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MONITORING AND EVALUATING GROUND-SOURCE HEAT PUMPS

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

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MONITORING AND EVALUATING GROUND-SOURCE HEAT PUMPS

Final Report

Prepared for

THE NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

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ABSTRACT

This report presents the measured performance of four advanced residential ground-source heat pump (GSHP) systems. The GSHP systems were developed by WaterFurnace International to minimize the need for electric resistance backup heating and featured multiple speed compressors, supplemental water heating, and at most sites, multiple-speed fans. Detailed data collected for a complete year starting in June 1994 shows that the advanced design is capable of maintaining comfort without the use of electric resistance backup heating. In comparison with a conventional air-source heat pump, the advanced-design GSHP reduced peak heating demand by more than 12 kilowatts (kW) per residence and provided energy savings. The report describes the cooling and heating season operation of the systems, including estimated seasonal efficiency, hours of operation, and load profiles for average days and peak days. The electrical energy input, cooling output, and efficiency are presented as a function of return air temperature and ground loop temperature.

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SUMMARY

INTRODUCTION

GEOMET Technologies (GEOMET) installed monitoring systems and collected a full year of detailed data on the performance of four advanced-design residential ground-source heat pumps (GSHPs). The data and analysis provided by this project support the further development of advanced GSHP systems, and may assist in promoting energy savings and comfort advantages, with accurate measured results.

The New York State Energy Research and Development Authority (NYSERDA), Central Hudson Gas and Electric Company, the New York State Electric and Gas Company, WaterFurnace International, Inc. (the Sponsors), and a New York State ground loop manufacturer had previously entered into research agreements to design, develop, and demonstrate an advanced GSHP system capable of meeting 100 percent of a residential home's heating requirement without electric resistance heating. Four GSHP systems were installed by WaterFurnace at four demonstration sites selected by the Sponsors. GEOMET designed and installed monitoring systems at these four sites.

This report presents analysis of a full year of detailed monitoring data from the four sites. It also provides an overview of the measured system performance, a basis for understanding variations in performance among the four sites, and comparisons to the performance of a typical air-source heat pump system.

SITE CHARACTERISTICS

The four sites provided diverse characteristics of occupancy, structure, system installation, and type of ground field, as summarized on Table S-1. Two of the sites were new construction and two of the sites were existing houses where the new GSHP system replaced an existing heating system. Two types of ground field designs were tested. Horizontal ground loop systems were used in the new construction and vertical well systems were used for the retrofit installations. Also shown are the design heating load and the design cooling load engineering estimates prepared prior to the installation of the GSHP systems.

Table S-1. Site Characteristics					
Site No.	Location City	Installation Type	Ground Loop Length/Type	Engineering Design Thermal Load Estimates (Btu/hr)	
				Heating	Cooling
Site 1	Hyde Park	Retrofit	560' Vertical 2 Wells @ 280'	40,000	17,500
Site 2	Rhinebeck	New Construction	480' Horizontal Slinky @ 5'-6'	43,871	31,216
Site 3	Ithaca	Retrofit	560' Vertical 2 Wells @ 280'	55,000	20,000
Site 4	Stillwater	New Construction	700' Horizontal 6-Pipe @ 2'-6'	61,098	42,431

SUMMARY OF RESULTS

Table S-2 provides a summary of results from the four test sites. This table shows the electrical energy input, thermal output, and efficiency for cooling and heating modes of operation. As shown, the advanced-design heat pump systems satisfied the primary design objective by supplying the heating demands of three of the four sites without the use of electric resistance backup heating. The use of electric resistance backup heat at Site 2 was insignificant and does not indicate a design problem with the system. The heating capacity of the heat pump system at this site was equivalent to those of the other three sites. However, the heating requirements of this house exceeded the design capacity of the heat pump, and so electric resistance backup was required. The engineering estimate underestimated actual demand. A larger-capacity GSHP system would have eliminated the use of electric resistance backup.

Overall, the heating and cooling efficiencies calculated from the long-term monitored data are less than rated efficiencies calculated from short-term laboratory tests of the systems. This is due to differences in definitions of efficiency as well as differences in test conditions.

Table S-2. Performance Summary					
End Use Input, Output, and Efficiency		Site 1	Site 2	Site 3	Site 4
Heating	Electric Resistance Backup (kWh)	0.00	823	0.00	0.00
	Total Input (kWh)	5,131	10,547	6,062	8,161
	Thermal Output (MBtu)	38,541	68,098	42,699	54,691
	Water Heating (MBtu)	7,216	11,349	11,399	16,566
	COP	2.61	2.21	2.61	2.56
Cooling	Total Input (kWh)	1,012	77	187	2,189
	Output (MBtu)	9,749	873	2,403	22,405
	Cooling SEER (Btu/Watt)	9.63	11.39	12.84	10.19
	Water Heating (MBtu)	887	118	563	3,522

Standard laboratory tests provide a measure of the steady-state (continuously operating) efficiency of the systems. Field measurements include periods of changing temperatures and intermittent operation that have the expected result of lowering the efficiency. Laboratory-rated efficiencies also exclude pump energy from the calculation of heating coefficient of performance (COP) and cooling seasonal energy efficiency ratio (SEER) for GSHP systems. The seasonal heating and cooling efficiencies shown above include pump energy and so may be expected to be lower than seasonal efficiency values estimated from laboratory tests.

The cooling SEERs shown by the table are the total seasonal output in British thermal units (Btu) divided by the total electrical input in Watt-hours (Watt-hrs). The supplemental water heating provided by the desuperheater during cooling mode operation is not included in the calculation of cooling season efficiency since this thermal energy is a useful byproduct of the cooling process that would have to be discharged to the ground loop if not recovered for water heating.

The seasonal heating efficiency is shown as the coefficient of performance (COP). The COP is calculated as the total seasonal thermal output in Btu, including space heating and water heating, divided by the total electrical energy input converted to thermal equivalent Btus. The average COP includes the supplemental water heating provided by the desuperheater since, in the heating mode, this energy could be used for space heating if it were not transferred to the domestic water.

Differences between laboratory and field testing can also be attributed to customer behavior and site-specific conditions. For example, at Site 4, the data showed unusually low return air temperatures in the cooling mode. A subsequent site visit found both supply and return registers located at the floor level in most rooms, a configuration that allows some cool supply air to be directly returned to the fan-coil unit without completely mixing with the room air. The low temperature of the return air in this case lowers the cooling efficiency of the GSHP system.

The variation of seasonal efficiency is also explained in part by the relative energy use of the auxiliary system components, including the distribution air fan, the ground loop circulation pump, and associated control systems. Energy consumption for these auxiliaries ranges from 29 to 45 percent of the total system energy input. In general, systems with lower auxiliary energy use have a higher overall SEER. For example, the average seasonal cooling efficiency at Site 1 may have been reduced by the customer's choice to run the fan continuously rather than allowing the fan to be automatically cycled on and off under control of the thermostat.

CONCLUSIONS

The analysis of these data shows that properly sized advanced design GSHP systems can eliminate the use of electric resistance backup heating for typical residences in New York State and thus substantially reduce peak electric energy demands.

Section 1
INTRODUCTION

GEOMET collected and analyzed detailed data on the performance of four advanced-design residential ground-source heat pump (GSHP) system. This report provides a presentation of results for a full year of monitoring from the four sites. The advanced design GSHP systems maintained comfortable conditions without the use of significant electric resistance backup heating. Information provided by this project will enable the project sponsors to promote the energy savings and comfort advantages of these systems.

BACKGROUND

The New York State Energy Research and Development Authority (NYSERDA), Central Hudson Gas and Electric Company, and the New York State Electric and Gas Company (the Sponsors) previously entered into a research agreement with WaterFurnace International and a New York State ground loop manufacturer to design, develop, and demonstrate an advanced GSHP system capable of meeting 100 percent of a residential home's heating requirement without electric resistance heating. Four GSHP systems were installed by WaterFurnace at demonstration sites selected by the Sponsors. GEOMET designed and installed monitoring systems at these four sites and collected data for one year.

GOALS AND OBJECTIVES

The project goals and objectives were to:

1. Design and install monitoring equipment at four GSHP demonstration sites.
2. Collect and analyze data from the four GSHP sites.
3. Evaluate and document the performance of the four GSHP demonstration sites.

Section 2

TECHNICAL APPROACH

GEOMET selected and installed instrumentation and monitoring systems to collect detailed data on the operation of four GSHP systems. The monitoring systems were installed in 1994, and consistent data was collected from all four sites from June 1994 through June 1995. Figure 2-1 provides a schematic illustration of a typical GSHP system, showing approximate locations of instruments used to measure various parameters. This section of the report documents the organization of the data and the presentation of results.

ORGANIZATION OF THE DATA

Table 2-1 lists measured and calculated parameters recorded at 15-minute intervals and other data stored in a database. The table also shows the equations to calculate heating and cooling output and efficiency.

The electrical input to the components of the system, including the ground loop pump, the supply air fan, and the compressor were monitored. Detailed data on the thermal performance of the system were also collected, including ground loop flow rates, entering and leaving ground loop temperatures, entering and leaving forced air temperatures, and entering and leaving water temperatures at the desuperheater. The terms "entering" and "leaving" are relative to the heat pump system; for example, the entering water temperature refers to the temperature of water from the ground loop entering the heat exchanger of the heat pump system. Similarly, entering air temperature refers to the temperature of return air from the house entering the air coil of the heat pump system.

Data were collected from each site via a telephone modem and automatically added to a data file for each site. Each week the raw data files were edited and the data added to a database that was maintained for each site.

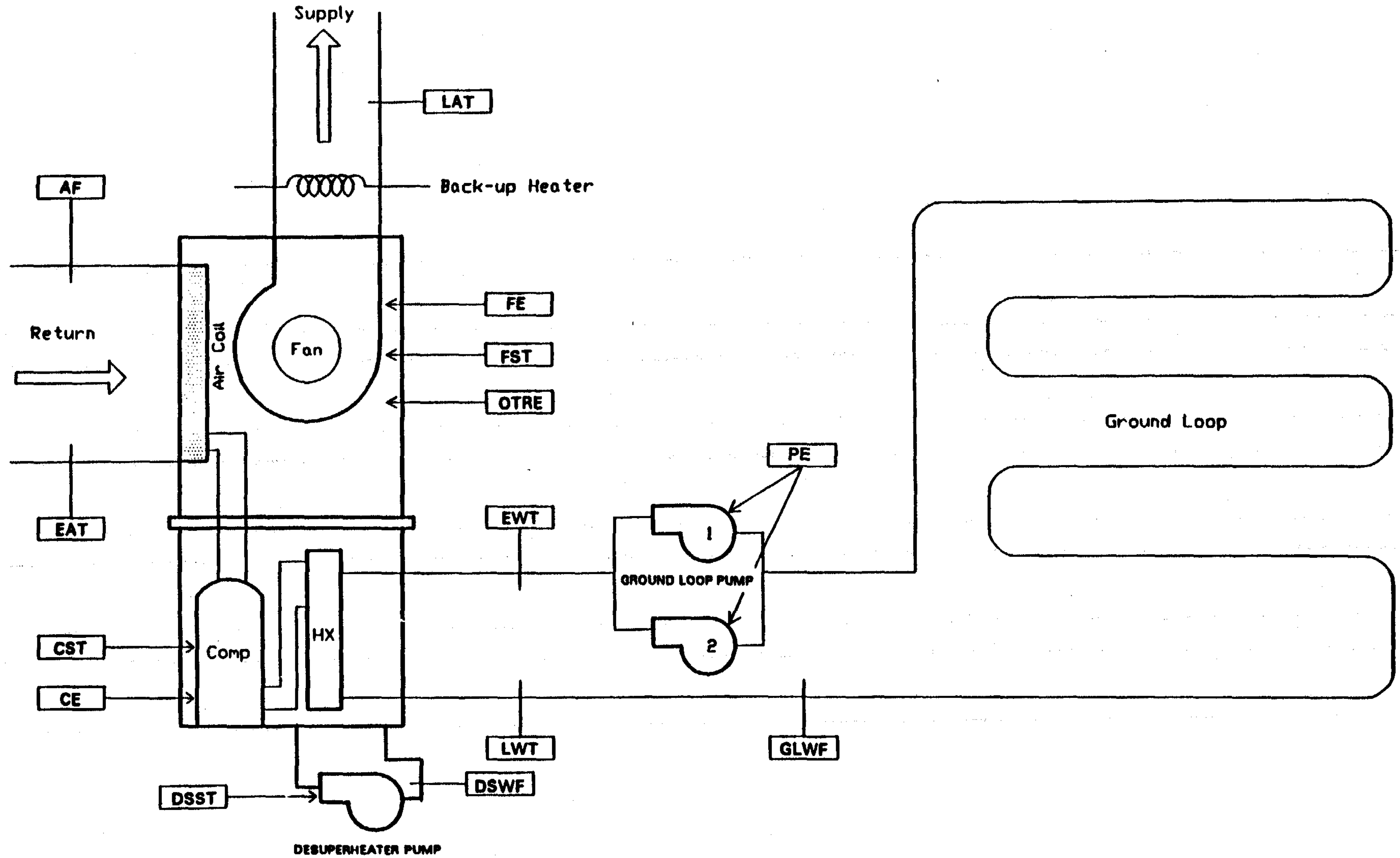

Figure 2-1. Schematic of the Ground-Source Heat Pump (GSHP) Showing System Instrumentation

Table 2-1. GSHP Monitored and Calculated Parameters and Other Data Included in Database

1. Unit - Site number & logger software number in use
2. DAY - Julian day
3. TIME - Hr:Min
4. EWT - Entering water temperature in °F
5. LWT - Leaving water temperature in °F
6. EAT - Entering air temperature in °F
7. LAT - Leaving air temperature in °F
8. GAT - Grill supply air temperature in °F
9. EDWT - Entering desuperheater water temperature in °F
10. LDWT - Leaving desuperheater water temperature in °F
11. IAT - Indoor air temperature in °F
12. OAT - Outdoor air temperature in °F
13. IRH - Indoor relative humidity (%)
14. CE - Energy consumed by the compressor (Watts)
15. OTRE - Energy consumed by the fan, pump, controls & resistance heat (Watts)
16. PE - Energy consumed by the ground loop pump (Watts)
17. FE - Energy consumed by the indoor fan (Watts)
18. DSST - Desuperheater status, fractional on-time
19. FSTL - Indoor fan status in low speed, fractional on-time
20. FSTM - Indoor fan status in medium speed, fractional on-time
21. FSTH - Indoor fan status in high speed, fractional on-time
22. GLWF - Ground loop water flow (Gallons)
23. DHWF - Domestic hot water flow (Gallons)
24. DHWE - Domestic hot water energy (Wh)
25. CESTL - Compressor status in low speed, fractional on-time
26. CESTH - Compressor status in high speed, fractional on-time

Performance Factor Calculations:

A. NETBTU (Btu/hr) = GLWF*Cp*8.33*4*(EWT-LWT)
B. CEBTU (Btu/hr) = CE*3.413
C. HEATBTU (Btu/hr) = (NETBTU+CEBTU), If (NETBTU > 0)
D. COOLBTU (Btu/hr) = -NETBTU-CEBTU + DSBTU, If (NETBTU < 0)
E. HCOP = (HEATBTU+DSBTU)/CEBTU
F. CCOP = COOLBTU/CEBTU CEER = COOLBTU/CE
G. DSBTU (Btu/hr) = DSGPM*60*8.33* (LDWT-EDWT), If (DSST > 0)

Where
Cp = 0.916 Btu/lb °F (water /antifreeze ground loop heat transfer medium)
Conversion Factor 8.33 lb/gal
DSGPM = Average flow rate in gallons per minute flowing through the desuperheater

Site one = 0.8313 gpm.
Site two = 1.6914 gpm.
Site three = 1.2048 gpm.
Site four = 1.1662 gpm.

Note: All the energy values are in Btu/h

SITE CHARACTERISTICS

The four sites provided diverse characteristics with regard to occupancy, structure, system installation, and the type of ground field. These are summarized on Table 2-2. As shown, two of the sites were new construction and two were existing houses in which the GSHP system replaced an existing heating system. Horizontal ground loop systems were used in the new construction and vertical well-type systems were used for the retrofit installations. The design heating load and the design cooling load shown on the table are engineering estimates that were prepared prior to the installation of the systems.

Additional details on the sites and the GSHP systems are included in Appendix A.

Table 2-2. Site Characteristics

Site No.	Location City	Installation Type	Ground Loop Length/Type	Design Heating Load	Design Cooling Load
Site 1	Hyde Park	Retrofit	560' Vertical 2 Wells @ 280'	40,000 Btu/hr	17,500 Btu/ hr
Site 2	Rhinebeck	New Construction	480' Horizontal Slinky @ 5'-6'	43,871 Btu/hr	31,216 Btu/hr
Site 3	Ithaca	Retrofit	560' Vertical 2 Wells @ 280'	55,000 Btu/hr	20,000 Btu/hr
Site 4	Stillwater	New Construction	700' Horizontal 6-Pipe @ 2'-6'	61,098 Btu/hr	42,431 Btu/hr

ORGANIZATION OF THE ANALYSIS AND RESULTS

The data have been analyzed to provide a graphic presentation of the results for each site and the calculation of total energy consumption and seasonal energy efficiency. Four types of analysis are presented:

- **Annual and Monthly Summaries:** These are provided by several tables and figures that show the total energy inputs and outputs, as well as average efficiencies and temperatures. Daily average outside air temperatures are also provided.

- **Average and Peak Day Load Profiles and Average Temperatures:** These figures provide an aggregation of the data by the 24 hours of the day. Peak day load profiles include the top five hottest and coolest days from the cooling and heating season respectively for the peak day profiles.

- **Heating and Cooling Performance Analysis:** This is presented as a graphic analysis of efficiency as a function of the ground loop water temperature, the entering air temperature, and the average on-time per cycle. These results are also presented as a cross tabulation of efficiency as a function of both groundwater temperature, cycling effects, and compressor speed

- **Energy Analysis Comparison of Air Source and Ground Source Systems:** The energy use of the advanced GSHP systems estimated using the "bin method," where the average performance is estimated for each five-degree range of outside temperature. Each five-degree range is considered as a bin. The energy use is calculated from the number of hours in each temperature bin using long-term weather data. Energy use for a typical air source system was developed by a computer simulation.

Section 3

PRESENTATION OF RESULTS

A graphic format has been used where possible to present aggregations of data. In general, graphs or tables, as appropriate, are shown for each site. These graphs and tables are proceeded by a brief narrative section to describe them and point out the highlights of the results. However, the goal of the presentation of results is to provide a sufficient compilation of data to provide comprehensive data short of the complete 15-minute interval data.

ANNUAL SUMMARIES

Table 3-1 shows a summary of results for the four sites. The parameters shown on the table are defined and described below:

- Site ID: Site Identification.
- Start Date: First date for which there is data.
- End Date: Last date for which there is data.
- Avg Outside Temp: Average Outside Air Temperature. Abbreviated as OAT. Note that the average temperatures at Sites 1 and 2 in the Poughkeepsie area are warmer than those of Sites 3 and 4 in Ithaca and Stillwater, respectively.
- Avg Indoor Temp: Average Indoor Air Temperature. Abbreviated as IAT. Note that Site 2 has the lowest IAT, despite very little use of air conditioning.
- Avg Indoor RH: Average Indoor Relative Humidity. Abbreviated as IRH.
- Total System kWh: Total electrical energy consumption of the GSHP system in kWh. Sites 2 and 4 appear roughly equal in this respect, although at Site 2 virtually all the energy is used for heating, while Site 4 shows a balance of heating and cooling energy.
- Compressor kWh: Total electrical energy consumption of the compressor in kWh.

Table 3-1. Summary of Annual Data (totals) from Four GSHP Sites

Site ID	1	2	3	4
Start Date	5-Jun-94	5-Jun-94	5-Jun-94	5-Jun-94
End Date	4-Jun-95	4-Jun-95	4-Jun-95	4-Jun-95
Avg Outside Temp	52.6	51.2	48.3	46.7
Avg Indoor Temp	75.3	68.2	69.8	73.5
Avg Indoor RH	43.4	49.0	49.9	39.3
Total System kWh	6,306	10,764	6,380	10,552
Compressor kWh	4,252	6,971	4,831	7,014
Pump kWh	796	1,124	884	1,092
Fan kWh	995	1,640	350	1,837
Miscellaneous kWh	263	367	311	609
Backup Heat kWh	-	662	-	-
Heating kWh	5,131	10,547	6,062	8,161
Heating MBtu	38,541	68,098	42,699	54,691
Heating Mode/DHW MBtu	7,216	11,349	11,399	16,566
Heating COP	2.61	2.21	2.61	2.56
Cooling kWh	1,012	77	187	2,198
Cooling MBtu	9,749	873	2,403	22,405
Cooling SEER	9.63	11.39	12.84	10.19
Cooling Mode/DHW Mbtu	887	118	563	3,522
Loop Gallons	1,275,181	1,305,339	1,273,573	1,833,203
Avg Loop EWT	44.37	35.36	39.80	43.11
Avg Loop LWT	42	30	36	41
Runtime Hrs	1,666.8	2,224.8	1,864.7	2,413.2
Comp Low Spd Hrs	1,735.5	1,697.9	1,803.0	2,160.6
Comp High Spd Hrs	9	714	115	373
Fan Low Speed Hrs	0	262	319	1,328
Fan Medium Speed Hrs	0.0	1,655.8	1,751.6	1,707.3
Fan High Speed Hrs	2,669	737	128	424
DHW Resistance kWh	5,075	1,784	69	-
Desuperheater DHW MBtu	8,108	11,467	11,967	20,100
DHW Gallons	26,719	15,788	-	-

- Pump kWh: Total electrical energy consumption of the ground loop pump, in kWh. Pumping energy appears related to the type of ground loop. Sites 1 and 3, which have lower measured pump energy use than sites 2 and 4 have vertical well-type systems. The combination of pump efficiency and ground loop design may warrant further study

- Fan kWh: Total electrical energy consumption of the forced air distribution system fan, in kWh. Note that Site 1 has a single-speed fan, while Sites 2, 3, and 4 have multi-speed fans with an electronically commutated motor (ECM). Sites 2 and 4 also have zoned systems in which zone dampers are actuated under the control of separate zone thermostats to restrict the flow of air to a zone when the zone setpoint is satisfied. However, the zone control was not coordinated with the fan controls. As the dampers restricted the flow of air, the ECM fan controls would respond by increasing the fan speed to maintain the total air flow volume. Fan efficiency would be improved by reducing the fan speed when air flow is restricted by a zone damper. The potential advantages of ECM fan control were probably not achieved at Sites 2 and 4 due to the interaction of fan speed and zone-damper control systems. Site 3 used an ECM motor without zone damper controls and had the lowest fan energy use. Further development and testing are recommended to optimize forced air distribution system fan motor and zone-damper controls.

- Miscellaneous kWh: Total electrical energy consumption of the GSHP system controls and the desuperheater pump. A method to reduce the miscellaneous standby losses of the control system is worthy of further consideration. For example, at Site 2, more than one percent of the annual total energy is consumed by miscellaneous controls during periods when the system is neither heating or cooling.

- Backup Heat kWh: Total electrical energy consumption of electric resistance backup heat, in kWh. There was no use of electric resistance backup heating at three of the four sites.

- Heating kWh: The total electrical energy use of the system during all periods (15-minute intervals) when the system was operating in the heating mode.

- Heating MBtu: The total space heating output of the system in 1000s of Btu (MBtu).

- Heating Mode/DHW MBtu: The total water heating output of the desuperheater during all periods when the system was operating in a heating mode.

