sides, although the left side yard is rarely used and overgrown. The front yard is 2/3 lawn and the rest well kept plantings. The front lawn abuts the sidewalk and is bordered by a concrete walkway from the driveway to the front door. It is approximately 27' from the edge of the front lawn by the front walkway to the interior utility closet.

The backyard is approximately 25' by 25' and is surrounded on 3 sides by plantings. The fourth side abuts a concrete patio.

The right side yard is well used and accessed by a typical fenced garden gate. The gate is 33' wide but one post can be easily removed to create a 48' access lane. The narrowest area of the right side yard is 5’ between the chimney and a portable storage shed.

The left side yard is paved with a 24’ concrete walkway, although it is rarely used. The side yard is 5’ wide. There is a typical garden gate/fence starting most of the way back along the garage. There is a side garage door immediately behind the gate that opens at the back of the garage right before the domestic water heater. It is approximately 55’ from the edge of the front lawn to an area just outside the side garage door in the side yard.

Garage

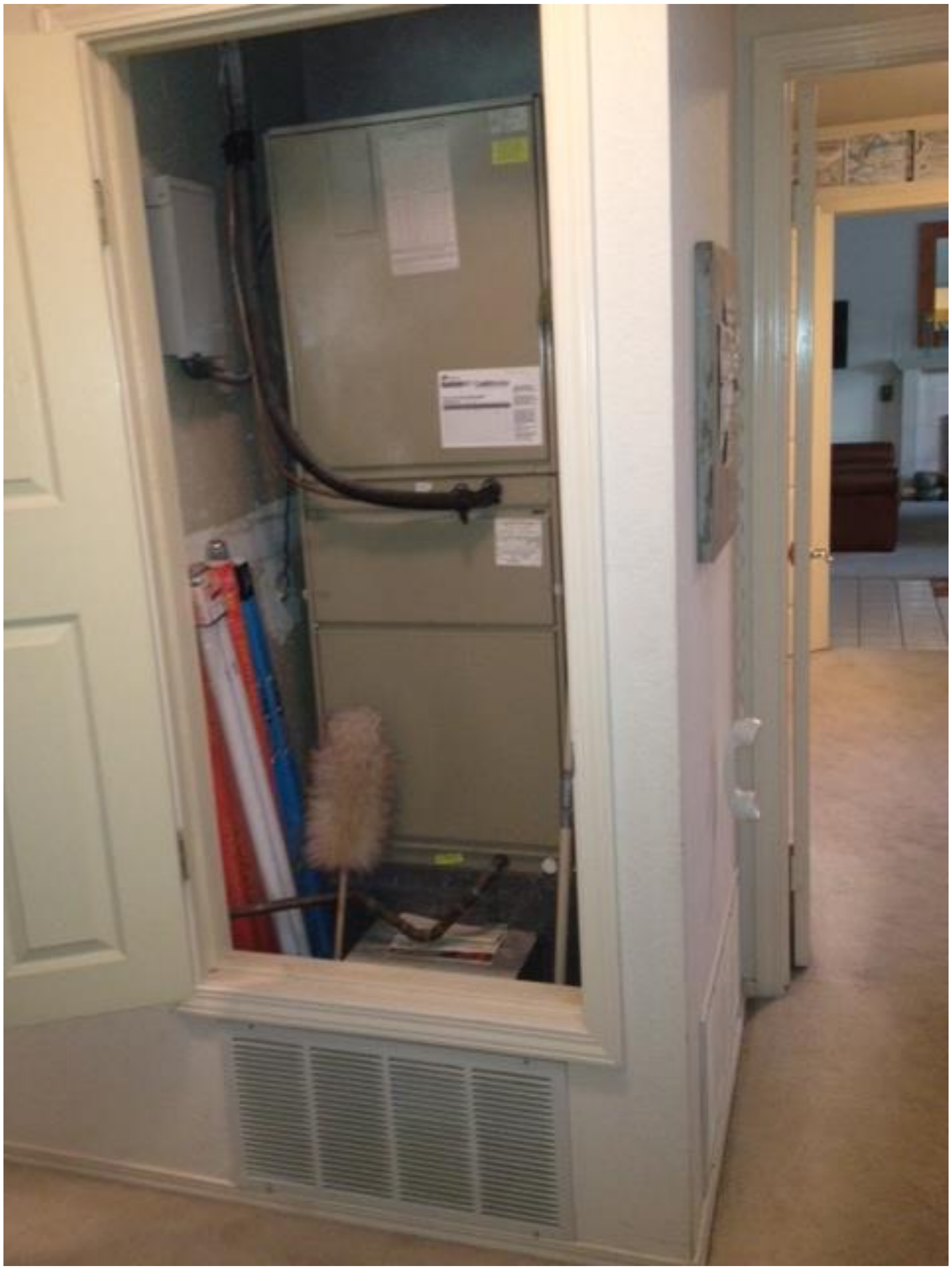
The garage has room for 2 cars, storage shelves along the sides and ample storage at the back. The domestic water heater is located at the back left corner of the garage next to the outside wall and very close to the side garage door. There is room next to the water heater for additional equipment. The back wall of the garage is drywall and extends into the attic area of the home.

Attachement 1

House from street

House from across street before work began

Close up of front door



View of inside HVAC closet

Closeup of HVAC closet

View of front lawn before work began

View of front lawn before work began

Front driveway showing left side yard access

View of left side yard at left front side of garage

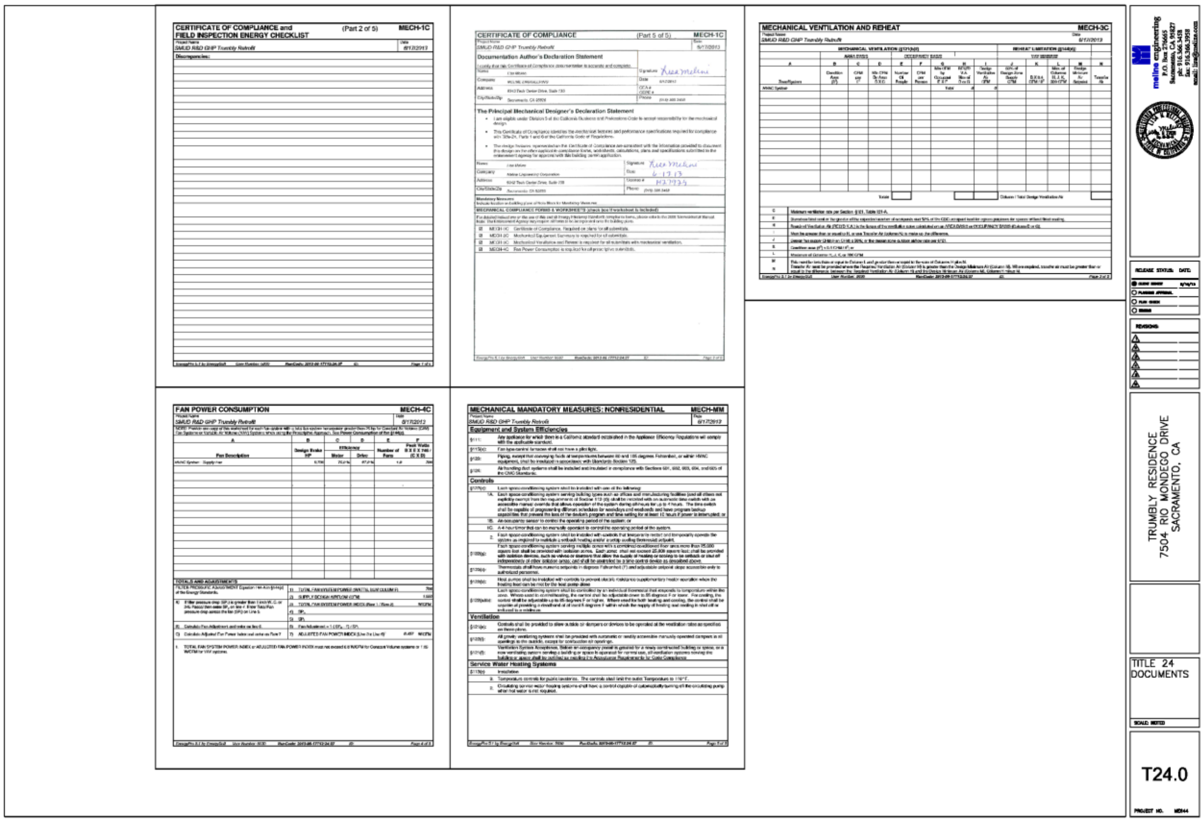
View of left side yard before gate

View of left side yard right behind gate looking at side garage door

View of left side yard, side garage door, and concrete walkway

View of garage inside looking to back left wall; view of water heater and garage door

Attachment 2: Title 24 Energy Calculations



Full Size copy

CERTIFICATE OF COMPLIANCE and FIELD INSPECTION ENERGY CHECKLIST	(Part 2 of 5)	MECH-1C
Project Name *SMUD R&D GHP Trumbly Retrofit*		Date *6/17/2013*
Discrepancies:		
EnergyPro 5.1 by EnergySoft *User Number: 5030* ***RunCode: 2013-06-17T12:24:27*** *ID:*		*Page 1 of 5*

CERTIFICATE OF COMPLIANCE (Part 5 of 5) MECH-1C

Project Name	Date
SMUD R&D GHP Trumbly Retrofit	*6/17/2013*

Documentation Author's Declaration Statement

I certify that this Certificate of Compliance documentation is accurate and complete.

Name	*Lisa Meline*	Signature	Lisa Meline
Company	*MELINE ENGINEERING*	Date	*6/17/2013*
Address	*9343 Tech Center Drive, Suite 135*	CEA # CEPE #	
City/State/Zip	*Sacramento, CA 95826*	Phone	*(916) 366-3458*

The Principal Mechanical Designer's Declaration Statement

- I am eligible under Division 3 of the California Business and Professions Code to accept responsibility for the mechanical design.
- This Certificate of Compliance identifies the mechanical features and performance specifications required for compliance with Title-24, Parts 1 and 6 of the California Code of Regulations.
- The design features represented on this Certificate of Compliance are consistent with the information provided to document this design on the other applicable compliance forms, worksheets, calculations, plans and specifications submitted to the enforcement agency for approval with this building permit application.

Name	*Lisa Meline*	Signature	Lisa Meline
Company	*Meline Engineering Corporation*	Date	6-17-13
Address	*9342 Tech Center Drive, Suite 135*	License #	M27974
City/State/Zip	*Sacramento, CA 95826*	Phone	*(916) 366-3458*

Mandatory Measures
Indicate location on building plans of Note Block for Mandatory Measures________

MECHANICAL COMPLIANCE FORMS & WORKSHEETS (check box if worksheet is included)

For detailed instructions on the use of this and all Energy Efficiency Standards compliance forms, please refer to the 2008 Nonresidential Manual.
Note: The Enforcement Agency may require all forms to be incorporated onto the building plans.

☑	MECH-1C	Certificate of Compliance. Required on plans for all submittals.
☑	MECH-2C	Mechanical Equipment Summary is required for all submittals.
☑	MECH-3C	Mechanical Ventilation and Reheat is required for all submittals with mechanical ventilation.
☑	MECH-4C	Fan Power Consumption is required for all prescriptive submittals.

MECHANICAL VENTILATION AND REHEAT — MECH-3C

Project Name	Date
SMUD R&D GHP Trumbly Retrofit	*6/17/2013*

MECHANICAL VENTILATION (§121(b)2)									REHEAT LIMITATION (§144(d))				
	AREA BASIS			OCCUPANCY BASIS					VAV MINIMUM				
A	B	C	D	E	F	G	H	I	J	K	L	M	N
Zone/System	Condition Area (ft^2)	CFM per ft^2	Min CFM By Area B X C	Number Of People	CFM per Person	Min CFM by Occupant E X F	REQ'D V.A. Max of D or G	Design Ventilation Air CFM	50% of Design Zone Supply CFM	B X 0.4 CFM / ft^2	Max. of Columns H, J, K, 300 CFM	Design Minimum Air Setpoint	Transfer Air
HVAC System						*Total*	*0*	*0*					
			Totals						Column I Total Design Ventilation Air				

C	Minimum ventilation rate per Section §121, Table 121-A.
E	Based on fixed seat or the greater of the expected number of occupants and 50% of the CBC occupant load for egress purposes for spaces without fixed seating.
H	Required Ventilation Air (REQ'D V.A.) is the larger of the ventilation rates calculated on an AREA BASIS or OCCUPANCY BASIS (Column D or G).
I	Must be greater than or equal to H, or use Transfer Air (column N) to make up the difference.
J	Design fan supply CFM (Fan CFM) x 50%; or the design zone outdoor airflow rate per §121.
K	Condition area (ft^2) x 0.4 CFM / ft^2; or
L	Maximum of Columns H, J, K, or 300 CFM
M	This must be less than or equal to Column L and greater than or equal to the sum of Columns H plus N.
N	Transfer Air must be provided where the Required Ventilation Air (Column H) is greater than the Design Minimum Air (Column M). Where required, transfer air must be greater than or equal to the difference between the Required Ventilation Air (Column H) and the Design Minimum Air (Column M), Column H minus M.

FAN POWER CONSUMPTION — MECH-4C

Project Name	Date
SMUD R&D GHP Trumbly Retrofit	*6/17/2013*

NOTE: Provide one copy of this worksheet for each fan system with a total fan system horsepower greater than 25 hp for Constant Air Volume (CAV) Fan Systems or Variable Air Volume (VAV) Systems when using the Prescriptive Approach. See **Power Consumption of fan §144(c)**.

A	B	C	D	E	F
		Efficiency			
Fan Description	Design Brake HP	Motor	Drive	Number of Fans	Peak Watts B X E X 746 / (C X D)
HVAC System - Supply Fan	*0.700*	*76.0 %*	*97.0 %*	*1.0*	*708*