- Heating COP: Heating Coefficient of Performance (COP). Calculated here as the total heating MBtu plus Heating Mode/DHW MBtu divided by the Btu equivalent of the Compressor electrical energy input. As defined here, heating COP is a measure of the overall heating season average efficiency of the systems, including pump, fan, miscellaneous, and backup heat kWh. It should be noted that the Air Conditioning and Refrigeration Institute (ARI) standard rating does not include pump energy and is measured under steady-state laboratory conditions. Desuperheater water heating is included in this efficiency calculation because it is assumed that this energy would have contributed to the total space heating if not used for water heating. The COP values for Sites 1, 3, and 4 are roughly equal, at approximately 2.6.

- Cooling kWh: The total electrical energy use of the system during all periods when the system was operating in the cooling mode.

- Cooling MBtu: The total space cooling output of the system in 1000s of Btus (MBtu).

- Cooling SEER: Cooling Seasonal Energy Efficiency Ratio (SEER) in Btu per Watt. Calculated as the Cooling MBtu divided by the Cooling kWh. As calculated, the SEER is a measure of the total system performance, including pump, fan, and miscellaneous electrical energy consumption. Desuperheater thermal energy output is not included, since this energy is considered a useful byproduct of the cooling process.

- Cooling Mode/DHW MBtu: The total water heating output of the desuperheater during all periods when the system was operating in a cooling mode.

- Loop Gallons: Total flow through the ground loop system in gallons.

- Avg Loop EWT: Average ground loop entering water temperature (EWT). Where entering is used consistently to indicate flow into the GSHP system.

- Avg Loop LWT: Average ground loop leaving water temperature (LWT). Where leaving is used consistently to indicate flow leaving the GSHP system.

- Runtime Hrs: Runtime Hours is the total on-time (time of operation) of the system when actively heating or cooling

- Comp Low Spd Hrs: Compressor low-speed hours of operation.

- Comp High Spd Hrs: Compressor high-speed hours of operation.

- Fan Low Speed Hrs: Fan low-speed hours of operation.

- Fan Medium Speed Hrs: Fan medium-speed hours of operation.

- Fan High Speed Hrs: Fan high-speed hours of operation.

- DHW Resistance kWh: Domestic Hot Water (DHW) resistance energy consumption in kWh. The electrical energy input to the conventional electric resistance water heaters was measured at Sites 1, 2, and 3.

- Desuperheater DHW MBtu: Total desuperheater thermal contribution to domestic hot water, in MBtu.
- DHW Gallons: Total domestic hot water consumption. Flow meters were installed on the cold water side of the domestic water heaters at Sites 1 and 2.

Annual Electrical Energy Inputs

Figure 3-1 shows the annual electrical energy inputs for for the total system including: backup heat, the fan, the compressor, the ground loop pumps and miscellaneous. These data are presented as a stacked column for each site where the stacked segments of each column represent the energy use by each of the submetered system components. The chart shows a considerable variation of total system energy consumption between the four sites. Variations of energy use by the compressor are related to variations of total heating and cooling thermal output, as expected. The difference in fan energy consumption at the various sites is greater than expected. In particular, Site 3 fan energy use is significantly less than the other sites. The unique configuration of the fan system at Site 3, where an efficient ECM fan motor is used without zone damper control, may explain the apparent efficiency. Energy consumed by miscellaneous system components and pumps does not show a significant variation between sites.

Annual Thermal Energy Outputs

The wide variation of cooling energy shown in Figure 3-2 is primarily a function of occupant behavior. The lowest cooling use (at Site 2) is the result of the occupants' simply choosing not to run the system. The relatively high use at Site 4 is the result of the occupants' choosing to use the air conditioning to maintain an especially cool inside temperature.

Figure 3-2 also indicates the relative importance of the supplemental water heating provided by the desuperheaters. At Sites 1 and 4, the desuperheater output is almost equal to cooling energy; whereas, at Sites 2 and 3, the desuperheater output is significantly greater than the cooling energy output. Overall, the supplemental water heating provided by the GSHP systems appears to be more important than the air conditioning, since the water would otherwise have been heated by electric resistance water heaters, at a much lower efficiency than that of the heat pump system.

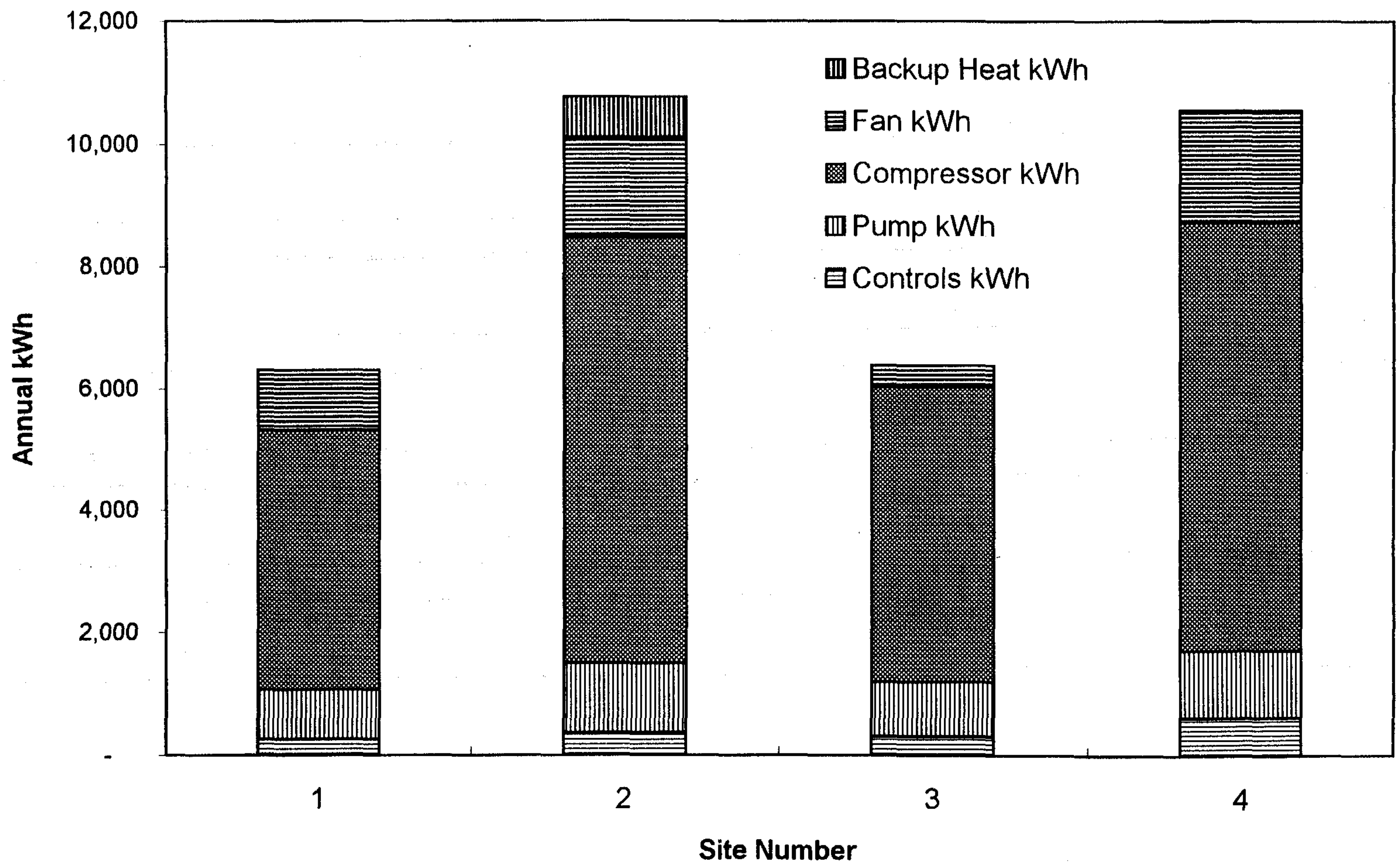

Figure 3-1. Comparison of GSHP System Electrical Energy Inputs

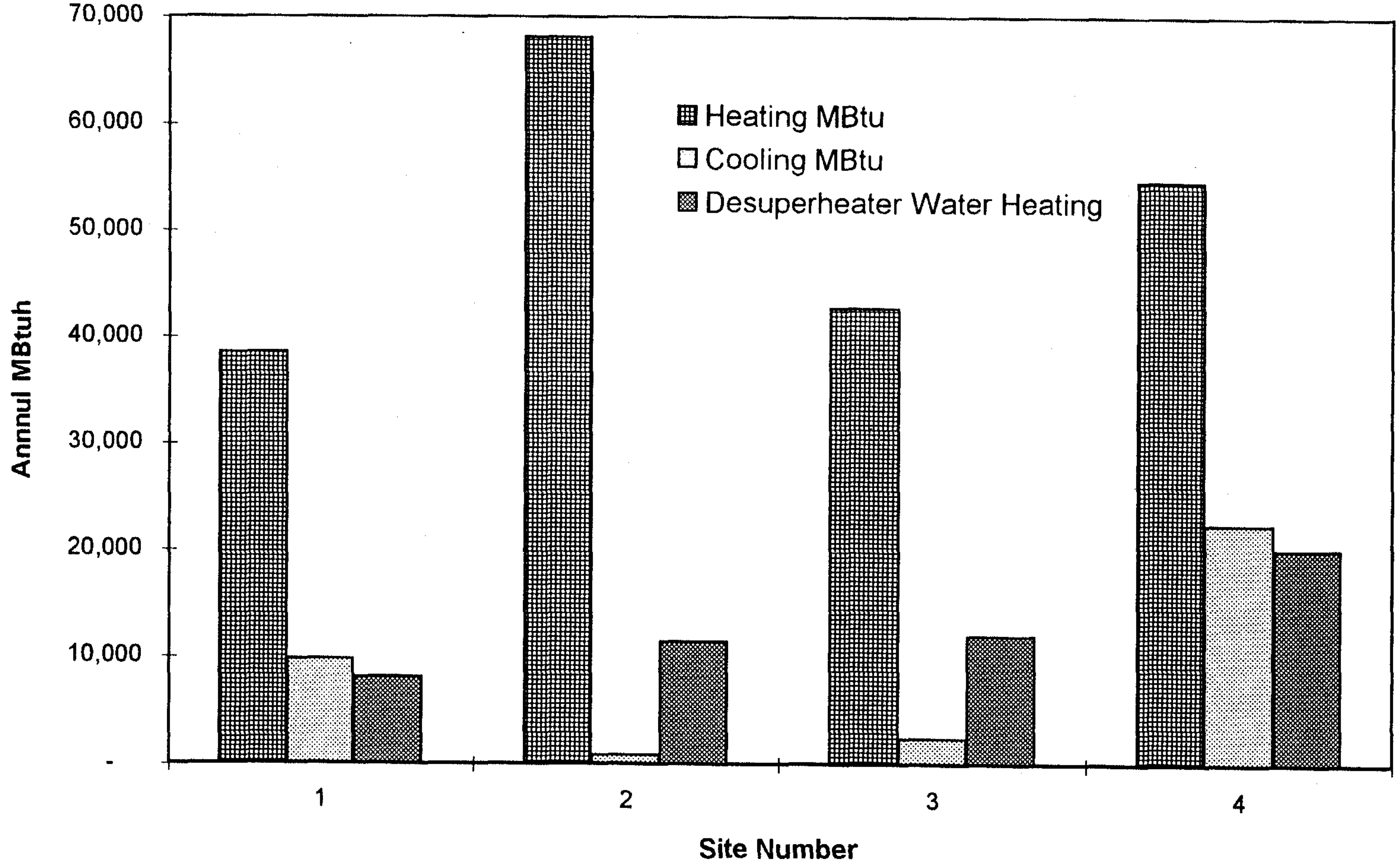

Figure 3-2. Comparison of Thermal Output

The desuperheater energy output at Site 3 benefits from a unique configuration of the domestic water heating system, where the desuperheater is connected to a separate preheat tank. Cold water flows first to the preheat tank, where it may be preheated by the desuperheater, and then to the main domestic water heating tank. The temperature in the preheat tank is cool compared to the main tank, which is heated by electric resistance elements. The preheat tank system can absorb more energy from the desuperheater because the preheat tank temperature is cooler than the main water heater tank. At the other sites, there are no preheat tanks and the desuperheater is connected directly to the main domestic water heating tank.

MONTHLY SUMMARIES

Graphs of Monthly Heating and Cooling Energy

Selected monthly energy use has also been graphed in Figures 3-3(1) through 3-3(4). These graphs show the total monthly energy use with a combination of stacked columns and lines. The stacked columns show the total monthly energy use as the combination of backup resistance heat, fan energy, compressor energy, pump energy, and miscellaneous/control energy use. Total cooling and heating energy are shown as lines marked by dots and triangles, respectively. The monthly data show a cooling season of only three months (June July and August) at Sites 1 to 3 with some cooling in September, too, at Site 4. In general, the heating seasons extended from October through May at all four sites.

Tables 3-2(1) through 3-2(4) provide monthly summaries for Sites 1 to 4, respectively. These tables present the same parameters presented in Table 3-1, except that the data are totalized or averaged on a monthly basis. These tabular summaries are provide here primarily for reference.

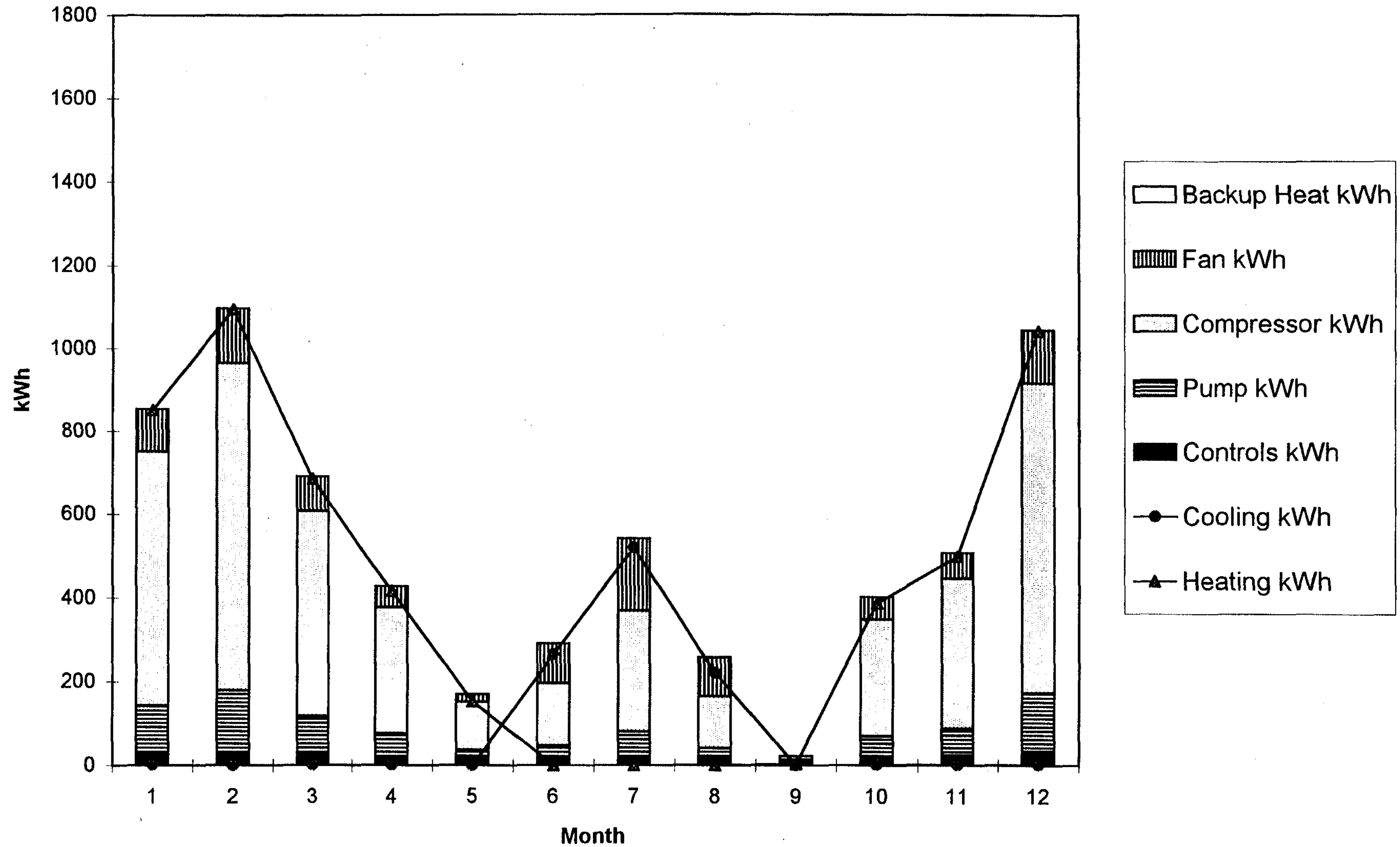

Figure 3-3(1). Site 1 - Monthly Energy Use

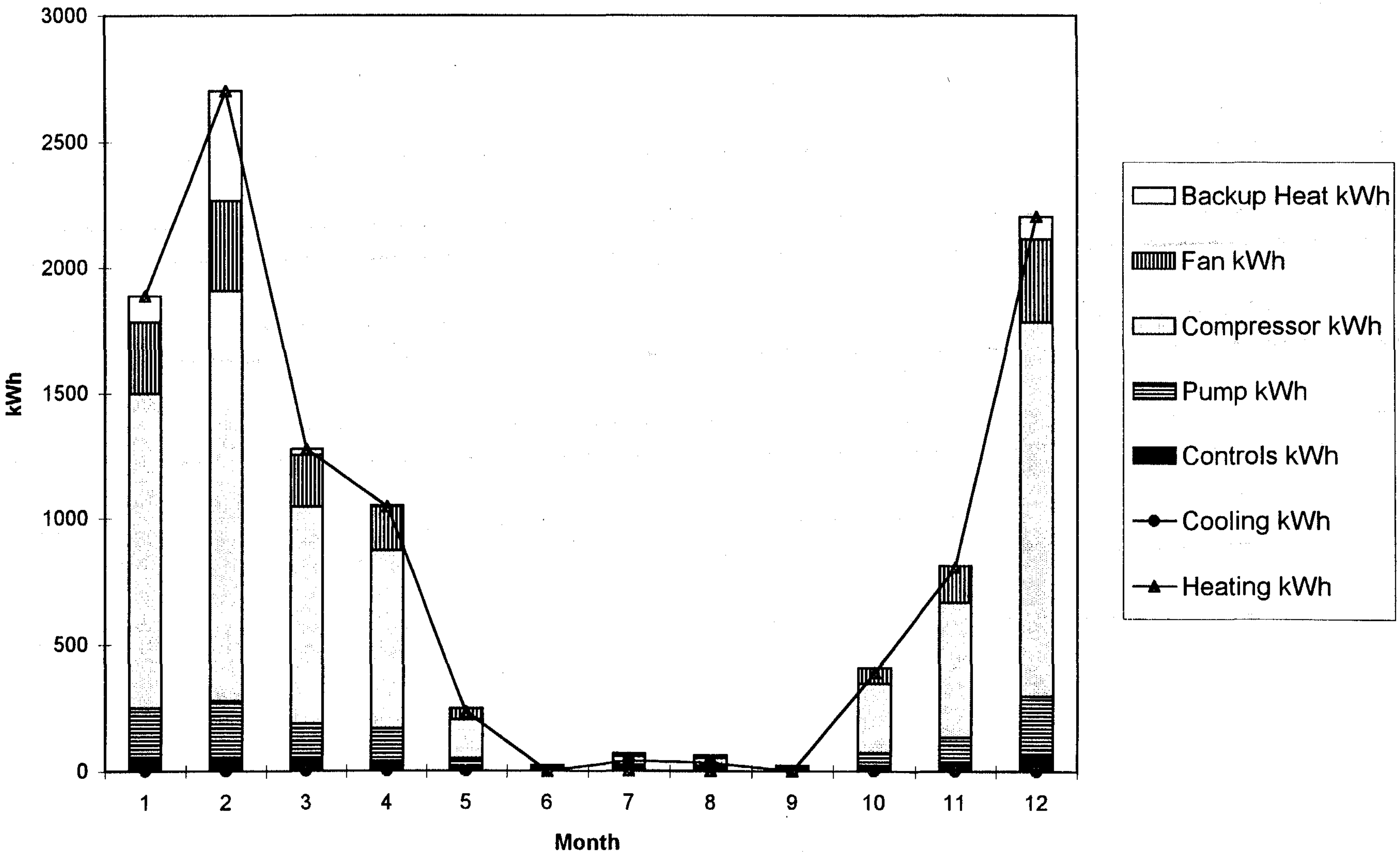

Figure 3-3(2). Site 2 - Monthly Energy Use

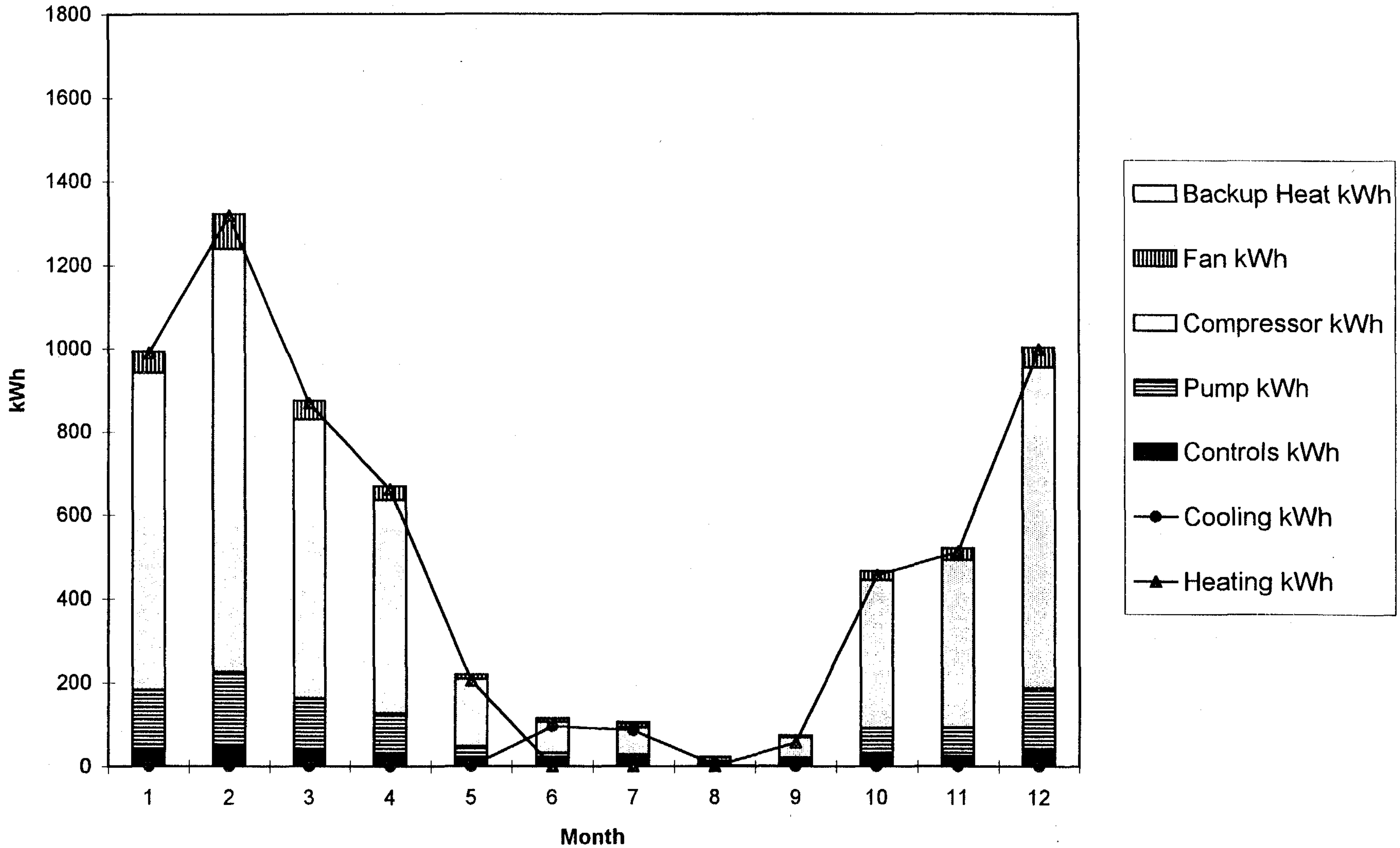

Figure 3-3(3). Site 3 - Monthly Energy Use

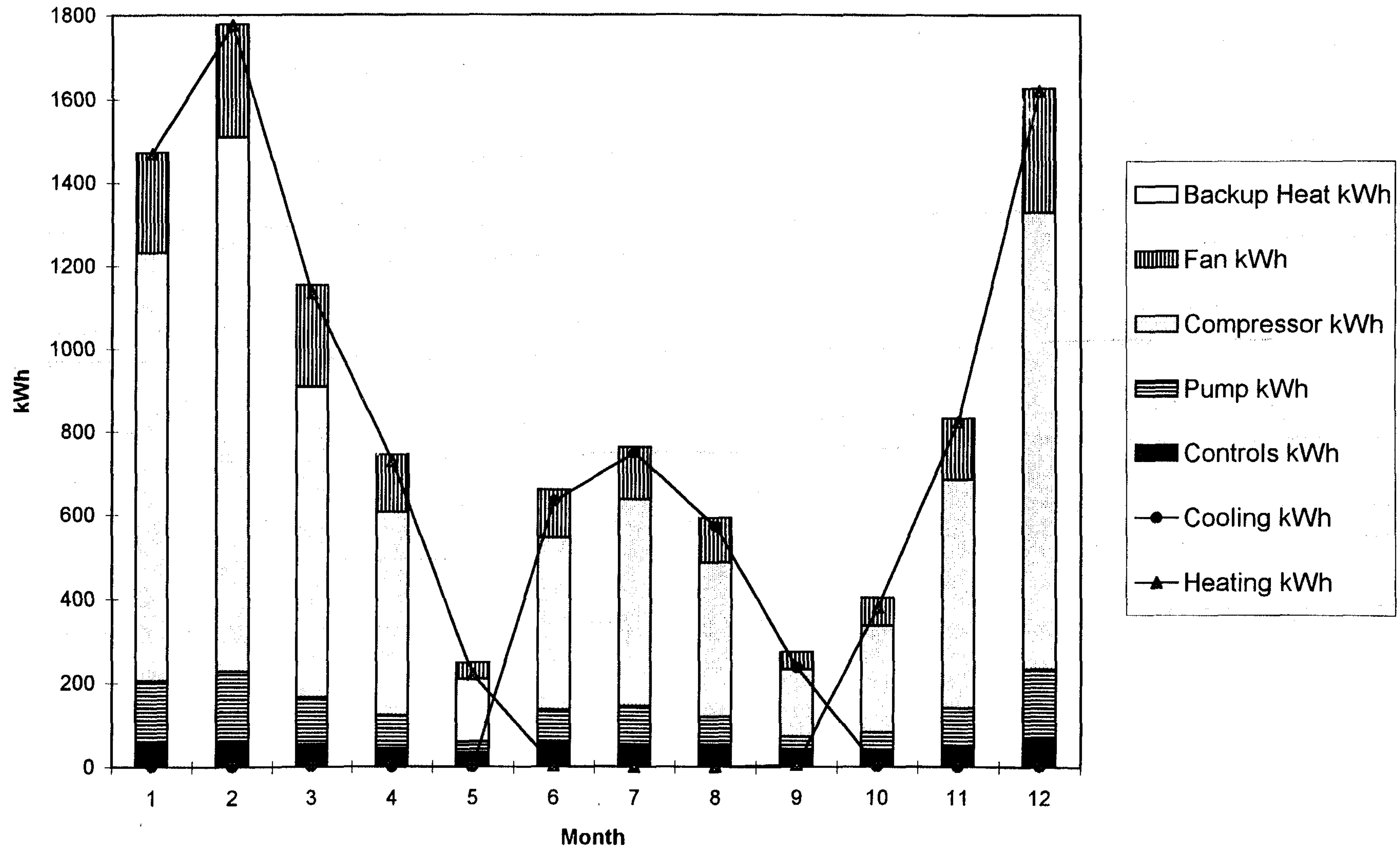

Figure 3-3(4). Site 4 - Monthly Energy Use

Table 3-2(1). Site 1 -- Monthly Summary

Site ID	14	14	14	14	14	13	13	14	14	14	14	14
Start Date	1-Jan	3-Feb	1-Mar	3-Apr	1-May	5-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec
End Date	26-Jan	28-Feb	30-Mar	30-Apr	31-May	4-Jun	31-Jul	31-Aug	30-Sep	31-Oct	30-Nov	31-Dec
Avg Outside Temp	36.0	27.1	42.1	48.2	58.7	71.2	74.8	68.6	61.9	51.8	46.7	35.2
Avg Indoor Temp	74.2	74.2	74.4	74.4	75.2	77.7	77.8	76.9	75.4	74.5	74.3	74.2
Avg Indoor RH	36	28	34	37	43	51	56	56	51	44	42	36
Total System kWh	854	1,096	691	428	170	291	543	258	23	401	508	1,044
Compressor kWh	609	785	490	302	115	149	288	123	9	279	359	744
Pump kWh	114	148	91	55	20	30	59	25	0	49	65	139
Fan kWh	103	131	84	51	19	95	175	94	0	53	62	128
Miscellaneous kWh	28	31	26	20	16	16	21	16	12	21	23	34
Backup Heat kWh	0	0	0	0	0	0	0	0	0	0	0	0
Heating kWh	851	1,094	685	417	153	0	0	0	4	387	499	1,042
Heating MBtu	6,458	8,264	5,053	3,111	1,114	0	0	0	29	2,968	3,706	7,837
Heating Mode/DHW MBtu	1,135	1,200	1,006	609	255	0	1	0	7	592	855	1,556
Heating COP	2.62	2.53	2.59	2.61	2.63	0.00	0.60	0.00	2.76	2.70	2.68	2.64
Cooling kWh	1	0	1	2	0	265	520	221	0	1	1	1
Cooling MBtu	6	3	8	13	3	2,523	5,051	2,121	0	5	10	6
Cooling EER	9.26	7.89	8.62	8.41	5.42	9.53	9.70	9.61	0.00	5.65	8.64	9.10
Cooling Mode/DHW MBtu	6	3	9	14	3	173	431	224	0	6	10	7
Loop Gallons	178,807	229,686	143,543	86,932	31,569	54,226	105,163	43,920	749	79,097	103,412	218,077
Avg Loop EWT	39.8	37.1	40.7	42.9	46.6	59.8	62.2	61.2	51.3	47.6	45.3	41.0
Avg Loop LWT	36.0	33.4	36.9	39.1	42.7	67.3	69.9	68.8	47.0	43.5	41.3	37.2
Runtime Hrs	240	292	195	117	41	66	128	53	1	103	137	294
Comp Low Spd Hrs	250	317	200	119	43	69	133	55	1	105	141	303
Comp High Spd Hrs	0	6	0	1	0	0	0	0	0	1	0	0
Fan Low Speed Hrs	0	0	0	0	0	0	0	0	0	0	0	0
Fan Medium Speed Hrs	0	0	0	0	0	0	0	0	0	0	0	0
Fan High Speed Hrs	278	354	228	140	52	251	466	252	1	144	164	340
DHW Resistance kWh	326	259	346	385	448	504	549	561	553	443	353	348
Desuperheater DHW MBtu	1,142	1,203	1,015	624	258	173	432	224	7	600	867	1,564
DHW Gallons	1,975	1,721	1,859	1,903	2,035	2,375	2,944	2,913	2,632	2,242	1,844	2,276
Month	1	2	3	4	5	6	7	8	9	10	11	12

Table 3-2(2). Site 2 -- Monthly Summary

Site ID	23	23	23	23	23	23	23	23	23	23	23	23
Start Date	1-Jan	3-Feb	1-Mar	2-Apr	1-May	5-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec
End Date	26-Jan	28-Feb	30-Mar	30-Apr	31-May	4-Jun	31-Jul	31-Aug	30-Sep	31-Oct	30-Nov	31-Dec
Avg Outside Temp	33.7	24.6	37.5	45.7	57.2	70.1	74.0	68.1	61.2	50.7	45.4	33.1
Avg Indoor Temp	64.2	63.3	64.6	66.0	67.7	75.9	78.9	74.6	68.6	64.6	62.9	63.9
Avg Indoor RH	32.6	19.3	29.0	35.3	49.4	62.3	68.9	70.3	68.4	57.0	47.5	33.1
Total System kWh	1,886	2,705	1,276	1,049	247	23	70	61	23	409	812	2,203
Compressor kWh	1,252	1,632	858	704	153	7	35	30	7	274	534	1,484
Pump kWh	193	221	144	130	32	3	9	8	3	51	99	231
Fan kWh	284	359	208	174	47	3	11	10	3	63	145	332
Miscellaneous kWh	53	54	41	37	16	9	14	13	10	22	33	65
Backup Heat kWh	104	439	25	4	0	0	0	0	0	0	0	90
Heating kWh	1,885	2,705	1,276	1,046	233	0	2	3	0	390	805	2,203
Heating MBtu	11,754	12,651	8,845	7,455	1,542	0	6	28	0	3,646	6,965	15,206
Heating Mode/DHW MBtu	2,194	2,656	1,347	1,176	430	0	3	5	0	600	765	2,173
Heating COP	2.17	1.66	2.34	2.42	2.49	0.00	1.80	3.32	0.00	3.19	2.82	2.31
Cooling kWh	0	0	0	1	0	0	42	32	0	0	0	0
Cooling MBtu	4	0	2	11	4	4	495	349	0	2	0	3
Cooling EER	17.75	5.33	10.59	14.33	11.70	9.42	11.84	10.79	0.00	7.22	0.00	32.86
Cooling Mode/DHW MBtu	4	0	2	12	4	(0)	54	37	0	2	0	3
Loop Gallons	221,653	252,967	167,025	150,660	36,370	91	8,185	6,366	0	65,853	124,140	272,029
Avg Loop EWT	32.1	29.9	30.6	32.4	40.2	53.1	63.9	67.8	0.0	55.8	46.3	35.3
Avg Loop LWT	26.4	23.6	25.3	27.5	35.4	61.6	72.8	75.6	0.0	49.6	40.6	29.6
Runtime Hrs	377	383	311	282	63	0	13	10	0	106	209	471
Comp Low Spd Hrs	268	211	234	246	67	0	13	10	0	108	199	342
Comp High Spd Hrs	149	276	82	39	0	0	0	0	0	0	14	154
Fan Low Speed Hrs	30	21	31	55	27	0	0	0	0	13	45	38
Fan Medium Speed Hrs	266	212	230	234	59	0	13	10	0	104	188	339
Fan High Speed Hrs	155	282	85	40	0	0	0	0	0	0	15	160
DHW Resistance kWh	56	42	64	157	249	181	207	226	233	167	143	60
Desuperheater DHW MBtu	2,198	2,656	1,349	1,188	435	(0)	58	42	0	601	766	2,175
DHW Gallons	887	2,056	965	1,624	1,435	366	1,442	1,593	1,415	1,406	1,317	1,282
Month	1	2	3	4	5	6	7	8	9	10	11	12

Table 3-2(3). Site 3 -- Monthly Summary

Site ID	34	34	34	34	34	34	34	34	34	34	34	34
Start Date	1-Jan	3-Feb	1-Mar	2-Apr	1-May	5-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec
End Date	26-Jan	28-Feb	30-Mar	30-Apr	31-May	4-Jun	31-Jul	31-Aug	30-Sep	31-Oct	30-Nov	31-Dec
Avg Outside Temp	32.2	22.3	36.4	41.7	55.2	66.7	69.2	63.7	57.6	48.9	43.8	32.7
Avg Indoor Temp	68.7	70.8	70.4	68.6	69.5	71.8	73.3	70.8	69.0	68.9	66.3	69.6
Avg Indoor RH	40	31	36	37	45	60	66	67	65	54	48	42
Total System kWh	992	1,323	874	669	218	114	105	22	74	466	521	1,002
Compressor kWh	761	1,015	667	509	160	74	64	8	49	354	400	768
Pump kWh	144	178	127	96	29	15	12	(0)	7	64	68	145
Fan kWh	50	84	45	34	12	9	10	2	5	22	29	49
Miscellaneous kWh	37	45	35	29	17	17	15	12	13	26	23	41
Backup Heat kWh	0	0	0	0	0	0	4	0	0	0	0	0
Heating kWh	989	1,319	868	661	204	0	0	0	57	456	511	997
Heating MBtu	6,912	9,617	6,345	4,871	1,221	0	0	0	351	3,006	3,110	7,262
Heating Mode/DHW MBtu	1,506	1,891	1,507	1,228	620	0	0	0	196	1,378	1,055	2,019
Heating COP	2.49	2.56	2.65	2.70	2.65	0.00	0.00	0.00	2.84	2.82	2.39	2.73
Cooling kWh	0	0	0	0	0	95	85	4	0	0	0	1
Cooling MBtu	3	3	3	3	2	1,211	1,110	51	(0)	4	6	7
Cooling EER	12.89	9.14	10.63	11.78	8.22	12.71	13.03	12.64	(0.94)	21.85	14.75	11.80
Cooling Mode/DHW MBtu	3	3	3	3	2	271	250	9	0	4	7	7
Loop Gallons	205,232	249,682	179,175	136,883	42,704	23,741	20,090	970	11,195	94,932	99,441	209,528
Avg Loop EWT	37.6	34.8	37.6	39.4	45.1	57.7	59.5	59.9	49.3	46.5	43.1	39.9
Avg Loop LWT	33.6	30.7	33.6	35.3	40.8	64.3	66.5	67.0	44.7	42.2	38.6	35.8
Runtime Hrs	292	380	273	206	56	32	27	1	16	137	128	315
Comp Low Spd Hrs	305	306	262	205	64	33	28	1	15	139	131	314
Comp High Spd Hrs	8	69	10	4	0	0	0	0	1	1	17	4
Fan Low Speed Hrs	26	18	27	27	13	47	75	0	5	27	19	34
Fan Medium Speed Hrs	298	308	256	197	60	31	26	1	14	130	126	304
Fan High Speed Hrs	9	76	12	5	0	0	0	0	1	2	18	4
DHW Resistance kWh	5	7	7	5	5	1	4	7	8	6	4	8
Desuperheater DHW MBtu	1,509	1,894	1,512	1,231	623	271	251	9	196	1,384	1,062	2,026
DHW Gallons	29,953	29,181	39,642	31,782	45,599	9,046	41,583	71,919	76,764	47,470	35,517	53,441
Month	1	2	3	4	5	6	7	8	9	10	11	12

Table 3-2(4). Site 4 -- Monthly Summary

Site ID	44	44	44	44	44	44	44	44	44	44	44	44
Start Date	1-Jan	3-Feb	1-Mar	3-Apr	1-May	5-Jun	1-Jul	3-Aug	1-Sep	1-Oct	1-Nov	1-Dec
End Date	26-Jan	28-Feb	30-Mar	30-Apr	31-May	4-Jun	24-Jul	31-Aug	30-Sep	31-Oct	30-Nov	31-Dec
Avg Outside Temp	26.2	15.0	33.0	40.1	55.4	70.9	74.9	67.2	60.5	48.4	40.1	25.6
Avg Indoor Temp	75.1	75.0	74.9	75.2	76.0	72.7	70.8	70.7	71.0	73.0	74.0	73.9
Avg Indoor RH	29	19	28	29	38	49	51	54	53	47	41	30
Total System kWh	1,474	1,778	1,154	745	248	661	763	593	274	403	834	1,625
Compressor kWh	1,027	1,282	743	485	149	411	493	368	161	255	546	1,095
Pump kWh	145	166	113	79	26	81	91	67	30	42	90	164
Fan kWh	243	269	245	138	40	115	126	107	42	67	148	296
Controls kWh	59	61	53	43	33	55	53	51	41	40	49	70
Backup Heat kWh	0	0	0	0	0	0	0	0	0	0	0	0
Heating kWh	1,470	1,776	1,135	730	219	3	0	0	5	380	825	1,618
Heating MBtu	9,807	11,059	7,393	5,201	1,640	24	0	0	53	2,456	5,852	11,206
Heating Mode/DHW MBtu	2,536	2,952	2,119	1,470	618	9	0	0	8	1,502	2,214	3,139
Heating COP	2.46	2.31	2.46	2.68	3.02	3.23	0.00	0.00	3.57	3.05	2.87	2.60
Cooling kWh	1	0	2	0	1	634	750	572	236	1	0	1
Cooling MBtu	10	3	6	6	7	6,509	7,542	5,742	2,573	1	4	3
Cooling EER	13.69	13.43	3.71	11.64	11.40	10.27	10.05	10.04	10.89	1.14	9.32	4.44
Cooling Mode/DHW MBtu	11	3	8	6	7	870	1,158	974	474	1	5	4
Loop Gallons	238,140	269,065	182,989	129,576	41,447	141,043	163,341	120,924	52,331	70,167	151,655	272,525
Avg Loop EWT	31.6	27.9	28.7	32.7	41.8	60.1	68.5	69.9	66.3	55.9	46.9	37.3
Avg Loop LWT	26.9	23.0	24.2	28.1	36.6	67.0	75.3	76.9	73.1	50.5	42.0	32.5
Runtime Hrs	313	325	252	179	56	189	214	157	68	91	202	368
Comp Low Spd Hrs	250	227	206	165	56	190	217	160	69	94	205	322
Comp High Spd Hrs	85	154	53	17	1	0	3	0	0	0	2	57
Fan Low Speed Hrs	136	123	197	74	18	164	210	65	22	42	91	187
Fan Medium Speed Hrs	243	223	197	157	52	29	0	152	65	86	192	311
Fan High Speed Hrs	87	157	54	18	1	0	47	0	0	0	2	58
DHW Resistance kWh	0	0	0	0	0	0	0	0	0	0	0	0
Desuperheater DHW MBtu	2,546	2,955	2,130	1,478	626	879	1,159	974	483	1,505	2,222	3,144
DHW Gallons	0	0	0	0	0	0	0	0	0	0	0	0
Month	1	2	3	4	5	6	7	8	9	10	11	12

At Site 2 (see Figure 3-3[2]) the data show the use of electric resistance backup heat, primarily in the month of February. To investigate why backup heating was only required at Site 2, selected data from each site for February have been extracted and are shown in Table 3-3. However, review of this monthly average data does not at first glance provide a satisfactory reason for the problems at Site 2. Outdoor temperatures and ground loop temperatures at Site 2 are comparable to conditions at the other sites and these temperatures are warmer than at Site 4, which did not require backup heat. Although the indoor temperature at Site 2 was maintained at a very cool 63 °F, the house required 12,651 MBtu of heat energy, and the heating demand exceeded the heating capacity of the compressor, requiring the use of the backup heat.

The question is why the efficiency of Site 4 was so much greater than at Site 2, although the total thermal outputs are equivalent and the ground loop temperatures are colder and the indoor temperatures warmer. The average COPs, including all thermal outputs and inputs, are 1.66 at Site 2 and 2.31 at Site 4. However, these heating thermal outputs and COPs provide an overall measure, including the energy use, and, if appropriate, the heat output, of all of the components of the heat-pump system, including pumps, fans, and backup heat. To provide a more precise comparison, the net thermal output COPs of the compressor are calculated, where net thermal output includes both space heating and desuperheater water heating, but does not include fan heat or backup heating. Thus recalculated, the net thermal output of the compressor and its efficiency at Site 4 are both greater than at Site 2. Other factors may explain these differences in performance. However, a more detailed analysis of this issue exceeds the specific scope of this project report.

Graphs of Average Ground Loop and Outside Air Temperatures

Figures 3-4(1) through 3-4(4) show the average temperatures entering and leaving the ground loop and the average air temperature. These temperatures are plotted together to provide a general basis for the comparison of ground-coupled systems with air-source systems. To provide more detail Figures 3-5(1) through 3-5(4) show the same temperatures averaged on a daily basis and plotted only for the days when the system was operated. Gaps in the plot of entering water temperature indicate days when the system was turned off.