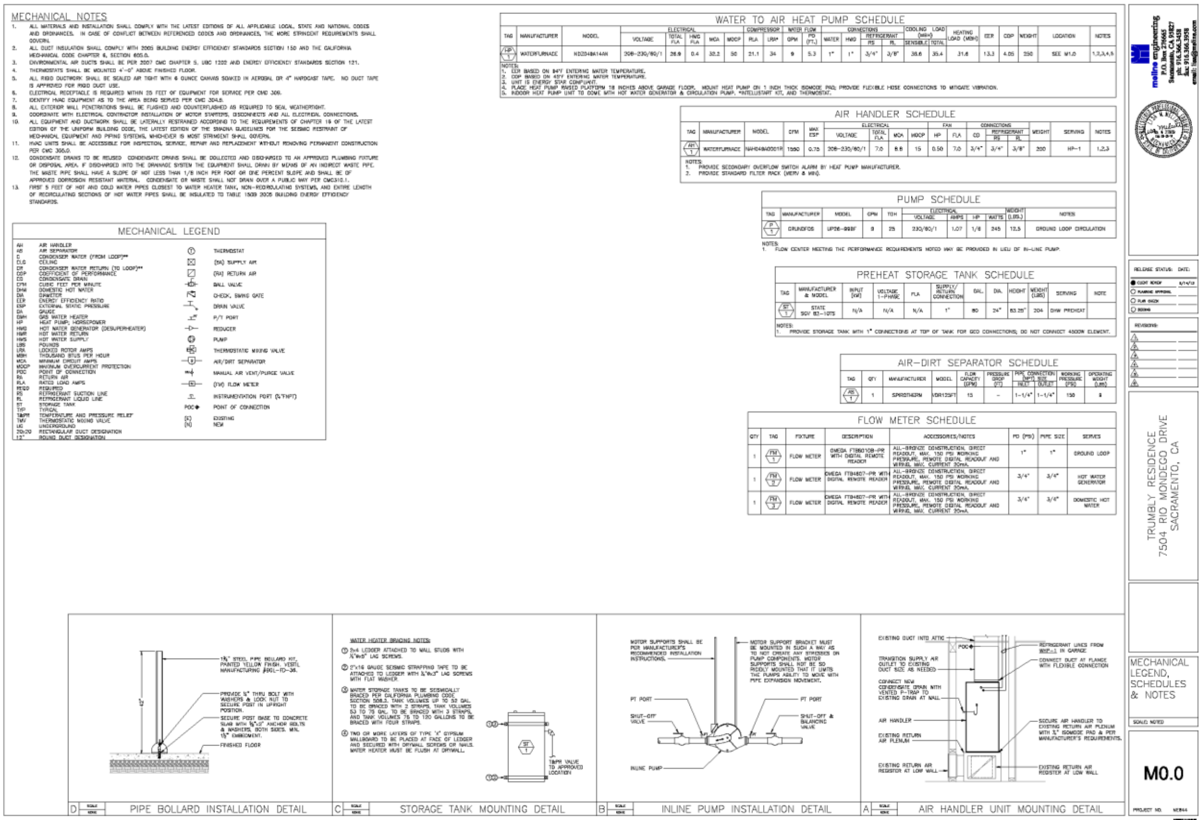
TOTALS AND ADJUSTMENTS

FILTER PRESSURE ADJUSTMENT Equation 144-A in §144(c) of the Energy Standards.	1) TOTAL FAN SYSTEM POWER (WATTS, SUM COLUM F)	*708*
	2) SUPPLY DESIGN AIRFLOW (CFM)	*1,550*
A) If filter pressure drop (SP_a) is greater than 1 inch W. C. or 245 Pascal then enter SP_a on line 4. Enter Total Fan pressure drop across the fan (SP_f) on Line 5.	3) TOTAL FAN SYSTEM POWER INDEX (Row 1 / Row 2)	W/CFM
	4) SP_a	
	5) SP_f	
B) Calculate Fan Adjustment and enter on line 6.	6) Fan Adjustment = 1-(SP_a – 1) / SP_f	
C) Calculate Adjusted Fan Power Index and enter on Row 7	7) ADJUSTED FAN POWER INDEX (Line 3 x Line 6)[1]	*0.457* W/CFM

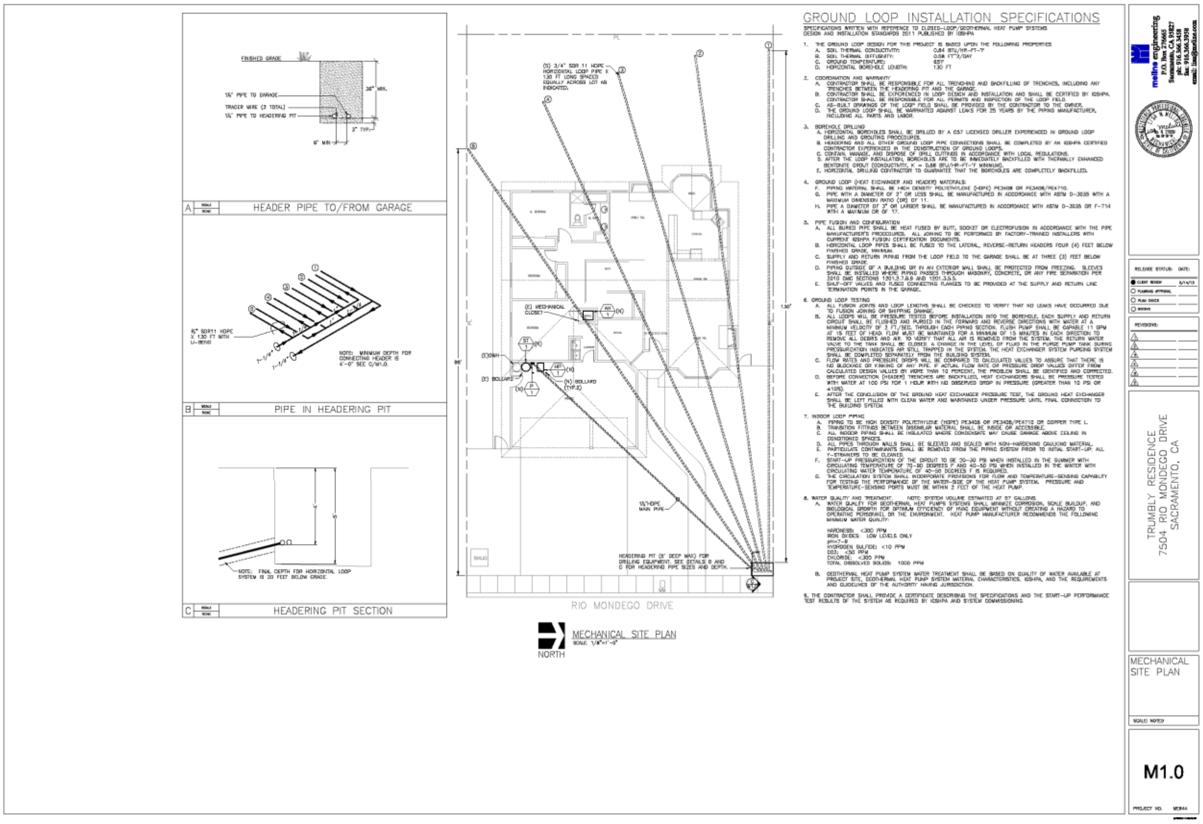
1. TOTAL FAN SYSTEM POWER INDEX or ADJUSTED FAN POWER INDEX must not exceed 0.8 W/CFM for Constant Volume systems or 1.25 W/CFM for VAV systems.

Attachment 3: Mechanical Drawings and Details

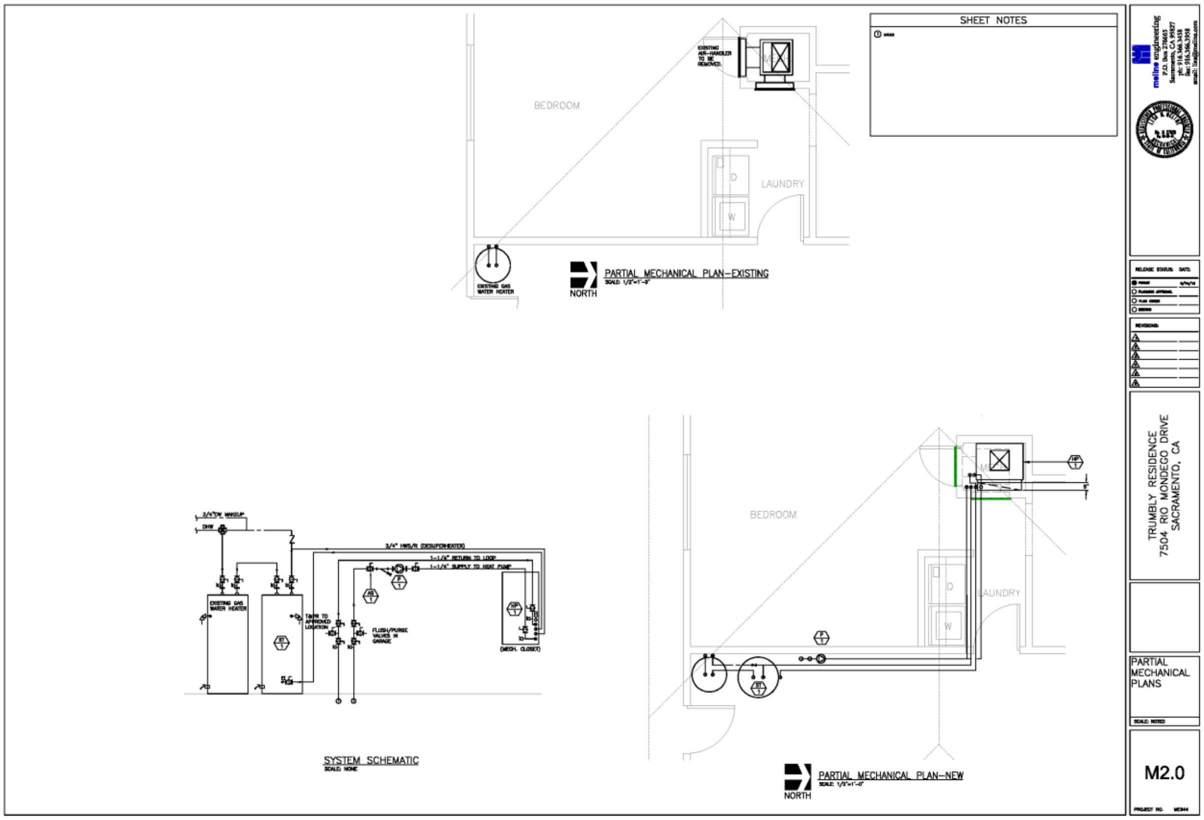
Mechanical Detail M0.0



Mechanical Detail Site Plan M1.0



Mechanical Detail Garage/Utility Room Heat Pump Connection M2.0



Attachment 4: Estimated Energy Use Calculations

Meline Engineering Energy Data Analysis Notes

Once the energy data had been collected for several weeks, Meline Engineering examined the actual performance of the GeoHeat Pump system. The calculation notes below are Meline Engineering's initial data analysis that supports the findings in this report.