Table 3-3. February Summary Data from Four Sites				
Site ID	1	2	3	4
Avg Outside Temp	27.1	24.6	22.3	15.0
Avg Indoor Temp	74.2	63.3	70.8	75.0
Total System kWh	1,096	2,705	1,323	1,778
Compressor kWh	785	1,632	1,015	1,282
Pump kWh	148	221	178	166
Fan kWh	131	359	84	269
Controls kWh	31	54	45	61
Backup Heat kWh	0	439	0	0
Heating kWh	1,094	2,705	1,319	1,776
Heating MBtu	8,264	12,651	9,617	11,059
Heating Mode/DHW MBtu	1,200	2,656	1,891	2,952
Heating COP	2.53	1.66	2.56	2.31
Avg Loop EWT	37.11	29.94	34.82	27.87
Avg Loop LWT	33	24	31	23
Comp Low Spd Hrs	317	211	306	227
Comp High Spd Hrs	6	276	69	154
Avg percent on	58%	86%	67%	84%
Net Thermal Output	9,015	12,584	11,221	13,092
Net COP	3.36	2.26	3.24	2.99

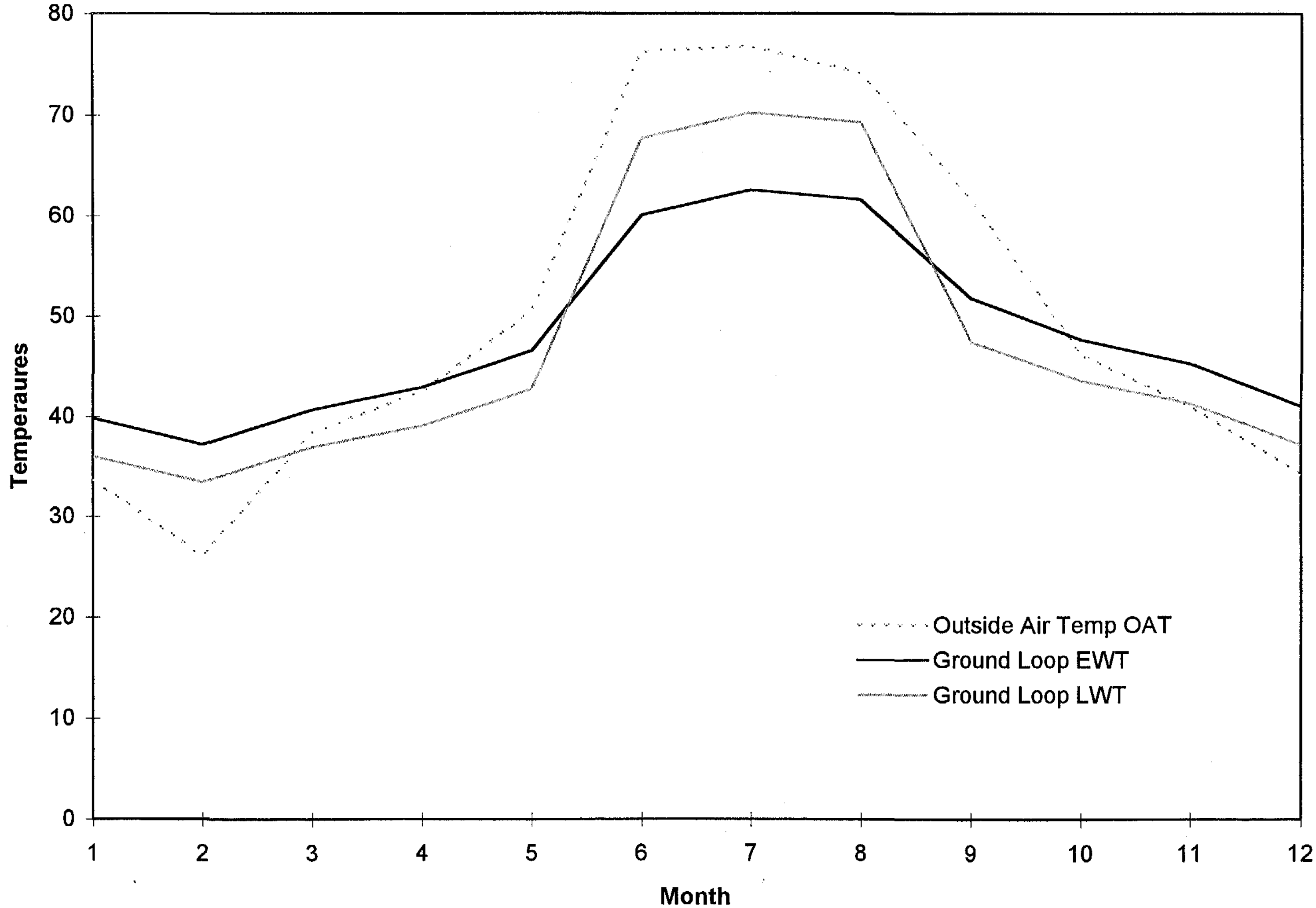

Figure 3-4(1). Site 1 - Monthly Average Ground Loop and Outside Air Temperatures

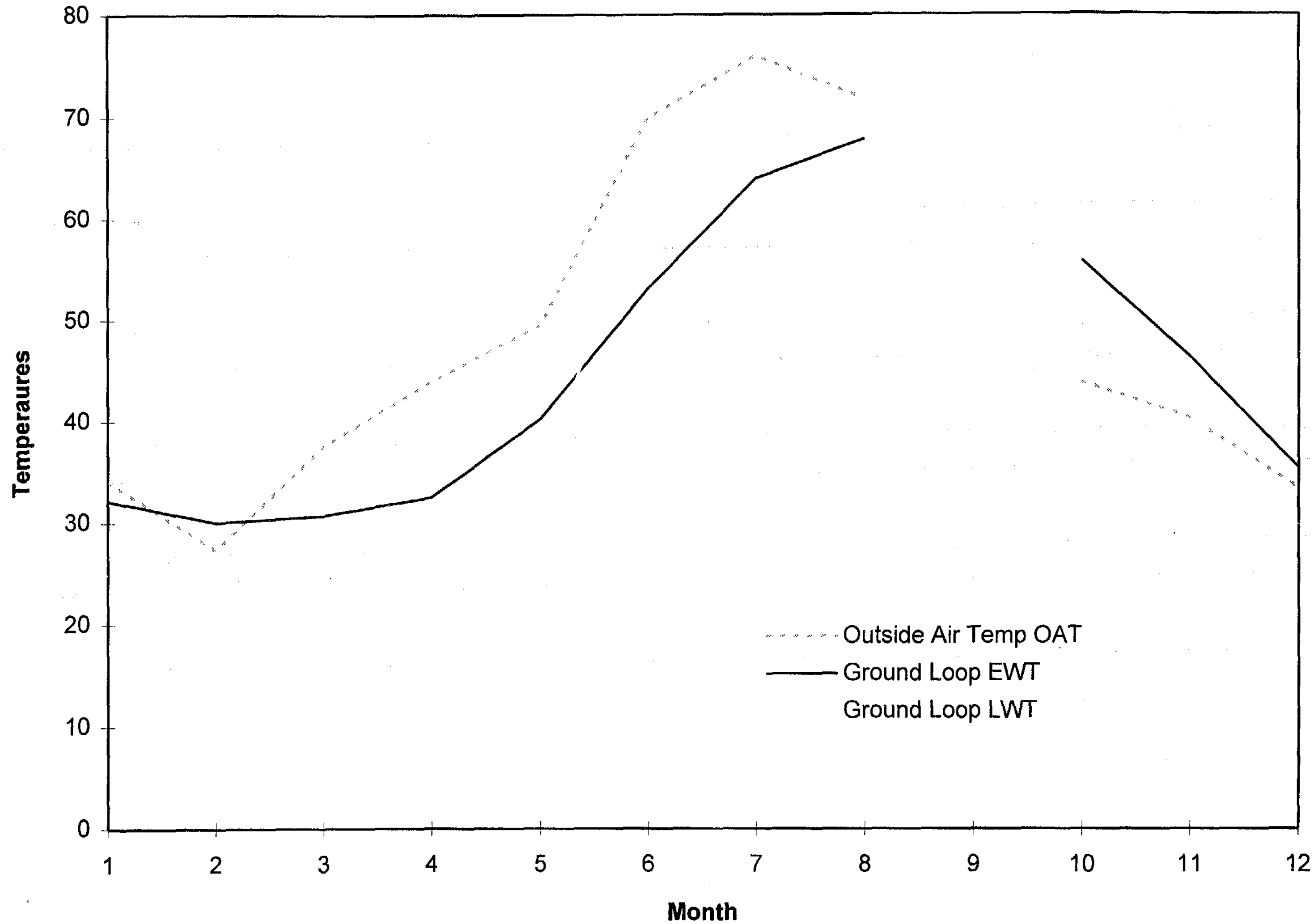

Figure 3-4(2). Site 2 - Monthly Average Ground Loop and Outside Air Temperatures

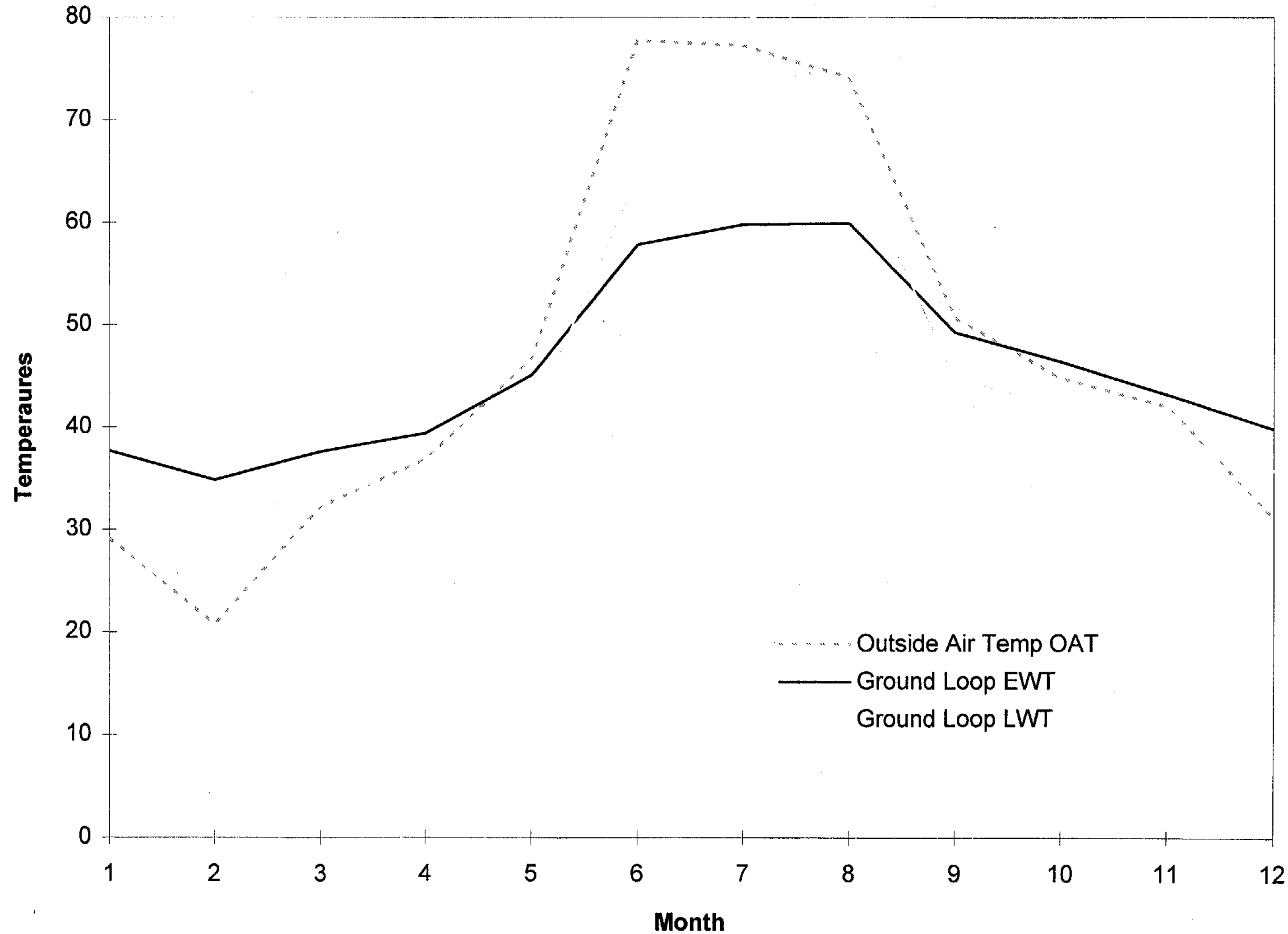

Figure 3-4(3). Site 3 - Monthly Average Ground Loop and Outside Air Temperatures

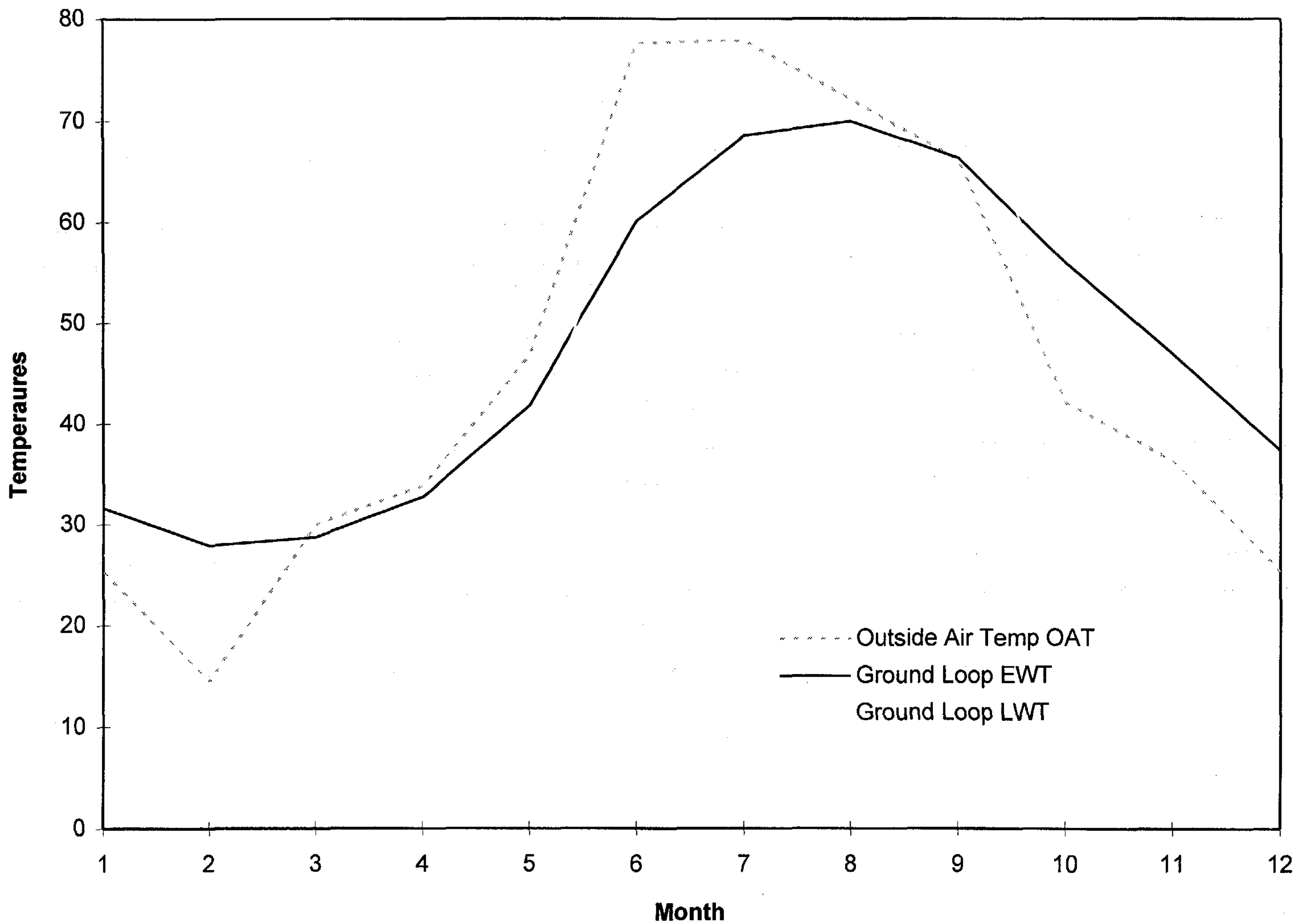

Figure 3-4(4). Site 4 - Monthly Average Ground Loop and Outside Air Temperatures

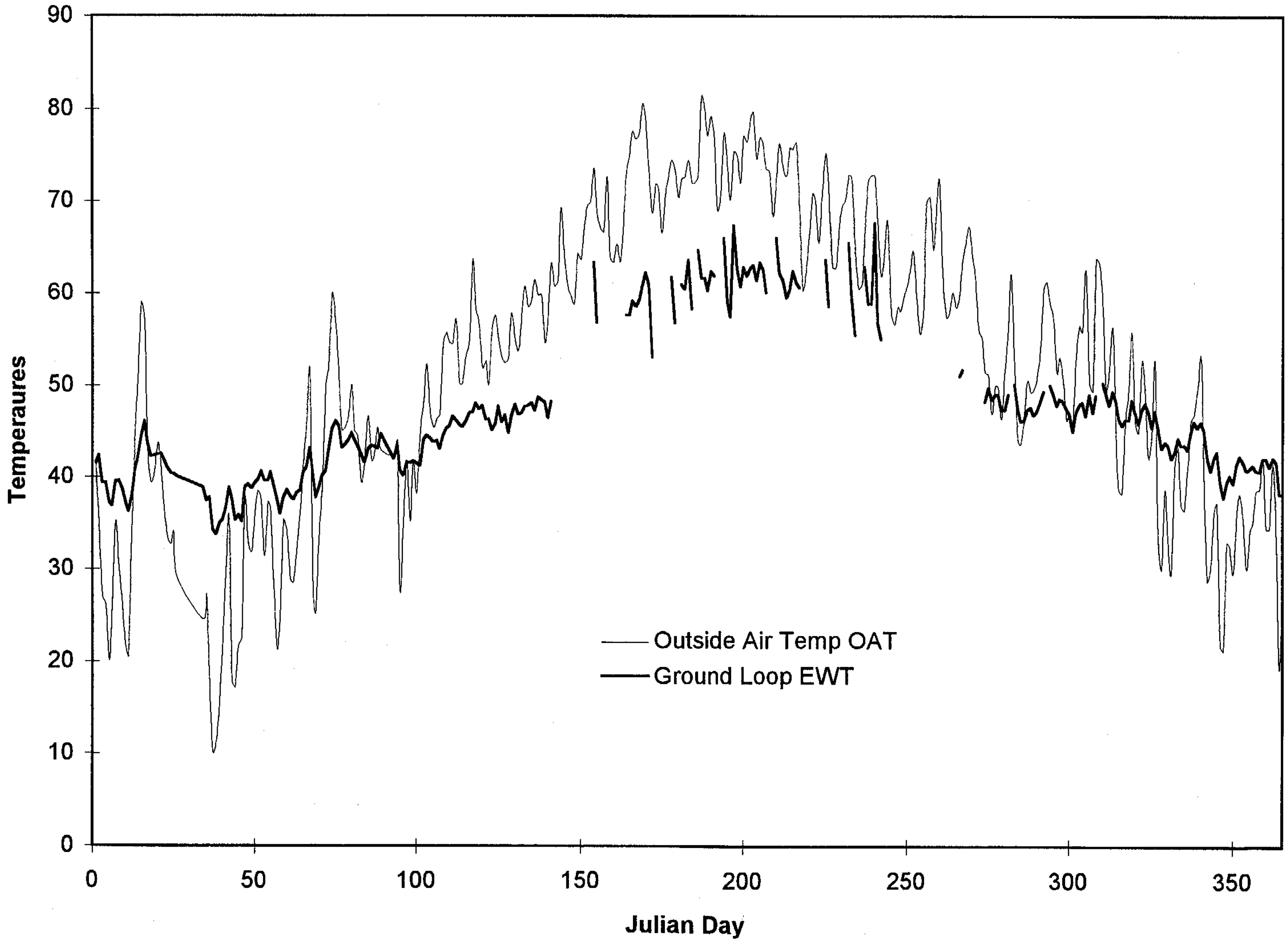

Figure 3-5(1). Site 1 - Daily Average Ground Loop and Outside Air Temperatures

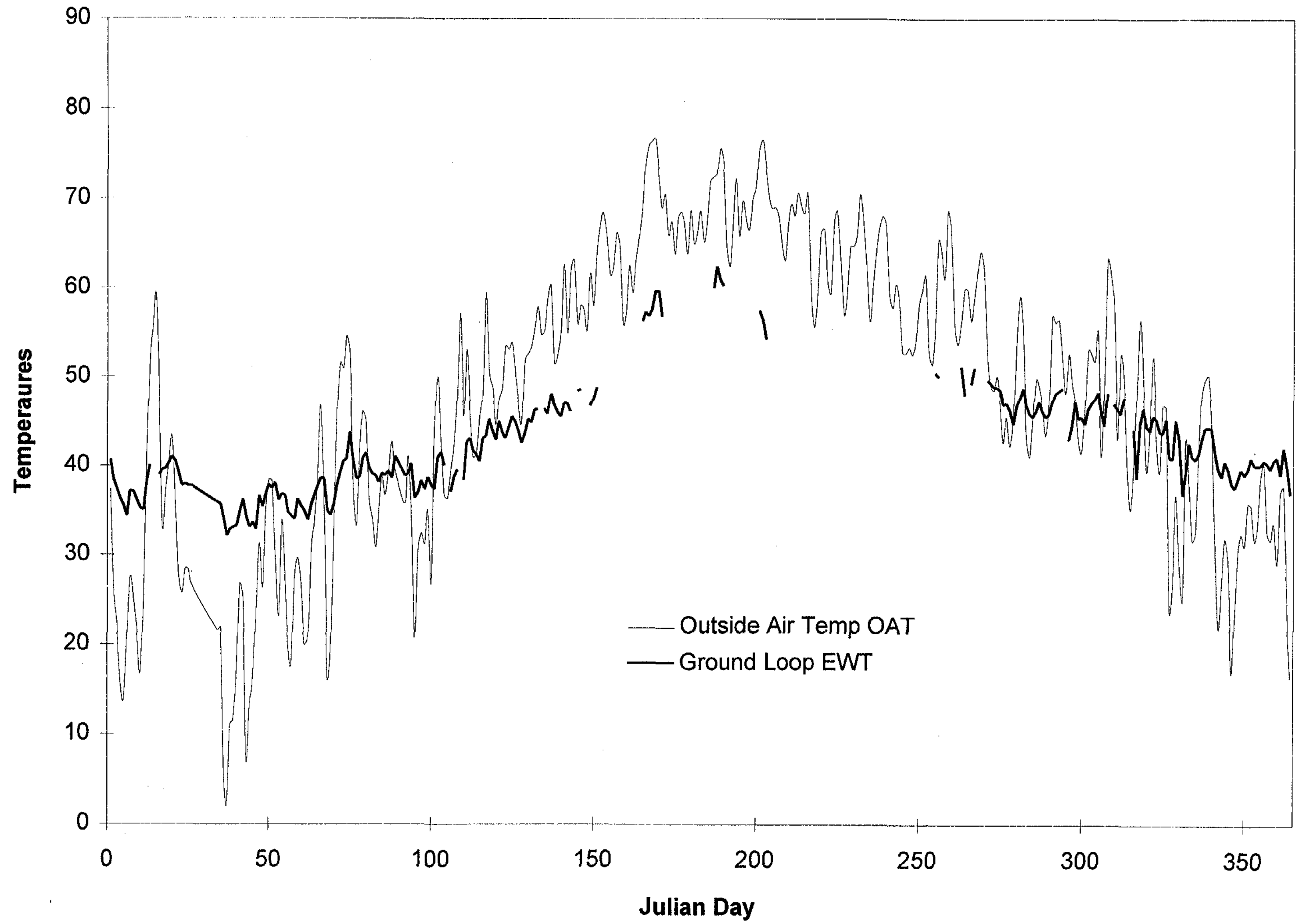

Figure 3-5(3). Site 3 - Daily Average Ground Loop and Outside Air Temperatures

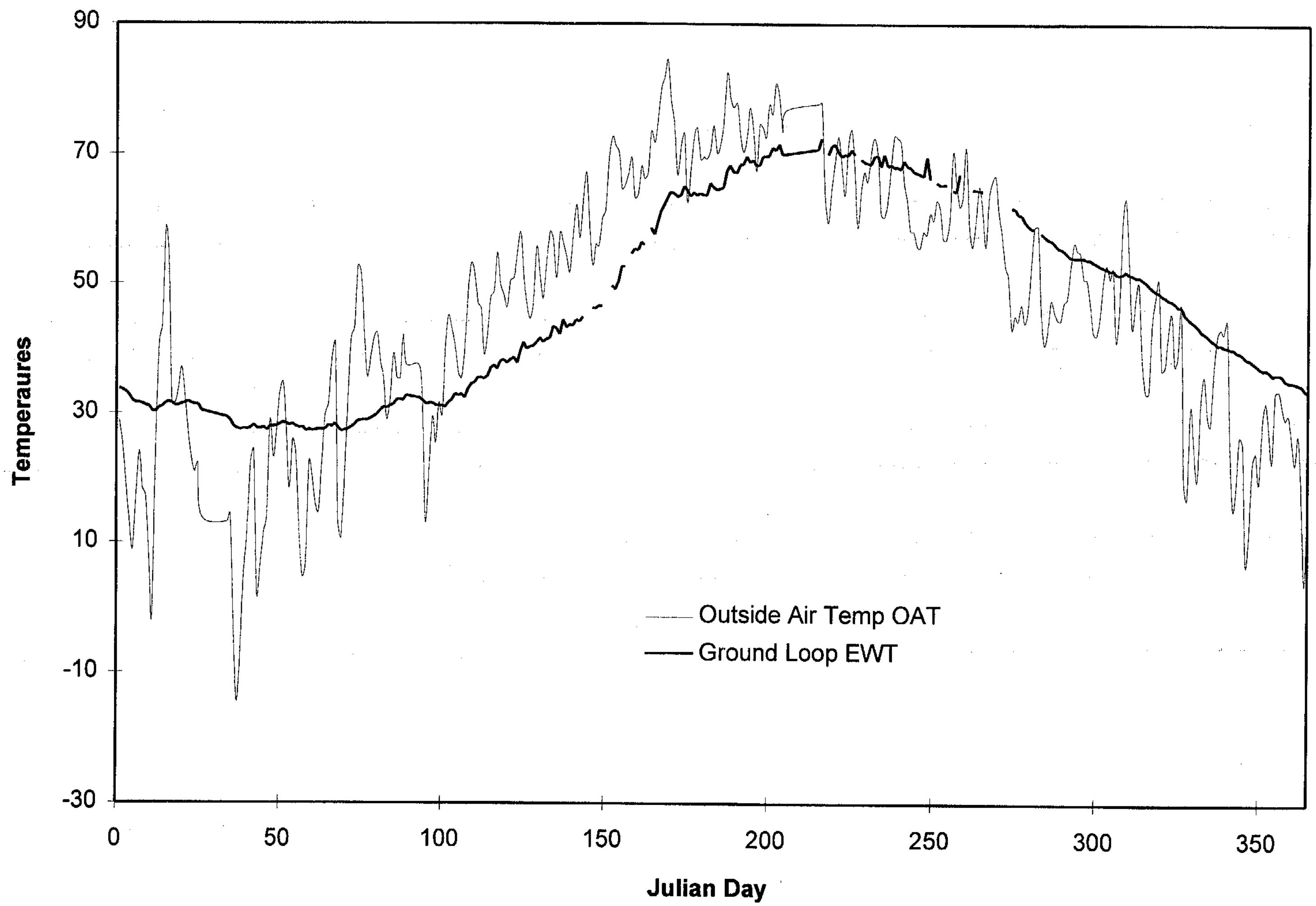

Figure 3-5(4). Site 4 - Daily Average Ground Loop and Outside Air Temperatures

In general, these figures show that the ground-loop water temperatures are not constant but tend to mimic outside air temperature. At first, this may seem surprising, since the temperature of undisturbed ground is relatively constant. However, the GSHP effectively couples the ground field to the outside air via the air-conditioned space. During the heating season, thermal energy is transported from the ground to the house to balance the loss of energy from the house to the outside air. This process cools the ground just as if the ground were in direct contact with the outside air. During the cooling season, the thermal flows are reversed as the temperature of the ground field is increased by the operation of the heat pump.

The type of ground field affects the relationship between outside air temperature profiles and ground loop temperature profiles. For the vertical systems (Sites 1 and 3) the profiles of air and loop temperatures are symmetrical. For the horizontal systems (Sites 2 and 4) the loop temperatures show a lag of two to three months relative to outside air temperatures. The lag occurs because the temperature effect of the outside air is delayed as it penetrates from the ground surface to the nominal six-foot depth of the horizontal ground loop systems. The horizontal field temperatures are affected both directly by the operation of the heat pump and indirectly as the effects of temperatures at the surface are delayed by the thermal diffusivity of the ground. Because of their greater depth, the temperatures of the vertical systems are not so much a function of delayed thermal effects at the surface as of the operation of the heat pump system.

The temperature plots also show that during the coldest weather, the ground loop temperatures are significantly warmer than outside air temperatures. The warmer temperature of the ground field relative to the air temperatures allows the ground-coupled systems to operate with greater efficiency and capacity than air-source systems during the coldest weather. However, as shown by data from all four sites, there are significant periods during the heating season when the ground temperature is colder than the air temperature. During these periods, an air-source system could theoretically operate more efficiently. From the comparison of ground loop and outside air temperatures, it can be anticipated that ground-coupled systems will provide superior performance during peak load conditions of very cold outside air temperatures. However, based on the examination of these monthly temperatures, ground coupling does not provide an unequivocal thermal source temperature advantage under typical heating season conditions.

During the cooling season, temperatures of the ground field are cooler than outside air temperatures most of the time at most of the sites. Other factors being equal, these cooler temperatures will allow a ground-coupled heat pump to operate with greater efficiency and capacity than an air-source system during the cooling season in general and during periods of hot weather in particular. However, a primary reason that the ground temperatures remain cool is that the cooling load, and thus the quantity of heat rejected to the ground field is small compared to the thermal demand of the heating season. Site 4, which used the most cooling energy, shows the effect of operation of the system in the cooling mode on the ground loop temperatures. There are significant periods of time during the latter half of the cooling season at this site (see Figures 3-4[4] and 3-5[4] when the ground temperature has also been raised by the operation of the system to point that it exceeds the air temperature. With air temperatures cooler than the ground field temperature, a heat pump could theoretically operate more efficiently using the outside air as its thermal sink.

HEATING AND COOLING SEASON LOAD PROFILES

Load profiles, showing the average demand of an appliance as a function of the time of day, are often used by utilities as a basis for demand-side management (DSM) planning and evaluation and as input for end-use forecasting models. Load profiles for these purposes should be based on a representative sample of customers. Since this is a familiar format, load profiles have been prepared for weekdays, weekend days, and five selected peak days for each of the four sites. It should not be assumed that these profiles are necessarily representative of the potential performance of GSHP systems used by any other group of utility customers.

Figures 3-6(1) through 3-6(4) provide heating season load and temperature profiles for average and peak days for each of the four sites. Figures 3-7(1) through 3-7(4) provide the comparable profiles for the cooling season. Each figure includes four charts.

(1) Average Day Input Demand kW and Output Thermal MBH*

(2) Peak Day Input Demand kW and Output Thermal MBH

(3) Average Day Temperatures including
- Air Coil Entering Air Temperature (EAT)
- Outside Air Temperature (OAT)
- Ground Loop Entering Water Temperature (EWT)

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*MBH denotes 1000 Btu per hour.