Equipment Performance Specifications and Calculations

ENVISION SERIES INDOOR SPLIT SPECIFICATION CATALOG

Performance Summary
ARI/ISO/ASHRAE/ANSI 13256-1
Performance Ratings

ARI/ASHRAE/ISO 13256-1
English (IP) Units

Model	Capacity Modulation	Flow Rate		Water Loop Heat Pump				Ground Water Heat Pump				Ground Loop Heat Pump			
				Cooling Brine EWT 86°F		Heating Brine EWT 68°F		Cooling EWT 59°F		Heating EWT 50°F		Cooling Brine Full Load 77°F Part Load 68°F		Heating Brine Full Load 32°F Part Load 41°F	
		gpm	cfm	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP
026	Full	8	900	25,000	14.6	30,500	5.1	27,800	21.8	25,000	4.6	26,200	17.0	19,500	3.9
	Part	7	700	18,500	16.6	22,000	5.6	21,300	28.4	17,700	4.8	21,000	24.5	16,200	4.4
038	Full	9	1200	34,000	14.6	40,100	5.0	34,300	20.4	33,100	4.5	35,000	17.1	25,700	3.8
	Part	8	800	25,000	16.6	30,000	5.3	25,200	27.0	24,400	4.4	27,000	25.3	22,100	4.2
049	Full	12	1500	45,900	14.0	56,800	4.7	50,500	20.2	46,700	4.4	47,700	16.1	37,000	3.8
	Part	11	1300	35,000	16.2	43,000	5.5	37,300	25.8	33,000	4.7	38,000	22.9	30,500	4.3
064	Full	16	1800	56,300	14.7	67,100	4.6	63,800	19.2	55,800	4.3	59,100	15.5	43,200	3.6
	Part	14	1500	42,900	15.7	49,500	5.1	50,000	24.9	41,000	4.3	47,900	22.2	36,800	3.9
072	Full	18	1800	60,400	13.3	80,600	4.6	67,900	17.8	63,100	3.9	62,700	15.0	50,300	3.4
	Part	16	1600	49,700	14.6	60,200	4.8	57,200	22.8	48,400	4.0	53,800	20.0	42,800	3.8
022	Single	8	800	19,700	16.3	23,500	5.3	23,300	27.9	18,900	4.5	21,800	19.5	14,000	3.7
030	Single	8	1000	25,800	17.3	32,000	5.5	28,500	24.9	25,300	4.9	26,800	19.8	19,700	4.0
036	Single	9	1200	31,400	17.6	37,600	5.5	33,900	27.0	30,000	4.7	31,900	19.8	24,000	4.0
042	Single	10	1400	39,000	17.3	41,400	5.3	42,900	25.3	33,000	4.5	39,900	19.9	25,300	3.7
048	Single	12	1500	44,200	15.5	55,400	5.2	48,900	23.8	45,100	4.5	46,200	18.1	35,300	3.8
060	Single	15	1800	54,600	14.4	66,300	4.6	62,300	21.1	52,900	4.1	57,000	17.0	44,500	3.6
070	Single	18	1800	60,200	13.2	76,000	4.0	68,500	19.2	63,000	3.7	63,200	15.1	50,800	3.3

Notes: Cooling capacities based upon 80.6°F DB, 66.2°F WB entering air temperature.
Heating capacities based upon 68°F DB, 59°F WB entering air temperature.
All ratings based upon operation at the lower voltage or dual voltage rated models.
Refer to the air handler compatability table for matching air handler.

7/21/08

ARI PERFORMANCE CERTIFIED www.aridirectory.org

Calculations:

$$\text{Fan energy} = \frac{(\text{cfm} \times 0.472)(\text{esp} \times 249)}{300} = W_f$$

Pump energy = 245W = W_f

(1) for AHRI performance ratings above, the fan e.s.p is 0" and pump energy is include

(2) for Design performance ratings (next sheet), the fan e.s.p is 0.20" and no pump energy is included.