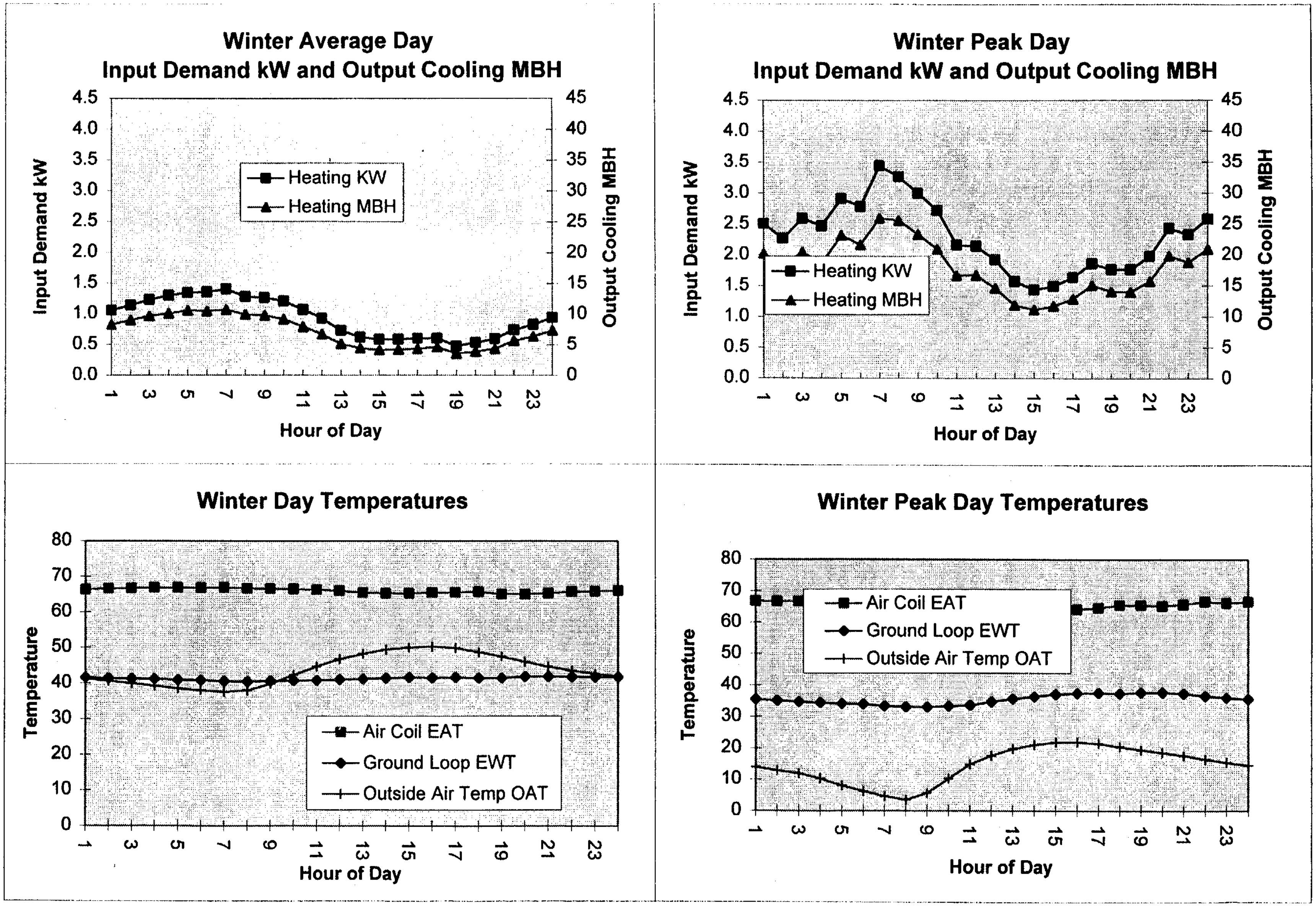


Figure 3-6(1). Site 1 - Winter Average and Peak Day Profiles

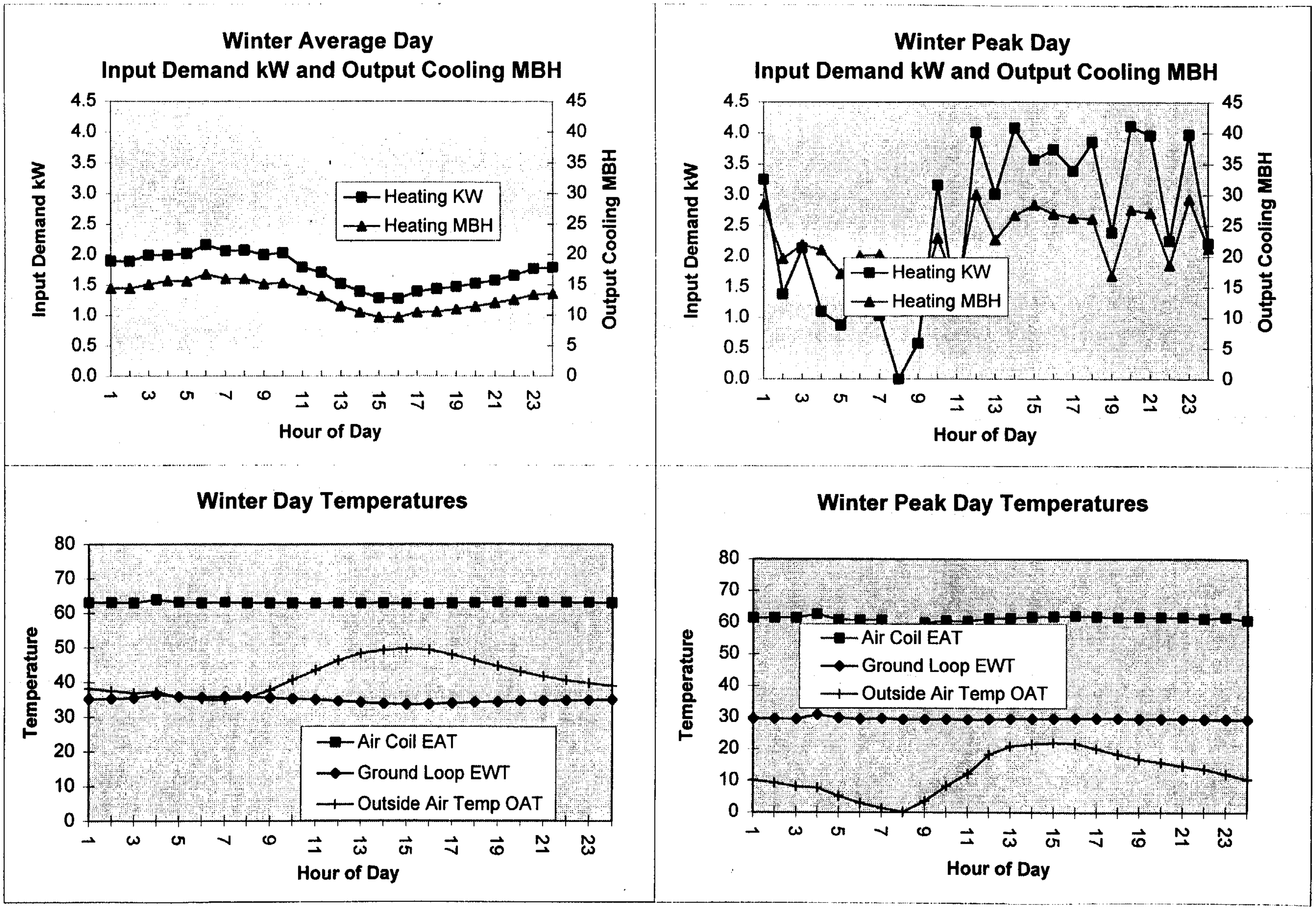


Figure 3-6(2). Site 2 - Winter Average and Peak Day Profiles

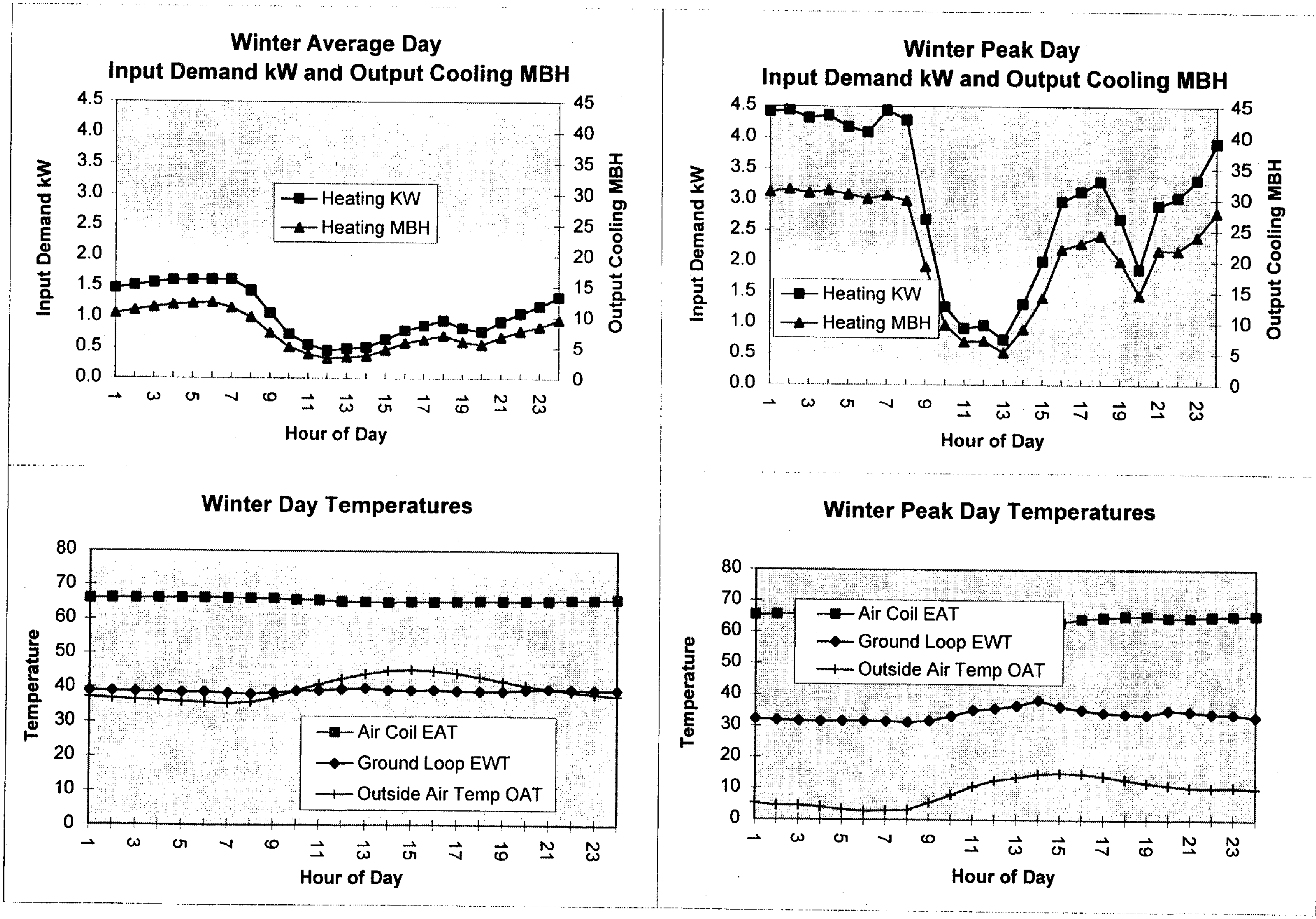


Figure 3-6(3). Site 3 - Winter Average and Peak Day Profiles

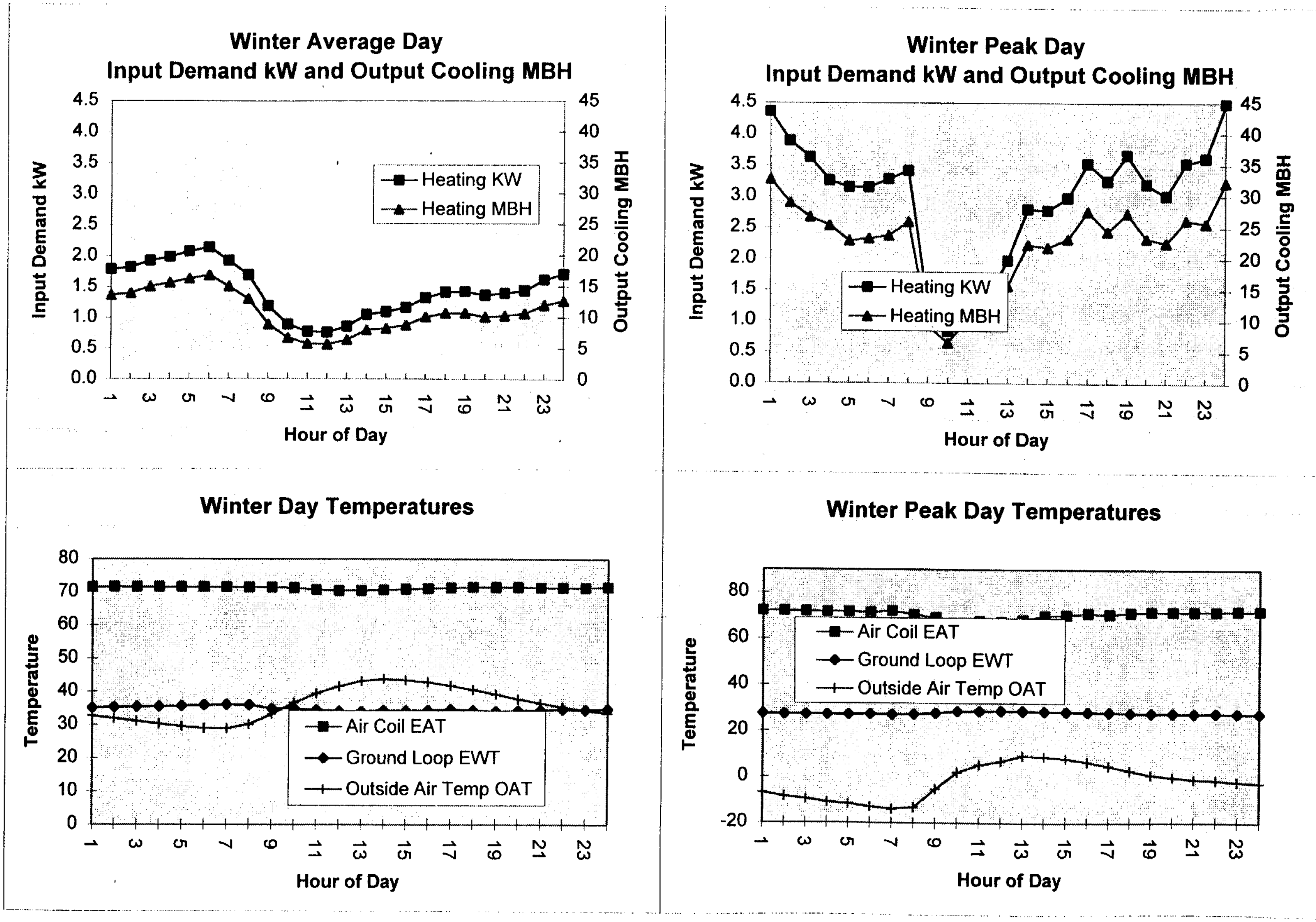


Figure 3-6(4). Site 4 - Winter Average and Peak Day Profiles

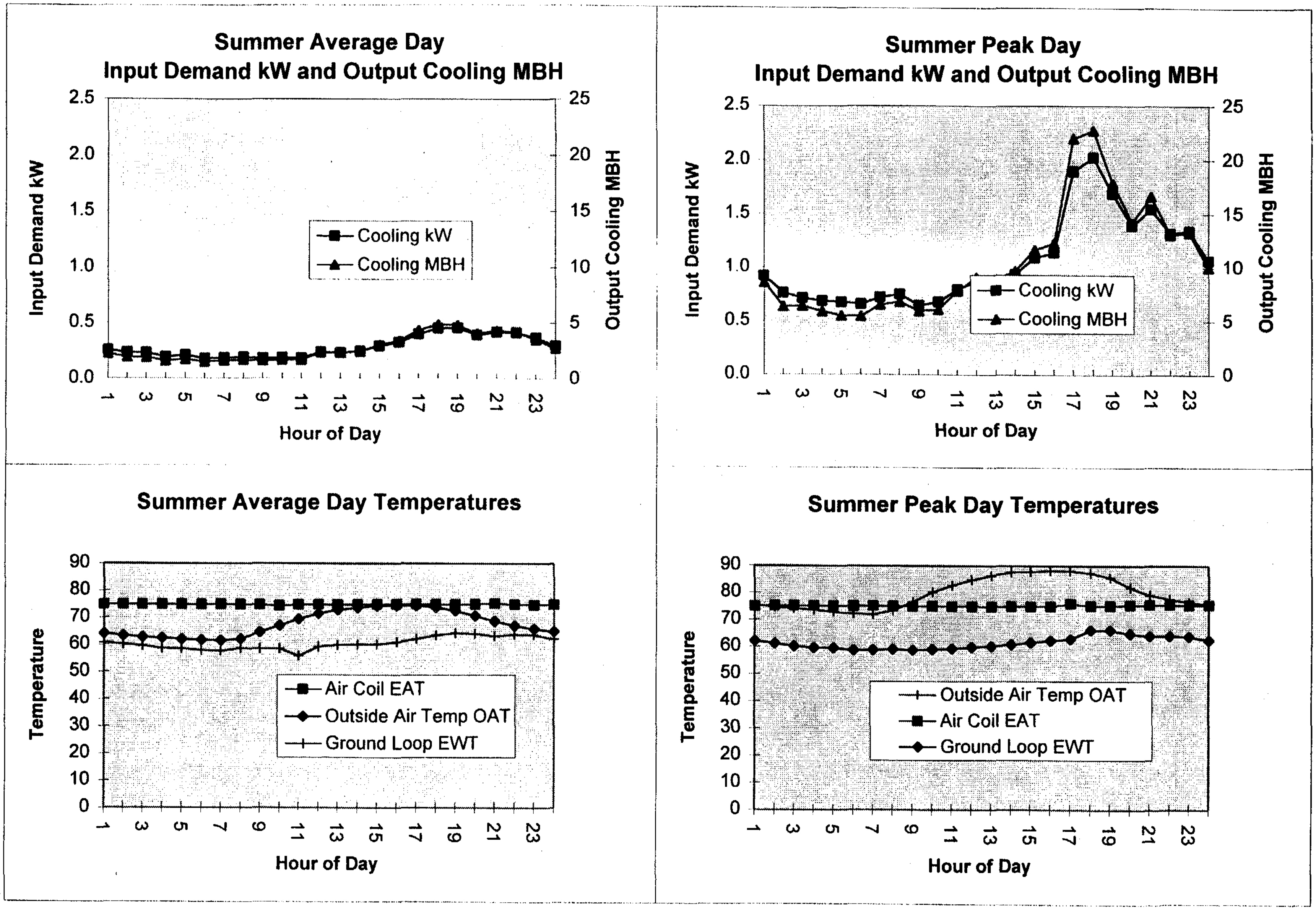


Figure 3-7(1). Site 1 - Summer Average and Peak Day Profiles

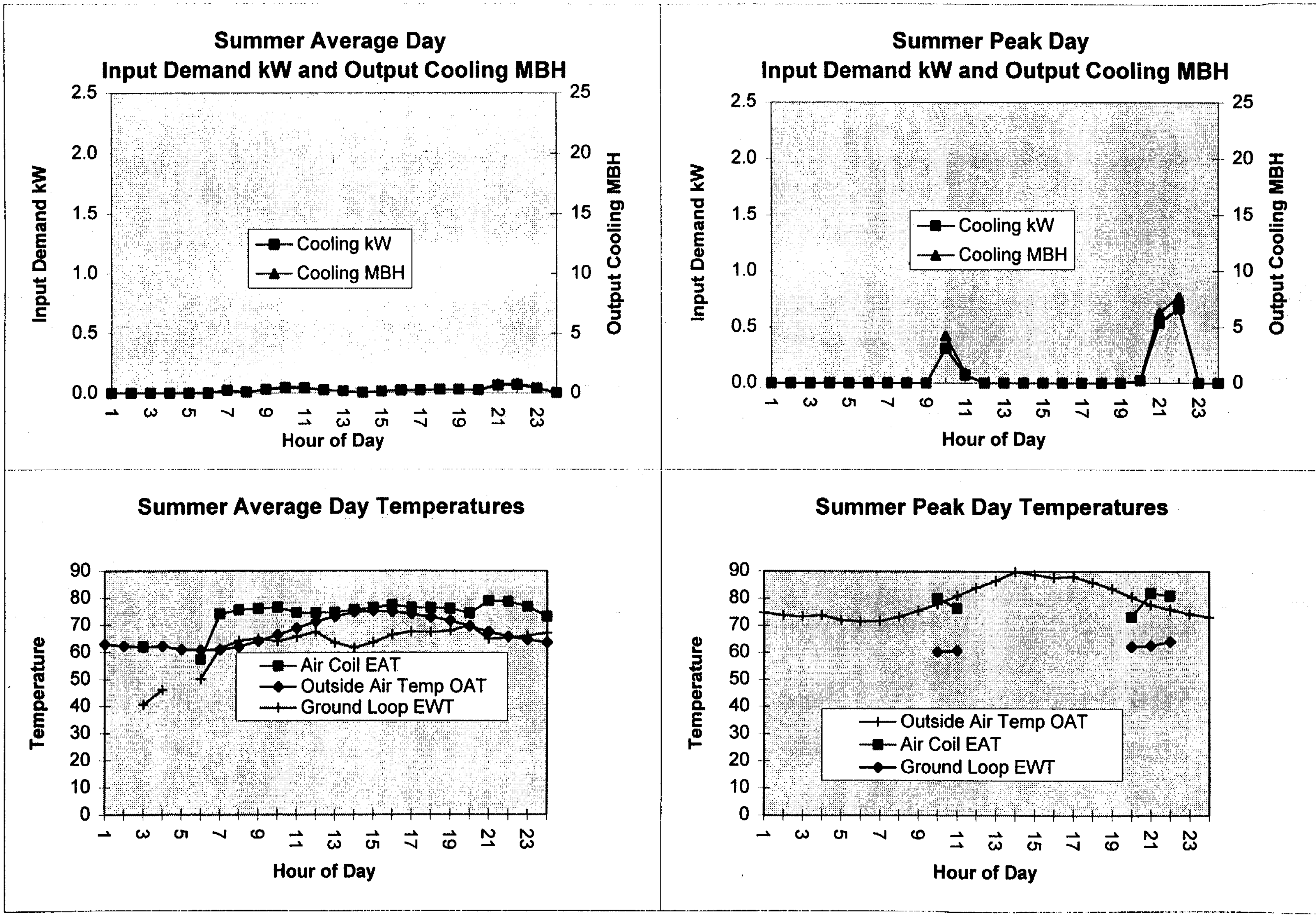


Figure 3-7(2). Site 2 - Summer Average and Peak Day Profiles

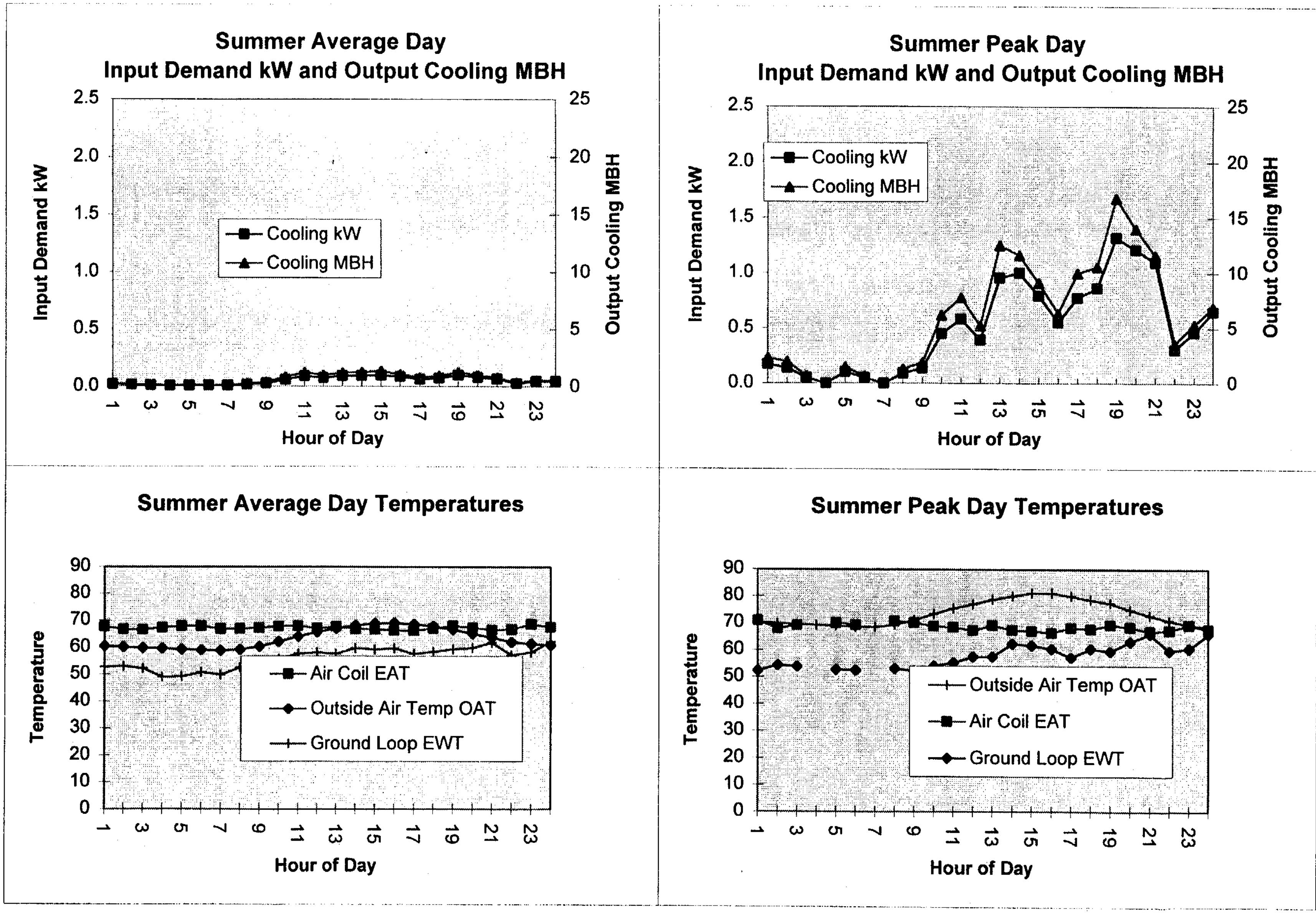


Figure 3-7(3). Site 3 - Summer Average and Peak Day Profiles

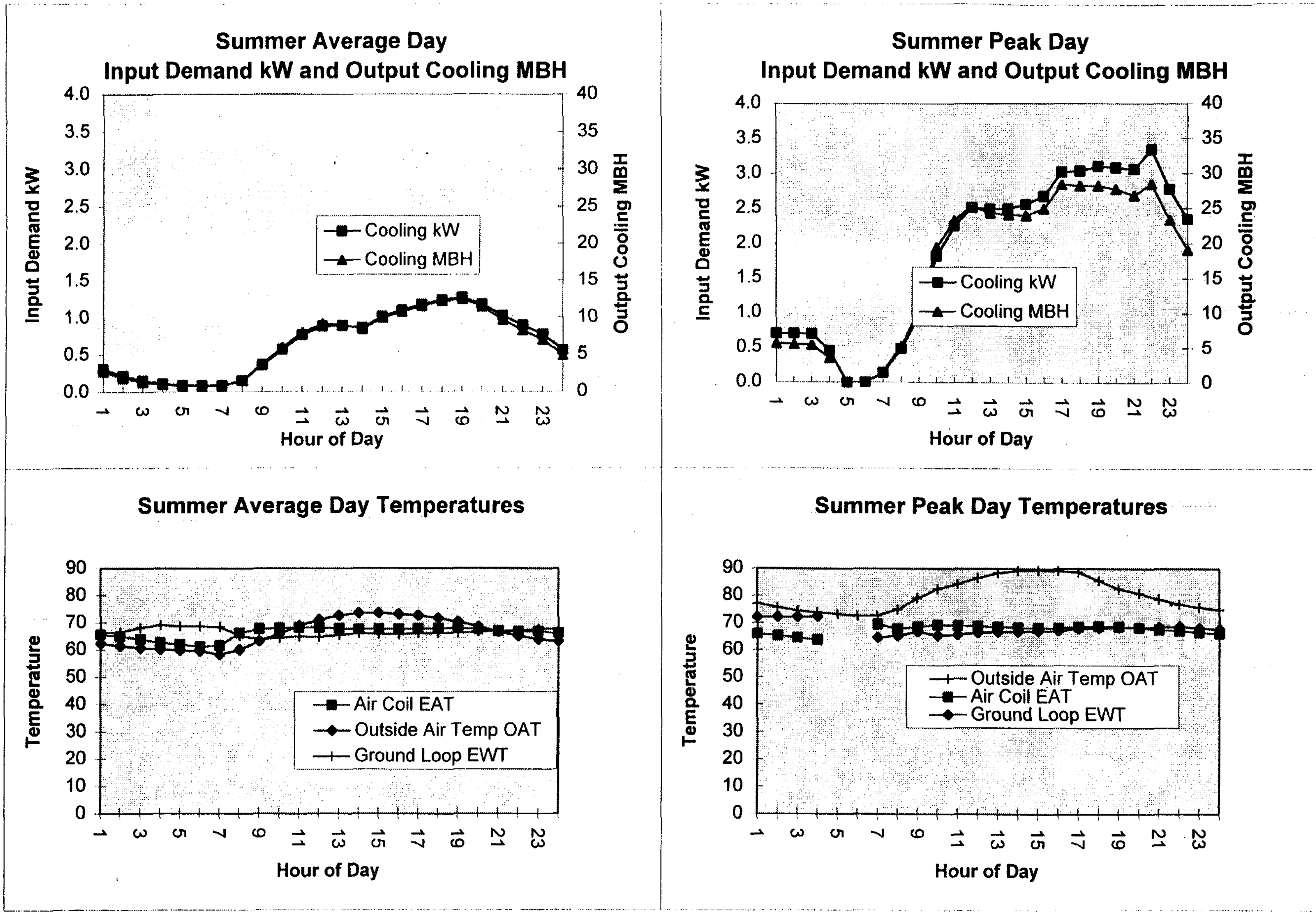


Figure 3-7(4). Site 4 - Summer Average and Peak Day Profiles

(4) Peak Day Temperatures
- Air Coil Entering Air Temperature (EAT)
- Outside Air Temperature (OAT)
- Ground Loop Entering Water Temperature (EWT)

Values are averaged by time-of-day. In addition, the load profile graphs use two vertical axes; the left axis indicates input demand in kW, and the right axis indicates thermal output in MBH. The left and right scales have a one-to-ten relationship, so that overlapping input and output profiles indicate an EER of approximately 10. Average energy input in kW should be read from the left-hand axis, and thermal heating or cooling output in MBH should be read from the right-hand axis.

The average winter day load profiles show a peak demand from 1.5 kW to 2.0 kW. Average peak day load profiles vary from 3.5 to 4.5 kW. As noted previously, the peak day load profiles average the five coldest days to provide a single profile from a larger number of GSHP systems. As such, the profiles do not show the maximum individual customer demand. The average day temperature profiles show that the outside air temperature is typically cooler than the entering ground loop water temperature in the morning and warmer than the ground loop temperature in the afternoon. Peak day temperature profiles show the advantage of ground coupling where the ground loop temperature provides a source of energy for the heat pump that is 20 to 30 °F warmer than the outside air temperature.

The average summer day load profiles show that the average day loads are insignificant, except at Site 4, where the average day electrical load reaches a high of over one kW in the afternoon. The average day temperature profile at Site 4 shows that the ground loop is generally cooler than the outside air temperature during hours with an air conditioning load. The peak day load profiles are highly variable both in terms of magnitude and time of peak. For example, Site 1 shows a peak of about 2.0 kW at 18:00, while Site 4 shows a peak of almost 3.5 kW at 22:00. Site 2 shows approximately 2 hours of operation in the morning, with the system turned off during the middle of the day, and approximately two hours of operation in the afternoon.

SYSTEM PERFORMANCE

A heat pump moves heat from a source that is cooled to a heat sink that is warmed. The closer the source temperature is to the sink temperature, the higher the potential efficiency of the system. In the heating mode, the ground is the source and the room space is the sink. In the cooling mode, the room space is the source and the ground is the sink.

From engineering principles, the performance of a GSHP system is a function of ground loop water temperature, the temperature of the air heating/cooling coil, the compressor speed, the fan speed, and the effect of cycling. As entering loop water temperature is increased, cooling output and efficiency are expected to decrease. In contrast, as entering air temperature is increased, cooling capacity and efficiency are expected to increase.

Other factors that are expected to affect the system efficiency include the compressor speed, the fan speed and the affect of on/off cycling. Low-speed compressor operation is expected to be more efficient than high-speed operation. However, low-speed operation may not provide sufficient capacity. Increased fan speed and air velocity may improve the thermodynamic efficiency by increasing the heat transfer at the air coil, but at the expense of increased fan energy. In general, cycling is expected to provide less-efficient operation than the steady continuous operation of the compressor.

The performance factors that have been monitored are presented as three series of graphs for each site showing:

- Heating and cooling efficiency as a function of the loop temperature entering the heat exchanger at the heat pump,
- Heating and cooling efficiency as a function of the entering air temperature at the heating/cooling air coil of the heat pump, and
- Heating and cooling efficiency as a function of the average duration of compressor on-time per cycle in minutes.

In general the data show heating efficiencies with the average COPs ranging from 2.5 to 3 under typical conditions at most sites. Cooling efficiencies are found to be much more variable, with EERs ranging from 8 to 15.

Performance as a Function of Entering Water Temperatures

Figures 3-8(1) through 3-8(4) show daily average heating and cooling efficiencies as as a function of the average daily entering ground loop water temperature. Heating COP values should be read from the left vertical axis and cooling SEER values should be read from the right vertical axis. The scales of the right and left vertical axes have been selected so that heating COP and cooling EER are directly comparable. For example, a heating COP of 5 is equal to an EER of 17.07 Btu per Watt. The entering ground loop water temperatures are shown by a common horizontal axis.

The COP values at all four sites show that heating COP is only weakly dependent on the entering water temperature. Data from all sites show a gradual increase in COP with increasing water temperatures. The cooling EER shows a non-intuitive response to water temperature at Sites 1 and 2, where the efficiency appears to increase with warmer ground loop water temperature. From the second law of thermodynamics, the maximum theoretical efficiency of an air conditioner is decreased with increasing temperature of the thermal sink, in this case the ground loop.

Performance as a Function of Entering Air Temperatures

As with the entering water temperatures. the entering air temperatures, as shown in Figure 3-9(1) through 3-9(4), do not appear to have a significant or consistent effect on heating or cooling efficiencies. From the second law of thermodynamics, one would expect that heating efficiency would be decreased and cooling efficiency would be increased with increasing temperatures of entering air. The scatter plot of heating efficiencies should have a negative slope (increasing with entering air temperatures) and cooling efficiencies should have a positive slope. The actual data do not show a significant pattern. At Site 1 and 3, both heating and cooling efficiencies show a slight positive slope. At Site 2, heating shows the expected negative slope but average air conditioning efficiency increases at higher entering air temperatures. Only at Site 4 do the heating and cooling