NDZ049 High Speed

1550 CFM Rated Airflow

EWT °F	Flow gpm	WPD		HEATING - EAT 70°F							COOLING - EAT 80/67 °F							
		PSI	FT	Airflow cfm	HC kBtuh	Power kW	HE kBtuh	LAT °F	COP	HWC kBtuh	Airflow cfm	TC kBtuh	SC kBtuh	S/T Ratio	Power kW	HR kBtuh	EER	HWC kBtuh
20	6.0	1.3	3.0	Operation not recommended							Operation not recommended							
	9.0	2.5	5.7															
	12.0	4.0	9.2	1350	30.7	2.74	21.3	91.0	3.28	5.2								
				1550	31.7	2.82	22.1	88.9	3.29	4.7								
30	6.0	1.2	2.9	Operation not recommended							Operation not recommended							
	9.0	2.4	5.5	1350	35.0	2.87	25.2	94.0	3.58	5.5	1350	46.3	28.5	0.62	1.90	52.8	24.4	-
				1550	36.1	2.96	26.0	91.5	3.57	5.1	1550	49.1	31.8	0.65	2.02	56.0	24.3	-
	12.0	3.9	8.9	1350	35.5	2.90	25.6	94.4	3.60	5.7	1350	46.8	28.5	0.61	1.81	53.0	25.9	-
				1550	36.7	2.99	26.5	91.9	3.60	5.2	1550	49.5	31.7	0.64	1.93	56.1	25.7	-
40	6.0	1.2	2.8	Operation not recommended							Operation not recommended							
	9.0	2.3	5.3	1350	39.9	3.00	29.7	97.4	3.90	6.1	1350	48.0	30.2	0.63	2.10	55.2	22.9	-
				1550	41.1	3.06	30.6	94.5	3.93	5.6	1550	50.8	33.6	0.66	2.22	58.4	22.9	-
	12.0	3.7	8.7	1350	40.6	3.03	30.3	97.9	3.93	6.3	1350	48.6	30.2	0.62	2.01	55.4	24.2	-
				1550	42.0	3.09	31.4	95.1	3.97	5.7	1550	51.2	33.6	0.66	2.13	58.5	24.1	-
50	6.0	1.2	2.7	1350	42.7	3.10	32.1	99.3	4.03	6.6	1350	48.6	31.0	0.64	2.50	57.2	19.4	2.9
				1550	44.1	3.14	33.3	96.3	4.11	6.1	1550	51.2	34.4	0.67	2.64	60.2	19.4	3.1
	9.0	2.2	5.2	1350	44.4	3.16	33.6	100.4	4.11	6.8	1350	49.2	31.4	0.64	2.35	57.2	21.0	2.7
				1550	45.6	3.21	34.7	97.3	4.17	6.2	1550	51.8	34.9	0.67	2.46	60.2	21.0	2.9
	12.0	3.6	8.4	1350	45.2	3.20	34.3	101.0	4.15	7.0	1350	49.7	31.5	0.63	2.26	57.4	22.0	2.5
				1550	46.7	3.24	35.7	97.9	4.23	6.4	1550	52.3	35.0	0.67	2.37	60.4	22.0	2.8
60	6.0	1.1	2.6	1350	46.6	3.23	35.6	102.0	4.23	7.4	1350	48.1	31.3	0.65	2.66	57.1	18.1	3.6
				1550	48.1	3.24	37.0	98.7	4.34	6.8	1550	50.4	34.7	0.69	2.78	59.9	18.2	3.8
	9.0	2.2	5.0	1350	48.7	3.31	37.4	103.4	4.31	7.6	1350	48.9	31.7	0.65	2.51	57.4	19.5	3.3
				1550	50.2	3.33	38.8	100.0	4.42	7.0	1550	51.2	35.2	0.69	2.62	60.2	19.6	3.6
	12.0	3.5	8.1	1350	49.8	3.35	38.4	104.2	4.36	7.8	1350	49.4	31.8	0.65	2.43	57.7	20.3	3.1
				1550	51.4	3.36	40.0	100.7	4.49	7.2	1550	51.8	35.4	0.68	2.54	60.4	20.4	3.4
70	6.0	1.1	2.5	1350	50.4	3.34	39.0	104.6	4.42	8.3	1350	47.8	31.9	0.67	2.91	57.7	16.4	4.5
				1550	52.0	3.33	40.6	101.1	4.57	7.7	1550	49.9	35.4	0.71	3.01	60.2	16.6	4.7
	9.0	2.1	4.9	1350	52.9	3.44	41.2	106.3	4.50	8.6	1350	48.8	32.3	0.66	2.77	58.3	17.7	4.2
				1550	54.6	3.43	42.8	102.6	4.66	7.9	1550	51.0	35.8	0.70	2.87	60.8	17.8	4.5
	12.0	3.4	7.9	1350	54.3	3.49	42.4	107.2	4.56	8.8	1350	49.3	32.5	0.66	2.69	58.5	18.3	3.9
				1550	56.0	3.47	44.2	103.5	4.73	8.1	1550	51.6	36.1	0.70	2.79	61.1	18.5	4.3
80	6.0	1.1	2.5	1350	53.5	3.52	41.5	106.7	4.45	9.3	1350	45.8	31.2	0.68	3.15	56.5	14.5	5.6
				1550	55.2	3.48	43.4	103.0	4.65	8.6	1550	47.7	34.6	0.73	3.24	58.7	14.7	6.0
	9.0	2.0	4.7	1350	56.5	3.65	44.0	108.7	4.54	9.6	1350	47.0	31.5	0.67	3.03	57.3	15.5	5.3
				1550	58.3	3.60	46.0	104.8	4.74	8.9	1550	48.9	34.9	0.71	3.11	59.5	15.7	5.7
	12.0	3.3	7.6	1350	58.1	3.69	45.5	109.8	4.62	9.9	1350	47.5	31.8	0.67	2.96	57.6	16.0	4.9
				1550	60.0	3.64	47.6	105.8	4.83	9.2	1550	49.4	35.3	0.71	3.04	59.8	16.2	5.4
90	6.0	1.0	2.4	1350	56.5	3.68	43.9	108.7	4.49	10.5	1350	43.0	29.9	0.70	3.38	54.6	12.7	7.1
				1550	58.4	3.61	46.1	104.9	4.74	9.7	1550	44.6	33.2	0.74	3.46	56.4	12.9	7.5
	9.0	2.0	4.5	1350	59.9	3.84	46.8	111.1	4.58	10.8	1350	44.3	30.2	0.68	3.29	55.5	13.5	6.6
				1550	61.9	3.76	49.1	107.0	4.83	10.0	1550	46.0	33.5	0.73	3.35	57.4	13.7	7.2
	12.0	3.2	7.3	1350	61.8	3.87	48.6	112.4	4.67	11.2	1350	44.8	30.5	0.68	3.22	55.8	13.9	6.1
				1550	63.9	3.80	50.9	108.2	4.92	10.3	1550	46.4	33.9	0.73	3.29	57.6	14.1	6.8
100	6.0	1.0	2.3	Operation not recommended							Operation not recommended							
	9.0	1.9	4.4								1350	42.3	29.6	0.70	3.65	54.8	11.6	8.2
											1550	43.7	32.7	0.75	3.70	56.3	11.8	8.9
	12.0	3.1	7.1								1350	42.8	29.9	0.70	3.59	55.0	11.9	7.6
											1550	44.1	33.2	0.75	3.64	56.5	12.1	8.5
110	6.0	1.0	2.2								Operation not recommended							
	9.0	1.8	4.2								1350	38.2	27.6	0.72	3.97	51.8	9.6	10.0
											1550	39.3	30.5	0.78	4.00	52.9	9.8	10.9
	12.0	2.9	6.8								1350	38.6	28.0	0.72	3.92	52.0	9.9	9.3
											1550	39.7	31.0	0.78	3.95	53.2	10.0	10.4
120	6.0	0.9	2.1								Operation not recommended							
	9.0	1.7	4.0								1350	35.5	26.4	0.74	4.42	50.6	8.0	12.1
											1550	36.3	29.2	0.80	4.42	51.4	8.2	13.2
	12.0	2.8	6.5								1350	35.8	26.9	0.75	4.37	50.8	8.2	11.3
											1550	36.6	29.7	0.81	4.37	51.6	8.4	12.5

Contractor: ______________________ P.O.: ______________

Engineer: ____

Project Name: ________________ Unit Tag: ______________

ENVISION AIR HANDLER
2-5 Tons

WaterFurnace. Smarter from the Ground Up™

Pressure Drop

Water Pressure Drop - Hydronic Coil

Flow gpm	Pressure Drop (PSI)						
	40°F	50°F	60°F	100°F	110°F	120°F	130°F
3.0	0.5	0.5	0.5	0.4	0.4	0.4	0.4
4.5	0.9	0.9	0.9	0.8	0.8	0.8	0.8
6.0	1.4	1.4	1.4	1.2	1.2	1.2	1.2
9.0	2.8	2.6	2.5	2.4	2.4	2.4	2.3
12.0	4.6	4.4	4.2	4.0	4.0	4.0	3.9
15.0	7.0	6.8	6.6	6.0	6.0	5.9	5.8

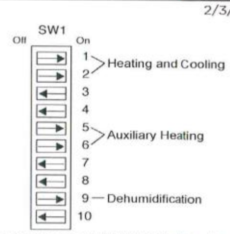
Blower Performance

Blower Performance Variable Speed ECM

Model	Max ESP (wg)	Blower Motor (hp)	HP CFM Setting		Normal Mode Htg & Clg			Dehumidification Mode Clg				Aux CFM Setting		Aux Emerg Mode
			S1	S2	Stg 2	Stg 1	Blower	S9	Stg 2	Stg 1	Blower	S5	S6	
022	0.50	1/2	On	On	900	700	450	Off	775	600	450	On	On	1000
	0.50	1/2	**Off**	**On**	**800**	**625**	**400**	Off	680	530	400	**Off**	**On**	**800**
	0.50	1/2	On	Off	700	540	375	Off	600	450	375	On	Off	775
	0.50	1/2	Off	Off	640	480	350					Off	Off	740
026	0.50	1/2	On	On	1050	800	525	Off	850	700	525	On	On	1150
	0.50	1/2	**Off**	**On**	**925**	**725**	**475**	Off	760	620	475	**Off**	**On**	**950**
	0.50	1/2	On	Off	800	625	425	Off	670	540	425	On	Off	925
	0.50	1/2	Off	Off	740	575	400					Off	Off	825
030	0.50	1/2	On	On	1150	950	600	Off	975	775	600	On	On	1250
	0.50	1/2	**Off**	**On**	**980**	**780**	**500**	Off	825	640	500	**Off**	**On**	**1000**
	0.50	1/2	On	Off	900	700	440	Off	750	580	440	On	Off	975
	0.50	1/2	Off	Off	800	630	425					Off	Off	900
036	0.50	1/2	On	On	1300	1025	760	Off	1105	871	760	On	On	1300
	0.50	1/2	**Off**	**On**	**1225**	**950**	**685**	Off	1041	808	685	**Off**	**On**	**1250**
	0.50	1/2	On	Off	1150	850	620	Off	940	690	620	On	Off	1225
	0.50	1/2	Off	Off	1075	800	550					Off	Off	1200
042	0.75	1	On	On	1500	1100	750	Off	1250	900	750	On	On	1550
	0.75	1	**Off**	**On**	**1425**	**1010**	**650**	Off	1180	840	650	**Off**	**On**	**1450**
	0.75	1	On	Off	1300	975	635	Off	1080	800	635	On	Off	1400
	0.75	1	Off	Off	1150	850	625					Off	Off	1275
048	0.75	1	On	On	1700	1300	975	Off	1400	1080	975	On	On	1700
	0.75	1	**Off**	**On**	**1625**	**1240**	**875**	Off	1350	1025	875	**Off**	**On**	**1550**
	0.75	1	On	Off	1450	1100	750	Off	1200	900	750	On	Off	1525
	0.75	1	Off	Off	1300	1000	675					Off	Off	1400
060	0.75	1	On	On	1850	1750	1175	Off	1540	1450	1175	On	On	1850
	0.75	1	**Off**	**On**	**1760**	**1625**	**1050**	Off	1460	1350	1050	**Off**	**On**	**1760**
	0.75	1	On	Off	1720	1575	1015	Off	1425	1300	1015	On	Off	1725
	0.75	1	Off	Off	1680	1525	975		1428			Off	Off	1700