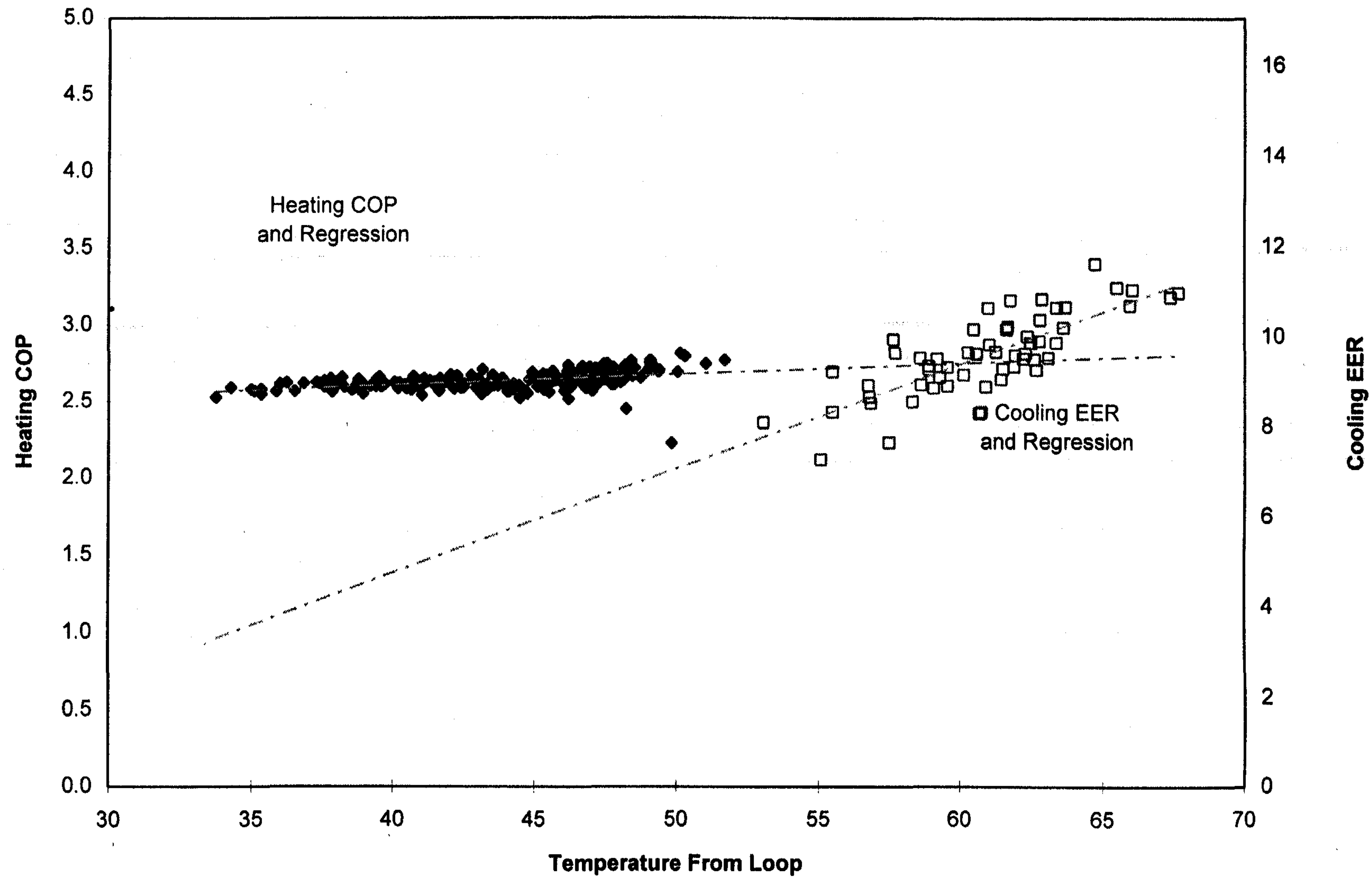


Figure 3-8(1). Site 1 - Efficiency and Ground Loop Temperatures

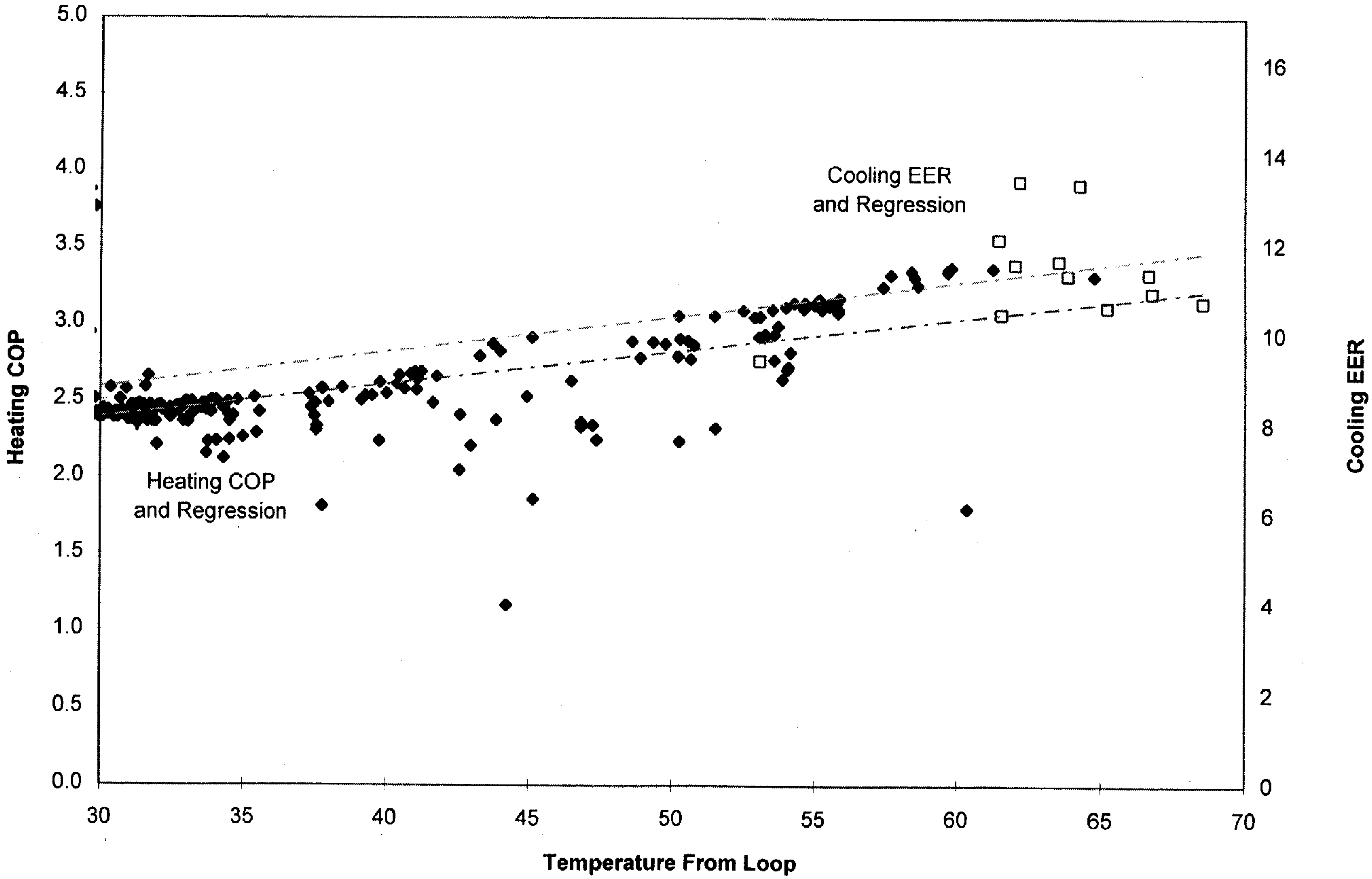


Figure 3-8(2). Site 2 - Efficiency and Ground Loop Temperatures

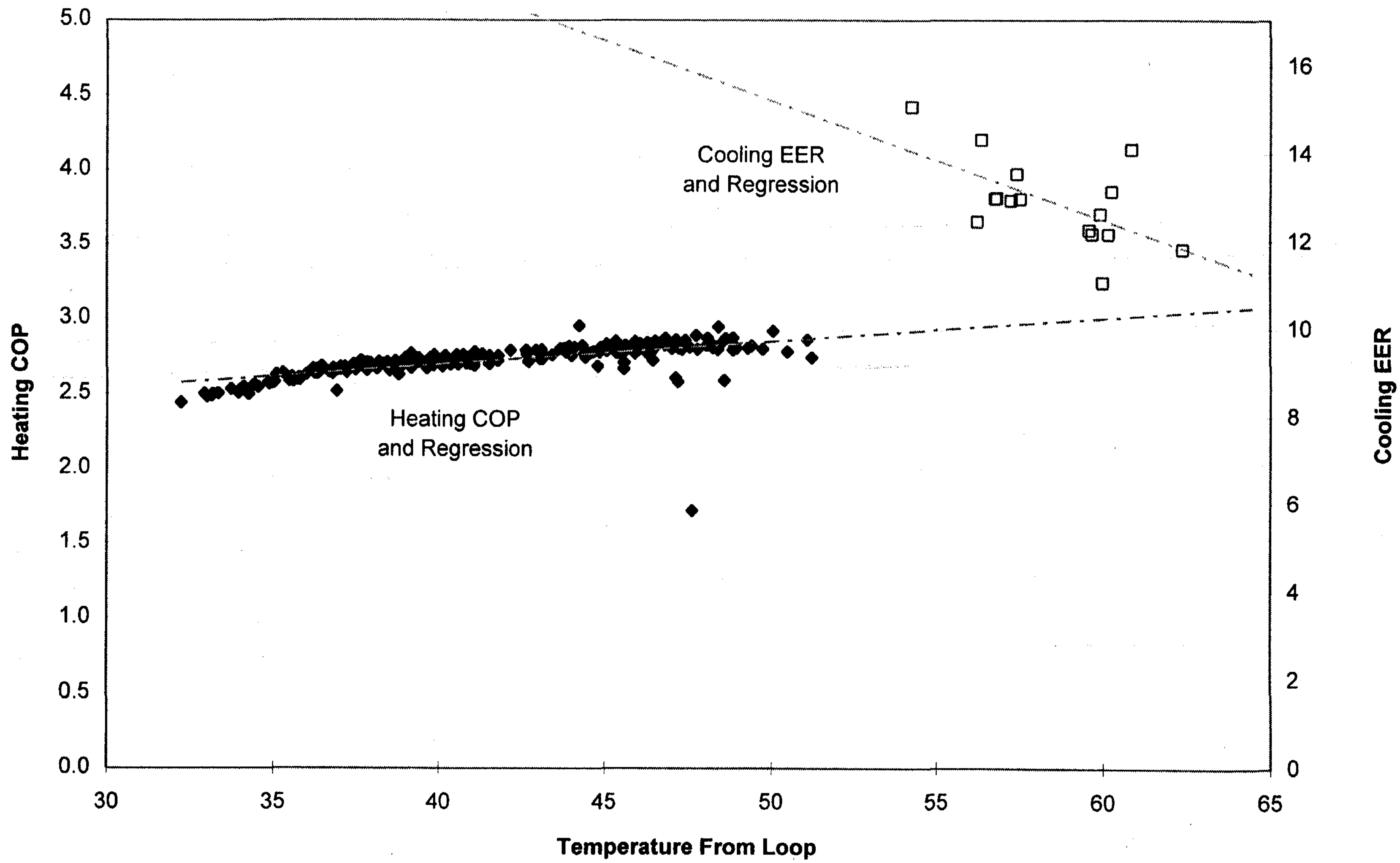


Figure 3-8(3). Site 3 - Efficiency and Ground Loop Temperatures

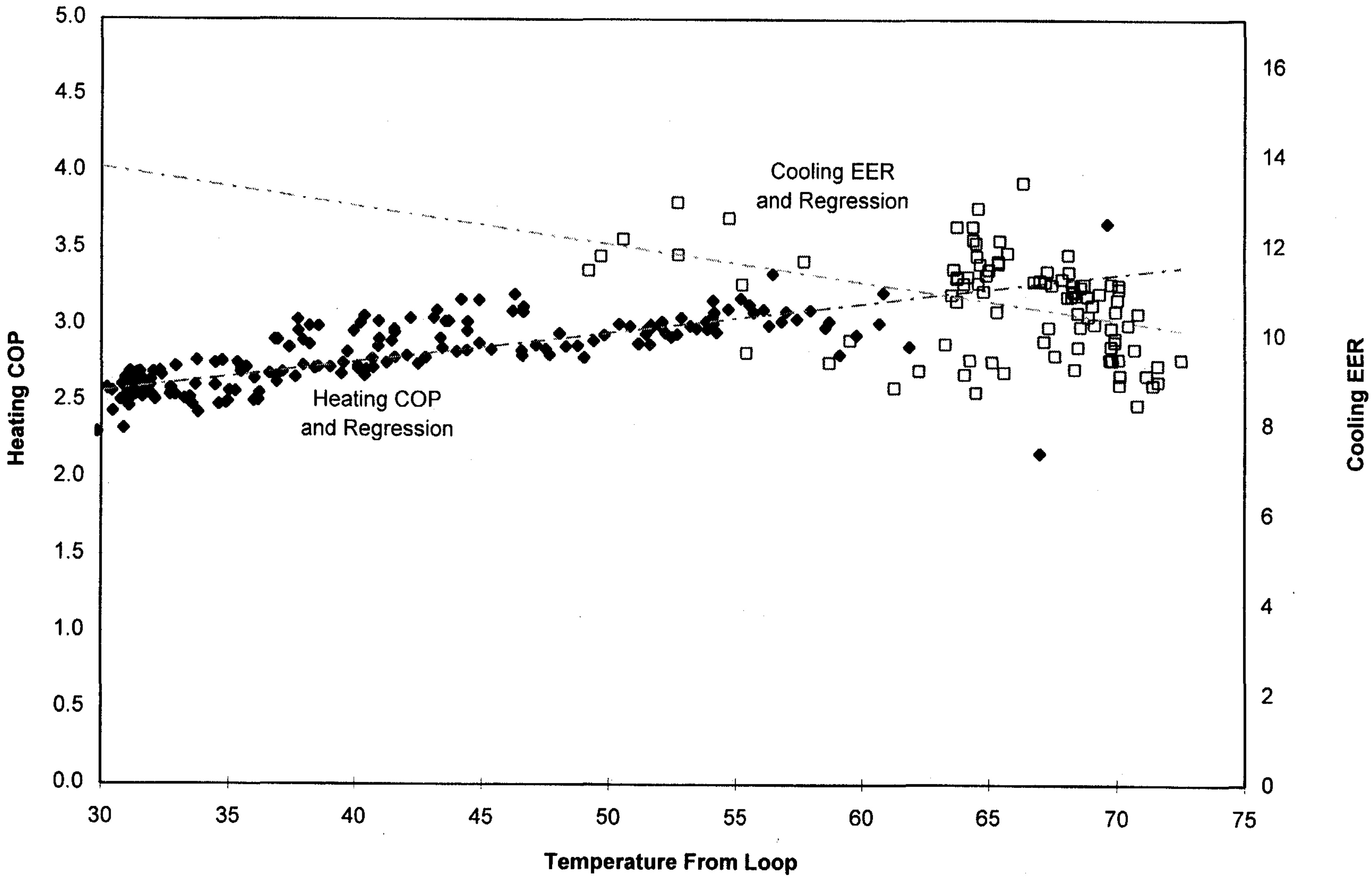


Figure 3-8(4). Site 4 - Efficiency and Ground Loop Temperatures

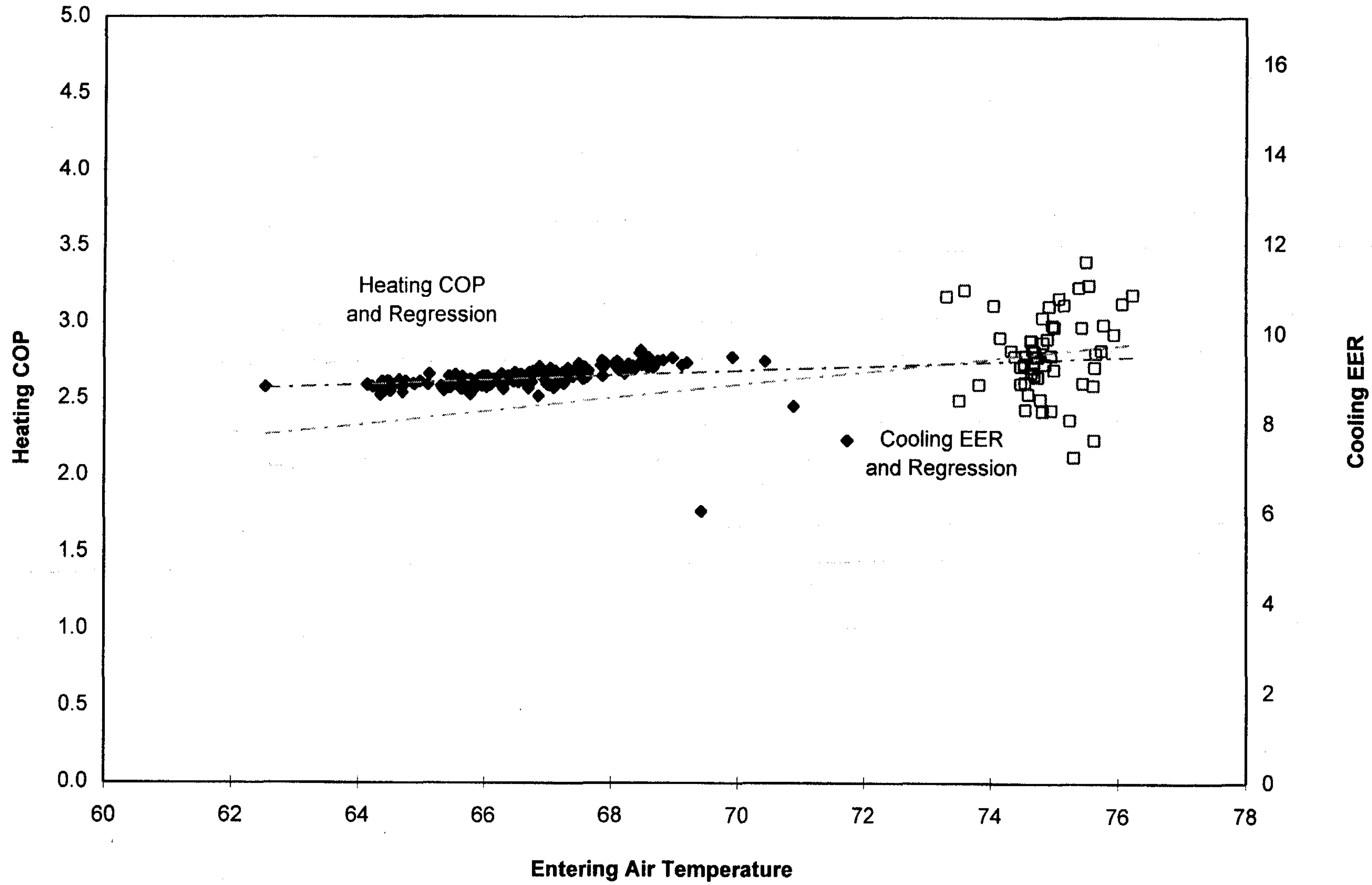


Figure 3-9(1). Site 1 - Efficiency and Entering Air Temperature

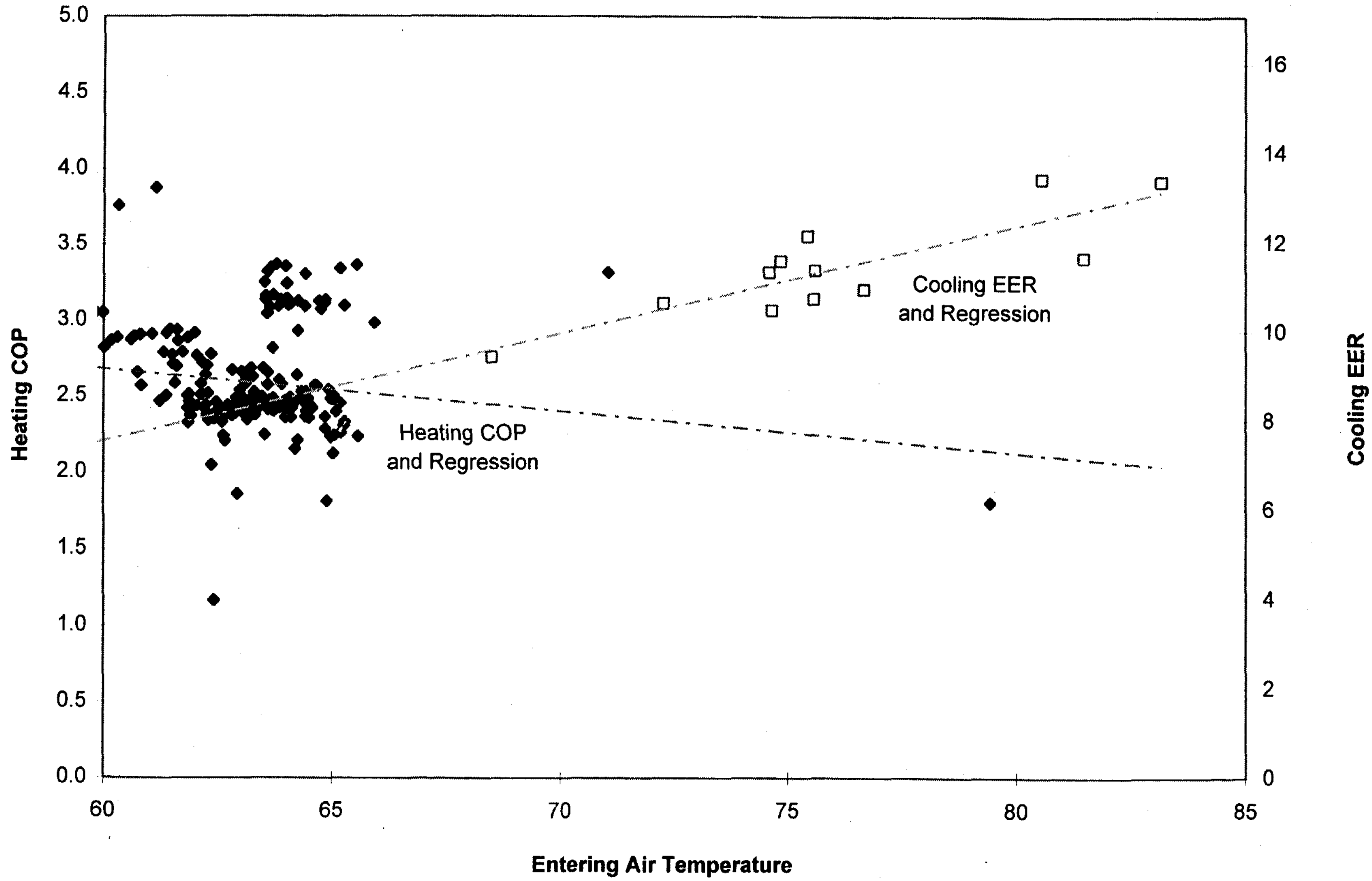


Figure 3-9(2). Site 2 - Efficiency and Entering Air Temperature

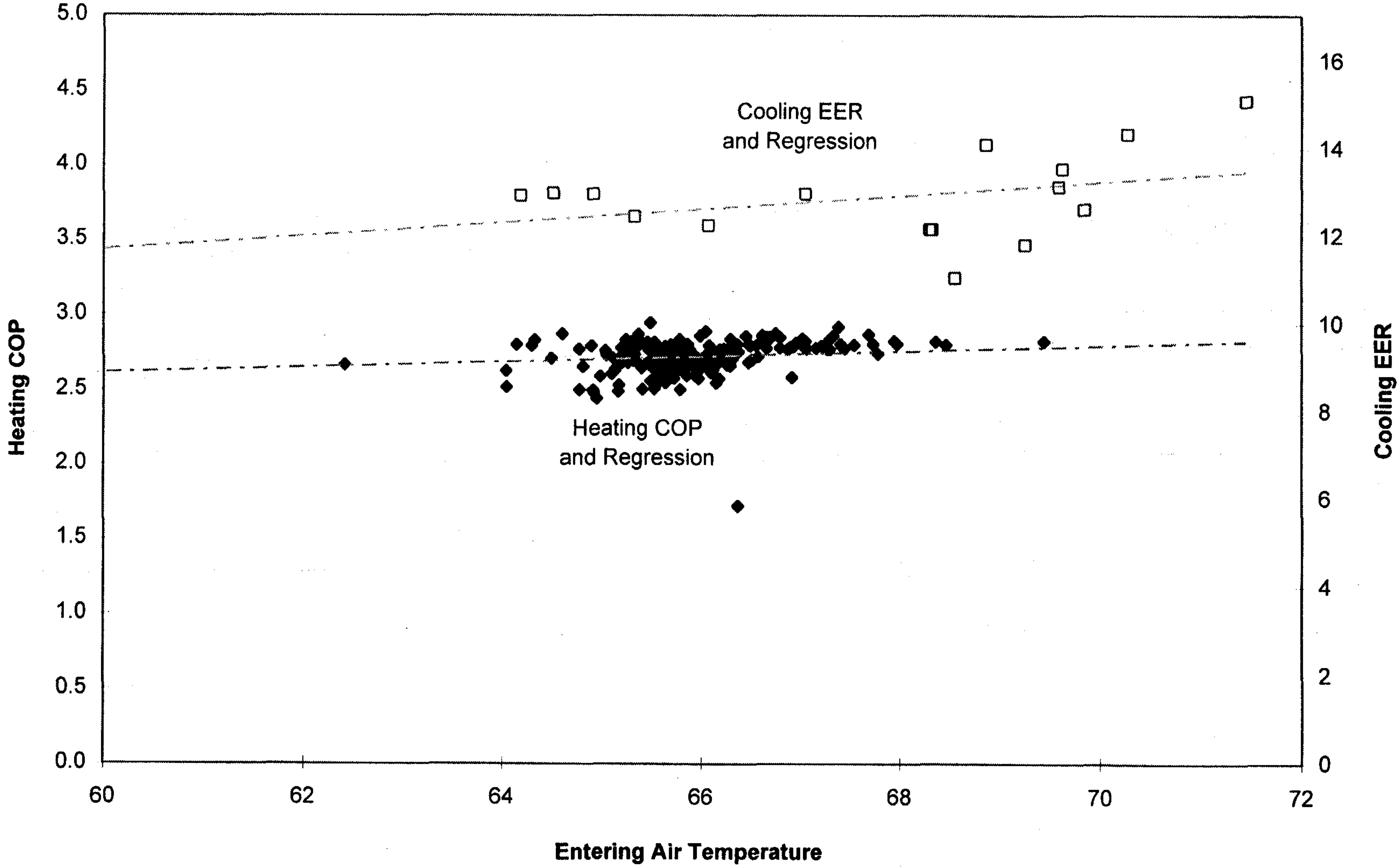


Figure 3-9(3). Site 3 - Efficiency and Entering Air Temperature

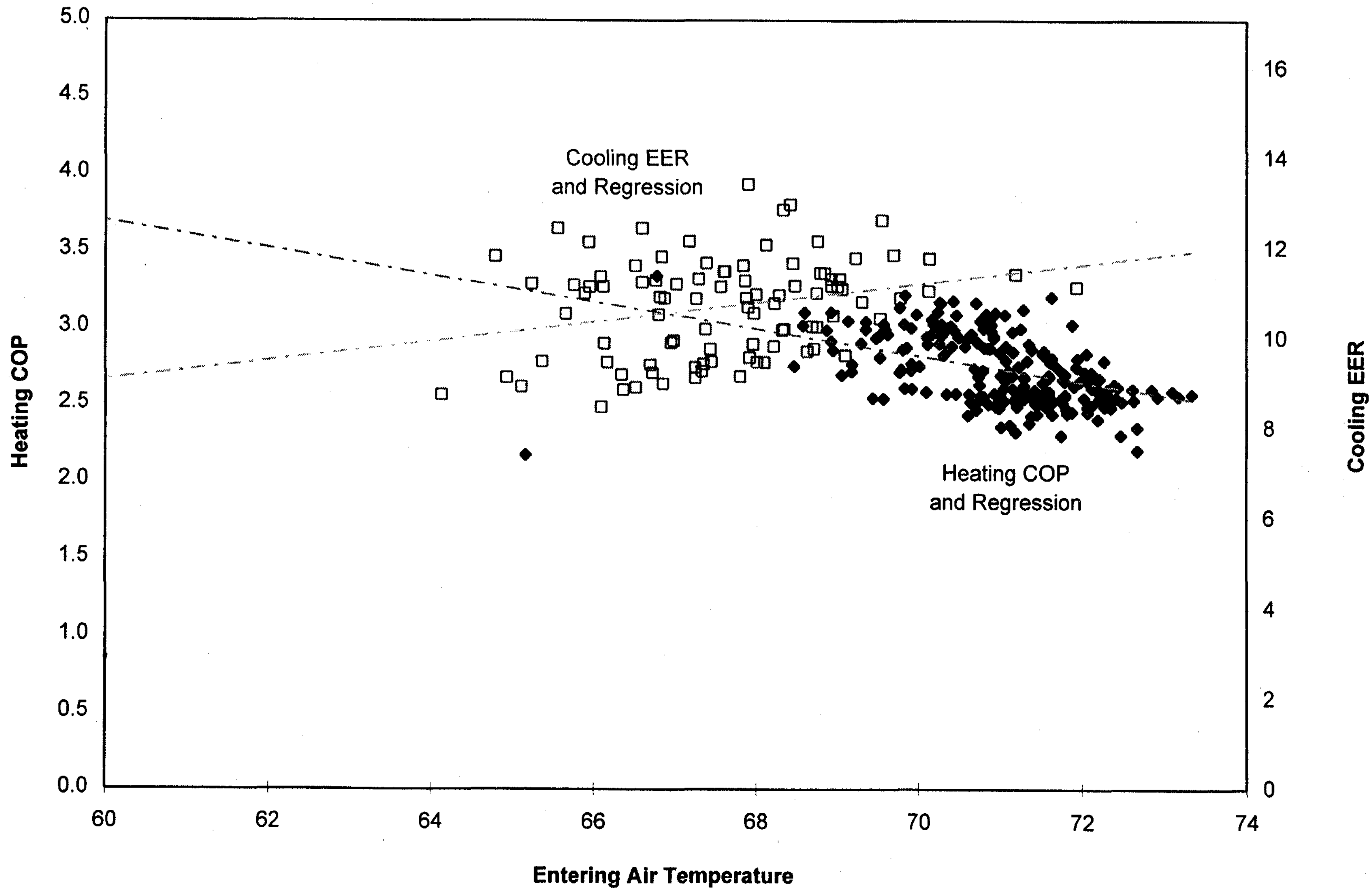


Figure 3-9(4). Site 4 - Efficiency and Entering Air Temperature

efficiencies show the expected tendencies for decreasing heating efficiencies and increasing cooling efficiencies associated with increasing entering air temperature. Note that Site 4 also shows that the entering air temperatures are lower in the cooling mode than in the heating mode. This is simply a function of the customer's choice to maintain cooler temperatures in the summer than in the winter. The cooler summer setpoint temperatures in conjunction with a system of return air grills at the baseboard level result in a relatively cool entering air temperature causing a lower cooling efficiency.