Factory CFM settings are in boldface
CFM is controlled within 5% up to maximum ESP
Maximum ESP includes allowance for wet coil and standard filter
DIP switch 9 must be 'OFF' to select dehumidification mode

2/3/10



Calculations

9.24.13 updated 1/2

Design Conditions for Sacramento, CA

Summer: 100°db/71°F wb
Winter: 30°F

Building Loads

Sensible Cooling: 35,400 Btu/hr
Latent cooling: 1,100 "
Total: 36,500 Btu/hr

Heating: 31,600 Btu/hr

AHRI Data[1] for Water Furnace NDZ049

	Cooling	EER	Temp
Full Load	47,700	16.1	77°F
Part Load	38,000	22.9	68°F

	Heating	COP	Temp
Full Load	37,000	3.8	32°F
Part Load	30,500	4.3	41°F

(1) Based on 80/66 EAT (summer)
68/59 EAT (winter)

Ground Heat Exchanger Design Temps

45° EWT min for winter

94° EWT max for summer (2)

(2) this design temperature is higher than what is usually specified for the Sacramento Area (90°F). Due to space limitations of the lot and the knowledge that ground water is at approximately 15 feet down in this location, it was assumed that the ground loop would recover quickly due to this ground water movement. Estimated deep earth temperature for this location is 65°F.

Heat Pump Correction Factors for AHRI Performance Rating Standards (77°F)

$$W_f = \frac{(1500 \times 0.472)[(0.75) \times 249]}{300} = 441\ W_f$$

TOPS.

2/3

Run comparison of efficiencies for high speed only @ design conditions:

Cooling (9 gpm, 1550 cfm)

EWT	TC/SC	EER	KW	
90	46/33.5	13.70	3.35	
94	45.1/33.2	12.94	3.49	← @ Design temp
100	43.7/32.7	11.80	3.70	

Heating (9 gpm, 1550 cfm)

EWT	HC	COP	KW
40°F	41.1	3.93	3.06
45°F	43.3	4.05	3.13
50°F	45.6	4.17	3.21

Cooling @ AHRI Performance Standards

$$\frac{47{,}700 \text{ Btu/hr}}{16.1 \text{ EER}} = 2.94 \text{ KW for HP @ } 77°F$$

$$\text{Corrected Capacity @ } 77°F = 47{,}700 - 441(W_f)(3.412) = 46{,}195 \text{ Btu/hr TC}$$

$$\text{Corrected EER} = \frac{46{,}195 \text{ Btu/hr}}{(2960 W_{HP} + 441 W_{fan})} = \underline{\underline{13.58}}$$

Cooling @ Peak Conditions of 94°EWT

First, correct for Fan Energy. Note that this manufacturer assumes a 0.20" e.s.p

$$W_f = \frac{1550 \times 0.472}{300}\left[(0.75-0.20) \times 249\right] = \underline{\underline{334 W_f}}$$

TOPS 35502

3/2

Corrected Capacity = $45,100 - 334 W_f (3.412)$
$= 43,960$ Btu/hr TC

Corrected EER = $\dfrac{43,960 \text{ Btu/hr}}{[3490 W_{HP} + 334 W_f + 245 W_p^{(3)}]} = \underline{10.8}$

$3490 W_{HP} + 334 W_f + 245 W_p = 4069$ W

(3) W_p given by manufacturer

Heating @ AHRI Performance Standards

$\dfrac{37,000 \text{ Btu/hr}}{3.8 \text{ COP}} = 9736/3.912 = 2854 W_{HP}$ for 32°F

Corrected capacity = $37,000 + 441 W_f (3.912)$
$= 38,505$ Btu/hr

Corrected COP = $\dfrac{38,505 \text{ Btu/hr}/3.412}{[2854 W_{HP} + 441 W_f]} = \underline{3.42}$

Note: Full-load AHRI Standard Temp = 32°F. Our Design Condition is 45°F.

Corrected capacity = $43,300 + 334 W_f (3.412)$
$= 44,439$ Btu/hr

Corrected COP = $\dfrac{44,439 \text{ Btu/hr}/3.912}{[3130 W_{HP} + 334 W_f + 245 W_p]}$
$= \underline{3.51}$

This analysis is to show how the AHRI performance standards vary from actual operating conditions. Note that there still need to be adjustments to these factors for

- cfm (1500 v 1550)
- Air Temp (80.6/60 v. 75/62)
- Pump gpm (12 gpm v 9 gpm)

TOPS. 35502

Reference Calculations

Heating Calculations:	Cooling Calculations:
$LWT = EWT - \frac{HE}{GPM \times 500}$	$LWT = EWT + \frac{HR}{GPM \times 500}$
$LAT = EAT + \frac{HC}{CFM \times 1.08}$	$LAT (DB) = EAT (DB) - \frac{SC}{CFM \times 1.08}$
	$LC = TC - SC$
$TH = HC + HW$	$S/T = \frac{SC}{TC}$

Operating Limits

	Cooling		Heating	
	(°F)	(°C)	(°F)	(°C)
Air Limits				
Min. Ambient Air	45	7.2	45	7.2
Rated Ambient Air	80	26.7	70	21.1
Max. Ambient Air	100	37.8	85	29.4
Min. Entering Air	50	10.0	40	4.4
Rated Entering Air db/wb	80.6/66.2	27/19	68	20.0
Max. Entering Air db/wb	110/83	43/28.3	80	26.7
Water Limits				
Min. Entering Water	30	-1.1	20	-6.7
Normal Entering Water	50-110	10-43.3	30-70	-1.1
Max. Entering Water	120	48.9	90	32.2

NOTE:
Minimum/maximum limits are only for start-up conditions, and are meant for bringing the space up to occupancy temperature. Units are not designed to operate at the minimum/maximum conditions on a regular basis. The operating limits are dependant upon three primary factors:

1) water temperature,
2) return air temperature, and
3) ambient temperature.

When any of the factors are at the minimum or maximum levels, the other two factors must be at the normal level for proper and reliable unit operation.

Legends and Notes

ABBREVIATIONS AND DEFINITIONS:

CFM = airflow, cubic feet/minute
EWT = entering water temperature, Fahrenheit
GPM = water flow in gallons/minute
WPD = water pressure drop, PSI and feet of water
EAT = entering air temperature, Fahrenheit (dry bulb/wet bulb)
HC = air heating capacity, MBTUH
TC = total cooling capacity, MBTUH
SC = sensible cooling capacity, MBTUH
kW = total power unit input, kilowatts
HR = total heat of rejection, MBTUH
HE = total heat of extraction, MBTUH
HWC = desuperheater capacity, MBTUH
EER = Energy Efficient Ratio = BTU output/Watt input
COP = Coefficient of Performance = BTU output/BTU input
LWT = leaving water temperature, °F
LAT = leaving air temperature, °F
TH = total heating capacity, MBTUH
LC = latent cooling capacity, MBTUH
S/T = sensible to total cooling ratio

Desuperheater capacity based on 0.4 GPM flow per nominal unit ton at 90°F entering hot water temperature. Capacity data on pages 16-32 do not include water pumping watts and are based upon 15% (by volume) methanol antifreeze solution. Multiple Flow Rates (for EWT) are shown in the tables on pages 16-32. The lowest flow rate shown is used for geothermal open loop/well water systems with a minimum 50° F. The second flow rate shown is the minimum geothermal closed loop flow rate. The third flow rate shown is optimum for geothermal closed loop and the suggested flow rate for boiler tower applications. Interpolation between EWT, GPM and CFM data is permissible. Extrapolation for heating data down to 25°F is permissible. Catalog illustrations cover the general appearance of products at time of publication. We reserve the right to make changes in design and construction at any time without notice.

Cooling Load Hours assuming air source heat pump

COOLING LOAD HOURS CALCULATIONS

Max Load [btu/h]	36500
Max Outside Temp	100
Indoor Design Temp	75
ΔT (MAX)	25
UA	1460

Project Name: SMUD R&D Project
Designer: Lisa Meline
Date: 9/24/2013

Assuming original equipment was "SEER 11"

TEMP RANGE	BIN RANGE	N(BIN)	Outside Temp.	Inside Temp.	Q	TOTAL COOLING CAPACITY	PLF	EQUIVALENT FULL LOAD COOLING HOURS	kW**	kW-hrs
110-114	0:00-8:00	0	112	75	54020	27900	1.94	0.00	5.12	0.0
	8:00-16:00	0	112	75	54020	27900	1.94	0.00	5.12	0.0
	16:00-24:00	0	112	75	54020	27900	1.94	0.00	5.12	0.0
105-109	0:00-8:00	0	109	75	49640	28550	1.74	0.00	4.98	0.0
	8:00-16:00	5	109	75	49640	28550	1.74	8.69	4.98	43.3
	16:00-24:00	2	109	75	49640	28550	1.74	3.48	4.98	17.3
100-104	0:00-8:00	0	102	75	39420	29200	1.35	0.00	4.85	0.0
	8:00-16:00	40	102	75	39420	29200	1.35	54.00	4.85	261.9
	16:00-24:00	19	102	75	39420	29200	1.35	25.65	4.85	124.4
95-99	0:00-8:00	0	97	75	32120	29800	1.08	0.00	4.7	0.0
	8:00-16:00	99	97	75	32120	29800	1.08	106.71	4.7	501.5
	16:00-24:00	45	97	75	32120	29800	1.08	48.50	4.7	228.0
90-94	0:00-8:00	0	92	75	24820	30400	0.82	0.00	4.56	0.0
	8:00-16:00	167	92	75	24820	30400	0.82	136.35	4.56	621.7
	16:00-24:00	75	92	75	24820	30400	0.82	61.23	4.56	279.2
85-89	0:00-8:00	1	87	75	17520	30600	0.57	0.57	4.43	2.5
	8:00-16:00	202	87	75	17520	30600	0.57	115.65	4.43	512.4
	16:00-24:00	98	87	75	17520	30600	0.57	56.11	4.43	248.6
80-84	0:00-8:00	8	82	75	10220	30800	0.33	2.65	4.23	11.2
	8:00-16:00	245	82	75	10220	30800	0.33	81.30	4.23	343.9
	16:00-24:00	144	82	75	10220	30800	0.33	47.78	4.23	202.1
75-79	0:00-8:00	34	77	75	2920	30800	0.09	0.00	4.23	0.0
	8:00-16:00	267	77	75	2920	30800	0.09	0.00	4.23	0.0
	16:00-24:00	196	77	75	2920	30800	0.09	0.00	4.23	0.0

**corrected to include fan energy

Bin Range	Equivalent Full Load Cooling Hours	Occupancy Factor	Total Cooling Run Hours	Total Cooling kW-hrs
0:00-8:00	3.23	1	3	14
8:00-16:00	502.70	0.29	144	2285
16:00-24:00	242.76	1	243	1100
		Totals:	390	3398

Heating Load Hours using air source heat pump

HEATING LOAD HOURS CALCULATIONS

Max Load [btu/h]	31600
Min Outside Temp	30
Indoor Design Temp	70
ΔT (MAX)	40
UA	790

Project Name: SMUD R&D Project
Designer: Lisa Meline
Date: 9/24/2013

Assuming original equipment was "SEER 11"

TEMP RANGE	BIN RANGE	N(BIN)	Outside Temp.	Inside Temp.	Q	HEATING CAPACITY	PLF	EQUIVALENT FULL LOAD HEATING HOURS	kW**	kW-hrs
65-69	0:00-8:00	235	67	70	2370	49400	0.05	0.00	5.12	0.0
	8:00-16:00	286	67	70	2370	49400	0.05	0.00	5.12	0.0
	16:00-24:00	300	67	70	2370	49400	0.05	0.00	5.12	0.0
60-64	0:00-8:00	412	62	70	6320	46800	0.14	0.00	4.98	0.0
	8:00-16:00	319	62	70	6320	46800	0.14	0.00	4.98	0.0
	16:00-24:00	355	62	70	6320	46800	0.14	0.00	4.98	0.0
55-59	0:00-8:00	522	57	70	10270	44200	0.23	121.29	4.85	588.2
	8:00-16:00	353	57	70	10270	44200	0.23	82.02	4.85	397.8
	16:00-24:00	415	57	70	10270	44200	0.23	96.43	4.85	467.7
50-54	0:00-8:00	506	52	70	14220	41600	0.34	172.96	4.7	812.9
	8:00-16:00	293	52	70	14220	41600	0.34	100.16	4.7	470.7
	16:00-24:00	400	52	70	14220	41600	0.34	136.73	4.7	642.6
45-49	0:00-8:00	418	47	70	18170	39000	0.47	194.75	4.56	888.0
	8:00-16:00	193	47	70	18170	39000	0.47	89.92	4.56	410.0
	16:00-24:00	313	47	70	18170	39000	0.47	145.83	4.56	665.0
40-44	0:00-8:00	343	42	70	22120	27910	0.79	271.84	4.43	1204.3
	8:00-16:00	116	42	70	22120	27910	0.79	91.94	4.43	407.3
	16:00-24:00	201	42	70	22120	27910	0.79	159.30	4.43	705.7
35-39	0:00-8:00	218	37	70	26070	27010	0.97	210.41	4.23	890.0
	8:00-16:00	41	37	70	26070	27010	0.97	39.57	4.23	167.4
	16:00-24:00	74	37	70	26070	27010	0.97	71.42	4.23	302.1
30-34	0:00-8:00	84	32	70	30020	26100	1.00	84.00	4.78	401.5
	8:00-16:00	11	32	70	30020	26100	1.00	11.00	4.78	52.6
	16:00-24:00	21	32	70	30020	26100	1.00	21.00	4.78	100.4
25-29	0:00-8:00	18	27	70	33970	25210	1.00	18.00	6.13	110.3
	8:00-16:00	1	27	70	33970	25210	1.00	1.00	6.13	6.1
	16:00-24:00	1	27	70	33970	25210	1.00	1.00	6.13	6.1
20-24	0:00-8:00	2	22	70	37920	24300	1.00	2.00	7.82	15.6
	8:00-16:00	0	22	70	37920	24300	1.00	0.00	7.82	0.0
	16:00-24:00	0	22	70	37920	24300	1.00	0.00	7.82	0.0

**corrected to include fan energy and auxiliary heat

Bin Range	Equivalent Full Load Heating Hours	Occupancy Factor	Total Heating Run Hours	Total heating kW-hrs
0:00-8:00	1075.25	1	1075	4399
8:00-16:00	415.60	0.29	119	1853
16:00-24:00	631.71	1	632	2783
Totals:			**1826**	**9036**

Cooling Load Hours using GeoHeat Pump

COOLING LOAD HOURS CALCULATIONS

Max Load [btu/h]	36500
Max Outside Temp	100
Indoor Design Temp	75
ΔT (MAX)	25
UA	1460

Project Name: SMUD R&D Project
Designer: Lisa Meline
Date: 9/24/2013

Assuming High-Speed GHP Operation

TEMP RANGE	BIN RANGE	N(BIN)	Outside Temp.	Inside Temp.	Q	SOURCE (EWT)	TOTAL COOLING CAPACITY	PLF	EQUIVALENT FULL LOAD COOLING HOURS	kW**	kW-hrs
110-114	0:00-8:00	0	112	75	54020	94	30066	1.80	0.00	4.12	0.0
	8:00-16:00	0	112	75	54020	94	30066	1.80	0.00	4.12	0.0
	16:00-24:00	0	112	75	54020	94	30066	1.80	0.00	4.12	0.0
105-109	0:00-8:00	0	109	75	49640	94	30066	1.65	0.00	4.12	0.0
	8:00-16:00	5	109	75	49640	94	30066	1.65	8.26	4.12	34.0
	16:00-24:00	2	109	75	49640	94	30066	1.65	3.30	4.12	13.6
100-104	0:00-8:00	0	102	75	39420	94	30066	1.31	0.00	4.12	0.0
	8:00-16:00	40	102	75	39420	94	30066	1.31	52.45	4.12	216.1
	16:00-24:00	19	102	75	39420	94	30066	1.31	24.91	4.12	102.6
95-99	0:00-8:00	0	97	75	32120	90	32451	0.99	0.00	3.95	0.0
	8:00-16:00	99	97	75	32120	90	32451	0.99	97.99	3.95	387.1
	16:00-24:00	45	97	75	32120	90	32451	0.99	44.54	3.95	175.9
90-94	0:00-8:00	0	92	75	24820	80	33851	0.73	0.00	3.59	0.0
	8:00-16:00	167	92	75	24820	80	33851	0.73	122.45	3.59	439.6
	16:00-24:00	75	92	75	24820	80	33851	0.73	54.99	3.59	197.4
85-89	0:00-8:00	1	87	75	17520	80	33851	0.52	0.52	3.59	1.9
	8:00-16:00	202	87	75	17520	80	33851	0.52	104.55	3.59	375.3
	16:00-24:00	98	87	75	17520	80	33851	0.52	50.72	3.59	182.1
80-84	0:00-8:00	8	82	75	10220	70	34751	0.29	2.35	3.31	7.8
	8:00-16:00	245	82	75	10220	70	34751	0.29	72.05	3.31	238.5
	16:00-24:00	144	82	75	10220	70	34751	0.29	42.35	3.31	140.2
75-79	0:00-8:00	34	77	75	2920	70	34751	0.08	0.00	3.31	0.0
	8:00-16:00	267	77	75	2920	70	34751	0.08	0.00	3.31	0.0
	16:00-24:00	196	77	75	2920	70	34751	0.08	0.00	3.31	0.0

Bin Range	Equivalent Full Load Cooling Hours	Occupancy Factor	Total Cooling Run Hours	Total Cooling kW-hrs
0:00-8:00	2.87	1	3	10
8:00-16:00	467.74	0.29	131	1591
16:00-24:00	220.82	1	221	812
			354	**2512**

**corrected to include fan and pump energy

Heating Load Hours using GeoHeat Pump

HEATING LOAD HOURS CALCULATIONS

Max Load [btu/h]	31600
Min Outside Temp	30
Indoor Design Temp	70
ΔT (MAX)	40
UA	790

Project Name: SMUD R&D Project
Designer: Lisa Meline
Date: 9/24/2013

Assuming High-Speed GHP Operation

TEMP RANGE	BIN RANGE	N(BIN)	Outside Temp.	Inside Temp.	Q	SOURCE EWT	HEATING CAPACITY	PLF	EQUIVALENT FULL LOAD HEATING HOURS	kW**	kW-hrs
65-69	0:00-8:00	235	67	70	2370	70	55649	0.04	0.00	4.41	0.0
	8:00-16:00	286	67	70	2370	70	55649	0.04	0.00	4.41	0.0
	16:00-24:00	300	67	70	2370	70	55649	0.04	0.00	4.41	0.0
60-64	0:00-8:00	412	62	70	6320	70	55649	0.11	0.00	4.41	0.0
	8:00-16:00	319	62	70	6320	70	55649	0.11	0.00	4.41	0.0
	16:00-24:00	355	62	70	6320	70	55649	0.11	0.00	4.41	0.0
55-59	0:00-8:00	522	57	70	10270	60	51249	0.20	104.60	4.19	438.3
	8:00-16:00	353	57	70	10270	60	51249	0.20	70.74	4.19	296.4
	16:00-24:00	415	57	70	10270	60	51249	0.20	83.16	4.19	348.5
50-54	0:00-8:00	506	52	70	14220	60	51249	0.28	140.40	4.19	588.3
	8:00-16:00	293	52	70	14220	60	51249	0.28	81.30	4.19	340.6
	16:00-24:00	400	52	70	14220	60	51249	0.28	110.99	4.19	465.0
45-49	0:00-8:00	418	47	70	18170	50	46649	0.39	162.81	3.95	643.1
	8:00-16:00	193	47	70	18170	50	46649	0.39	75.17	3.95	296.9
	16:00-24:00	313	47	70	18170	50	46649	0.39	121.91	3.95	481.6
40-44	0:00-8:00	343	42	70	22120	50	46649	0.47	162.64	3.95	642.4
	8:00-16:00	116	42	70	22120	50	46649	0.47	55.00	3.95	217.3
	16:00-24:00	201	42	70	22120	50	46649	0.47	95.31	3.95	376.5
35-39	0:00-8:00	218	37	70	26070	45	44399	0.59	128.00	3.89	497.9
	8:00-16:00	41	37	70	26070	45	44399	0.59	24.07	3.89	93.6
	16:00-24:00	74	37	70	26070	45	44399	0.59	43.45	3.89	169.0
30-34	0:00-8:00	84	32	70	30020	45	44399	0.68	56.80	3.89	220.9
	8:00-16:00	11	32	70	30020	45	44399	0.68	7.44	3.89	28.9
	16:00-24:00	21	32	70	30020	45	44399	0.68	14.20	3.89	55.2
25-29	0:00-8:00	18	27	70	33970	45	44399	0.77	13.77	3.89	53.6
	8:00-16:00	1	27	70	33970	45	44399	0.77	0.77	3.89	3.0
	16:00-24:00	1	27	70	33970	45	44399	0.77	0.77	3.89	3.0
20-24	0:00-8:00	2	22	70	37920	45	44399	0.85	1.71	3.89	6.6
	8:00-16:00	0	22	70	37920	45	44399	0.85	0.00	3.89	0.0
	16:00-24:00	0	22	70	37920	45	44399	0.85	0.00	3.89	0.0

**corrected to include fan and pump energy

Bin Range	Equivalent Full Load Heating Hours	Occupancy Factor	Total Heating Run Hours	Total Heating kW-hrs
0:00-8:00	770.74	1	771	3091
8:00-16:00	314.49	0.29	90	1277
16:00-24:00	469.79	1	470	1899
Totals:			1330	6267

Attachment 5: Informational Flyer

Sacramento Municipal Utility District

SMUD Energy Efficiency Retrofit Project

Drilling machine

During drilling

After drilling

Location: Steve and Becca Trumbly have graciously offered to have their home at 7504 Rio Mondego Dr, Sacramento be used for this energy retrofit.

Project Description: This R&D project will replace the home's heating and cooling (HVAC) system with a state-of-the-art GeoHeat Pump.

What is GeoHeat Pump? The Geo system uses the earth below the home to help heat the home in the winter and cool the home in the summer. This is accomplished by installing a closed circuit ground loop that circulates a fluid back to the home. The fluid enters the home HVAC system at the temperature of the ground. The heat pump uses a heat exchanger to extract heat in the winter and dissipate heat in the summer.

Why is SMUD interested in GeoHeat Pumps? A GeoHeat Pump can reduce the total annual energy (electricity and natural gas) used for space cooling, space heating, and domestic water heating by 50% to 70%. Just as important, the GeoHeat Pump can reduce the total electricity demand during the summer peak hours by 50%. This helps reduce the total carbon emissions attributable to this home's energy use.

Continued on back

Powering forward. Together.

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What is unusual about this project? Installing the ground loop is sometime new to Sacramento. In the front yard, a small drilling machine will work for 3-4 days to bore small holes in the earth under the home and pipes will be inserted. These pipes will be connected to the home's heat pump. When the drilling is done the yard will be restored to its former condition. Inside the home, the heat pump box will look like any other heat pump system. The GeoHeat Pump will also produce hot water that will help reduce the amount of natural gas needed to heat the home's water.

Questions or comments? Please feel free to talk to your neighbors Steve and Becca Trumbly about this project. This project will be receiving both the City of Sacramento and County of Sacramento permits before it is started. However, if you see anything that concerns you, please contact David Maul, the project manager or Bruce Baccei, the SMUD R&D manager, for this project right away.

For more information:
David Maul, Energy Efficency Retrofit Project manager, 530-304-8096
Bruc Baccei, SMUD R&D manager, 916-732-5715

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Attachment 6: Borehole Installation

Boring machine

Boring machine operation

Boring machine with slanted spade end

Garage floor with opening next to GeoHeat Pump unit

Front lawn four weeks after work comleted