Performance as a Function of Average Compressor On-Time

When the setpoint at the master thermostat is satisfied, the system is cycled off. When additional heating or cooling is needed, the system is cycled on. The actual rate of cycling is a complex function of thermostat deadband, heating and cooling system capacity, the weather, and the transient thermal response of the house. Each time the compressor starts or stops, potential thermal and mechanical losses are expected to adversely affect the average efficiency of the system. To investigate the effect of cycling of performance, the daily average heating and cooling efficiency was plotted as a function of the daily average on-time per cycle, where the daily average on-time per cycle is calculated as the total on-time in minutes divided by the total number of on/off cycles during the day.

The data from Site 1 (Figure 3-10[1]), show a clear correlation of short on-cycles with lower efficiency during cooling. It appears that the effect is most significant when the compressor operates for an average of less than 10 minutes per cycle. Heating efficiency appears to be unaffected by cycling at all four sites. Similar observations may be made about the data from Site 2 (Figure 3-10[2]), although infrequent use of cooling at this site limits the available data. Site 3 data (Figure 3-10[3]), show a contrary pattern, where the highest average cooling efficiencies are associated with average runtimes of less than 10 minutes per cycle. Cooling efficiencies at Site 4 show a slight but probably insignificant trend of lower efficiencies associated with longer average on-times. In general, the effects of cycling and temperatures tend to obscure one another where the mild temperatures conducive to a high thermodynamic efficiency are associated with mild thermal loads and increased cycling. Conversely, peak-load periods combine extreme temperatures which are expected to lower efficiencies with thermal loads that more closely match capacities, increasing runtimes and reducing cycling losses.

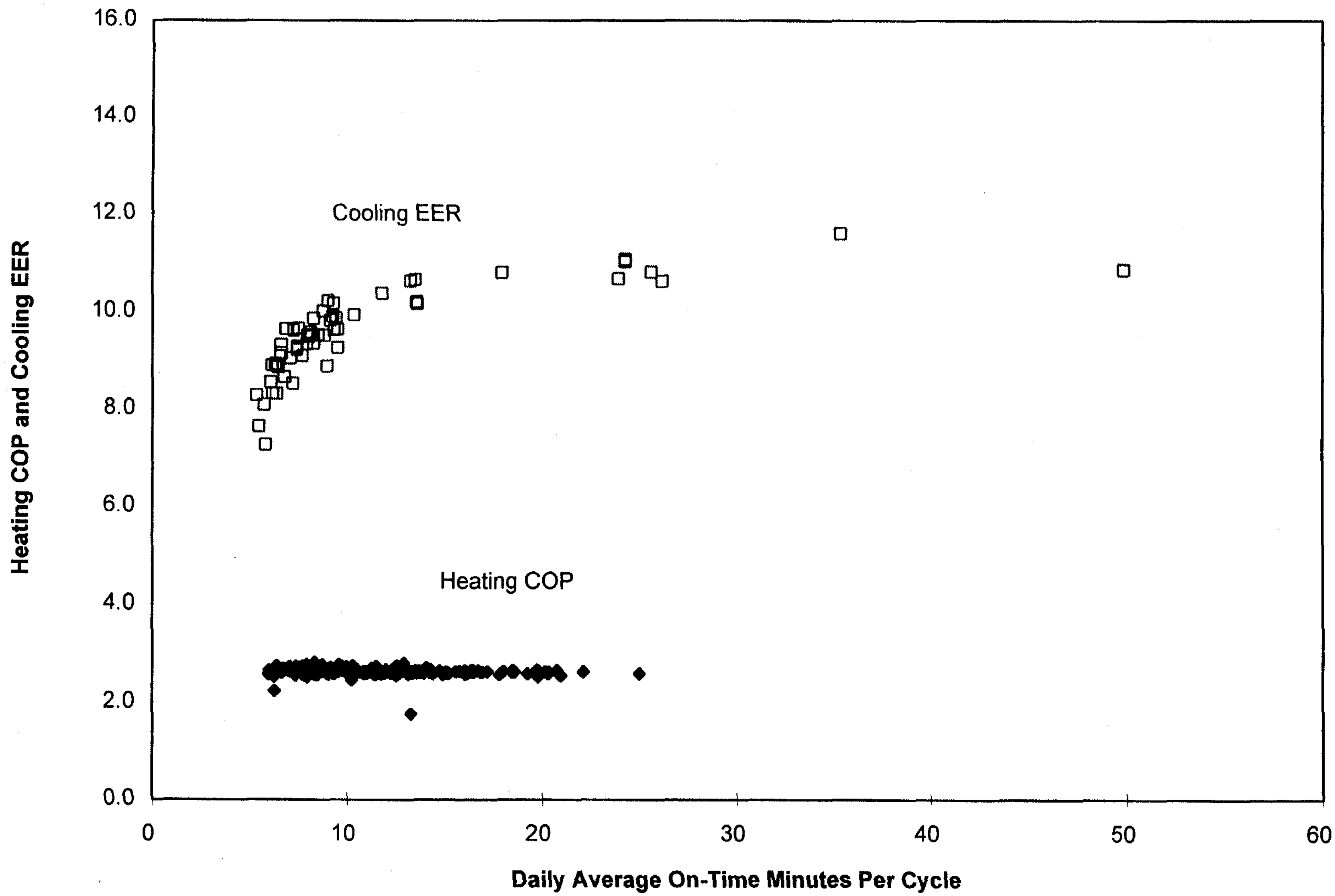


Figure 3-10(1). Site 1 - Efficiency and Average Cycle Runtime

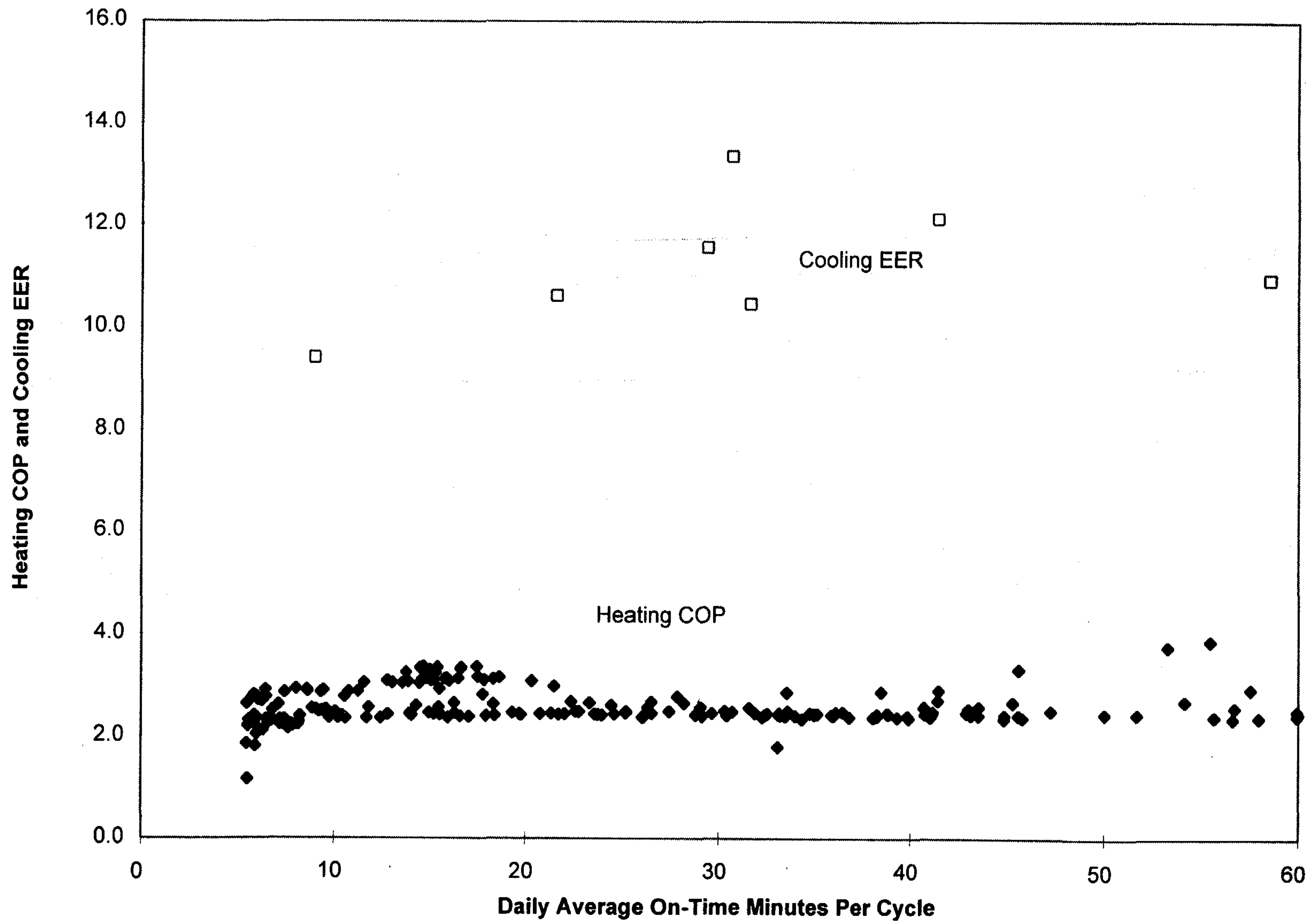


Figure 3-10(2). Site 2 - Efficiency and Average Cycle Runtime

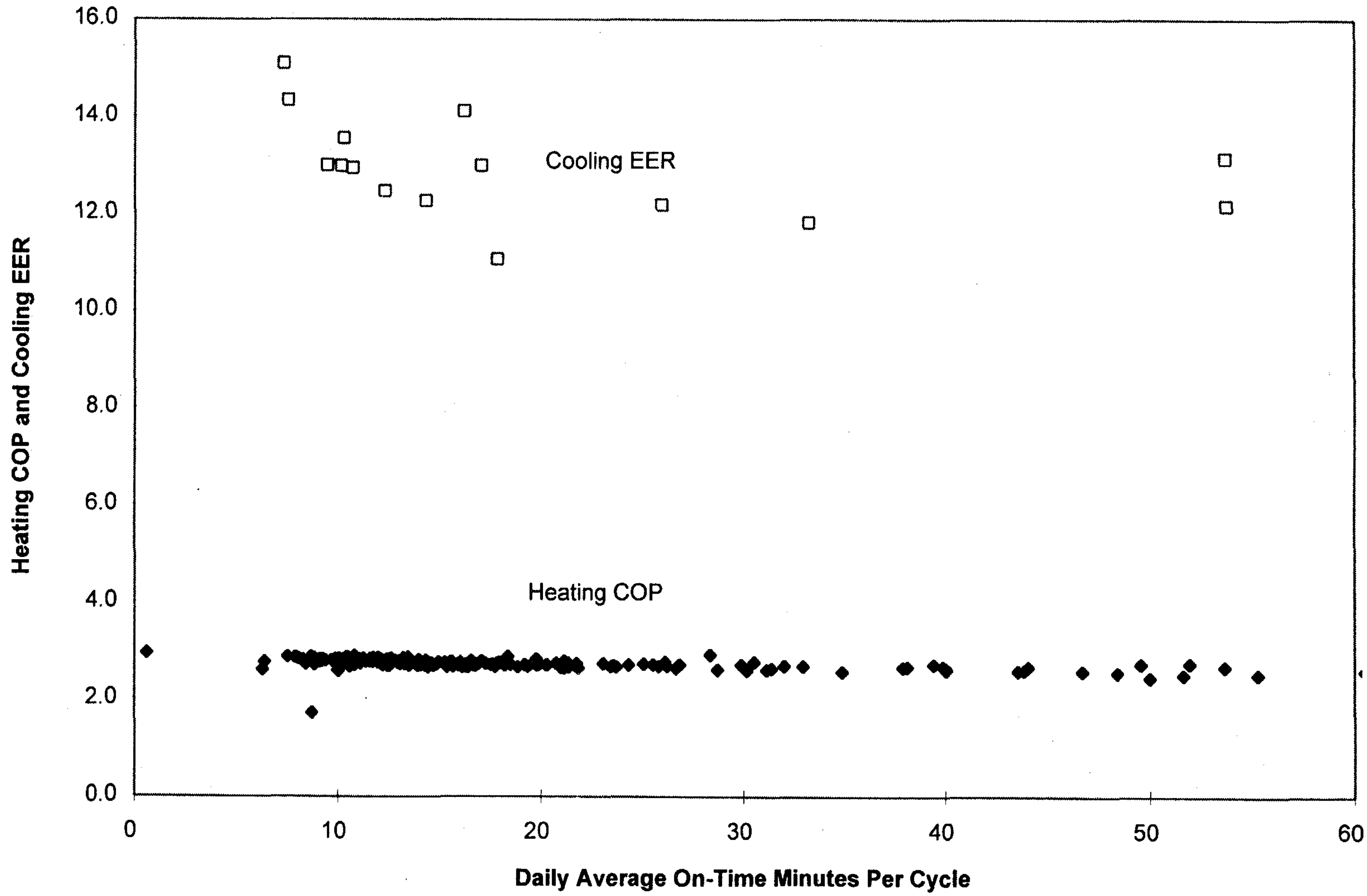


Figure 3-10(3). Site 3 - Efficiency and Average Cycle Runtime

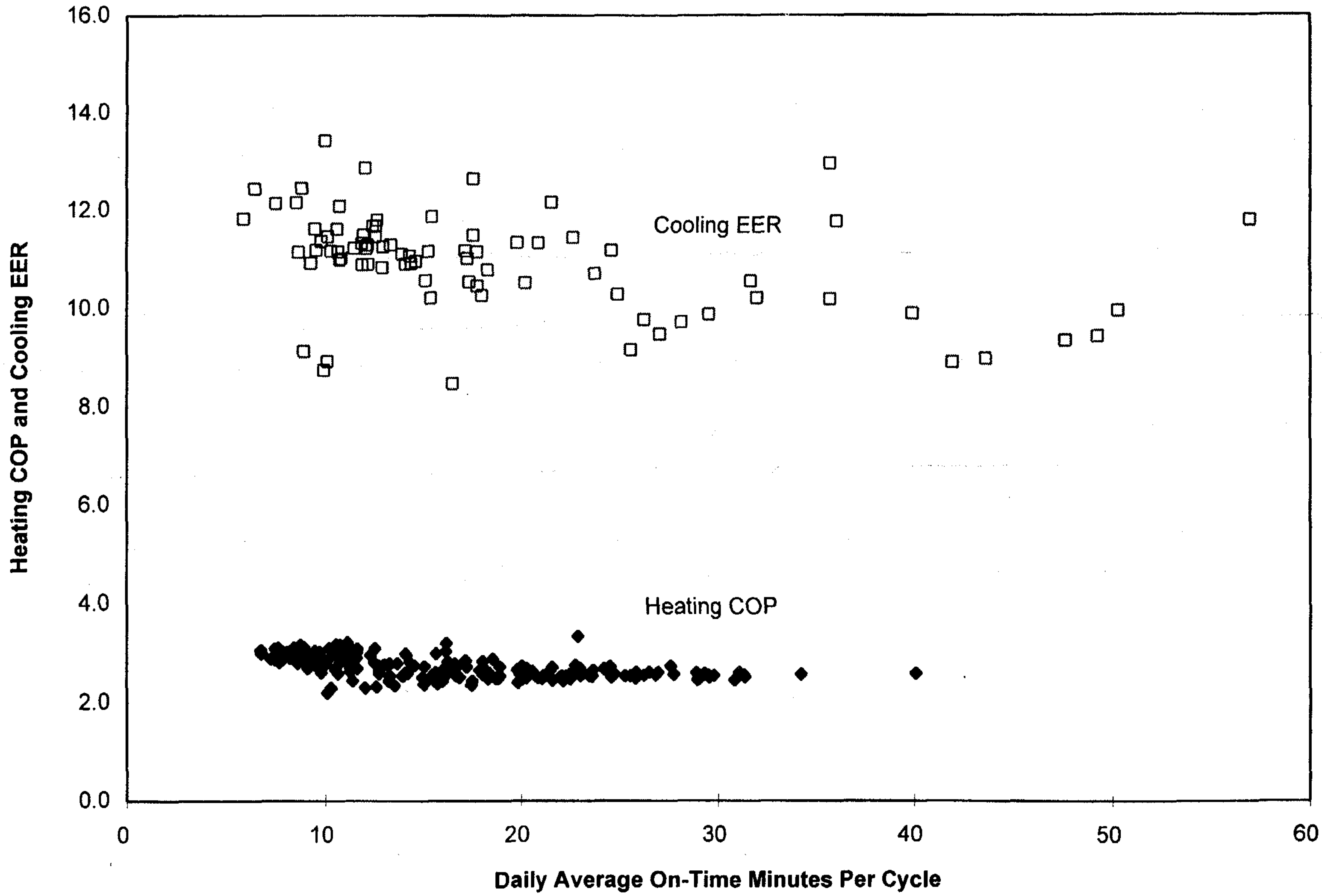


Figure 3-10(4). Site 4 - Efficiency and Average Cycle Runtime

Section 4

COMPARISON WITH CONVENTIONAL AIR-SOURCE HEAT PUMP PERFORMANCE

Based on monitored data on the GSHP systems, estimates of air-source heat pump data, and long-term weather data from Air Force Manual 88-29, Engineering Weather Data, for weather stations at the Albany and Newberg/Stewart airports, a comparison was made for the four sites between energy usage for the GSHP system and a typical air-source heat pump.

The analysis assumes that supplemental water heating from the desuperheaters of the GSHP systems effectively reduces the electrical energy input to the conventional electric water heater at the site. The air-source system is assumed not to have a desuperheater.

Table 4-1 lists the equipment efficiency ratings used in comparison. Electricity is assumed to be the only fuel with an average cost of $0.10 per kWh. Electric resistance water heating is assumed to have an efficiency of 100 percent with a conversion factor of 3.413 Btu per Watt.

Table 4-1. Equipment Efficiency Ratings

Function	Air-Source Heat Pump System	Ground-Source Heat Pump System
Heating	3.2 COP at 47° F	2.7 COP at ARI 330-hi 3.2 COP at ARI 330-lo
Cooling	10 EER at 95° F	14.0 EER at ARI 330-lo
Water Heating	Electric Resistance	Desuperheater Electric Resistance

Table 4-2 provides the results of the comparison and a simplified cost/benefit analysis. Because the annual energy use has been normalized by long-term weather data, the values shown in the table are not the same as the values shown elsewhere in this report that are based only on the actual monitored data. The table shows projected operating cost for ground-source and air-source given the actual space heating, space cooling and water heating requirements from the four test sites. Operating costs

Table 4-1 System Cost Comparison	Site 1 Hyde Park, NY	Site 2 Rhinebeck, NY	Site 3 Ithaca, NY	Site 4 Stillwater, NY
Annual Space Heating (MBtu)	50.5	89.1	49.7	54.1
Annual Space Cooling (MBtu)	11.5	1.0	8.9	26.9
Annual Water Heating (MBtu)	9.8	9.8	14.2	20.8
GEOMET calculated ground-source operating costs				
Heating	$565	$1,045	$550	$602
Cooling	$105	$1	$65	$215
Water Heating	$96	$131	$131	$176
Total	$766	$1,177	$746	$993
WaterFurnace Energy Analysis (WFEA) projected ground-source costs				
Heating	$485	$885	$477	$535
Cooling	$80	$7	$59	$182
Water Heating	$151	$180	$253	$369
Total	$716	$1,072	$789	$1,086
Actual GSHP costs vs. WFEA projected ground-source costs	Operating costs 6.8% higher than projected	Operating costs 9.8% higher than projected	Operating costs 5.3% lower than projected	Operating costs 8.5% lower than projected
WFEA projected air-source operating costs				
Heating	$803	$1,421	$809	$904
Cooling	$132	$25	$113	$252
Water Heating	$288	$288	$417	$606
Total	$1,223	$1,734	$1,339	$1,762
Estimated Annual Savings				
Heating	$318	$536	$332	$369
Cooling	$52	$18	$54	$70
Water Heating	$137	$108	$164	$237
Total	$507	$662	$550	$676
Percent Reduction	41%	38%	41%	38%

for the four sites were calculated by GEOMET and by WaterFurnace for both ground-source and air-source systems. The projected operating cost for the ground-source systems shows a very good agreement between the operating costs projected by the WaterFurnace Energy Analysis (WFEA) computer program and the GEOMET projections based on the monitored data. Air source heat pump operating costs have been projected using the WFEA program. These operating cost results are equivalent to an average Heating Season Performance Factor (HSPF) of 6 Btu per Watt and a SEER of 11 Btu per Watt for the air-source system performance. Estimated savings for the ground-source sytem are shown as the difference in costs projected by the WFEA program. Annual savings are estimated from $507 to $676 for the four test sites.

Typical system costs for ground source systems are estimated to be approximately $14,500 per site. For comparison, the cost of an air source system is estimated to be approximately $8000. The difference in cost is $6500. The cost savings estimated for the four sites provides a simple payback of from 10 to 13 years.

However it should be noted that the ground-source approach provides several advantages in addition to energy cost savings. Ground source system are expected to have a longer useful life than air source systems because none of the system components are exposed to the weather. With an air source system the compressor is typically located outdoors with the air-source heat exhanger. Also because air source system must be located outdoors they may require valuable yard space and are often a source of noise pollution. In comparison, a ground source system requires less space and operates much more quietly.

Ground-source systems are expected to provide a greater degree of thermal comfort. The monitored system results showed that space temperatures and more importantly supply air temperatures were maintained such that none of the test participants complained of discomfort or cold drafts, problems that are often associated with air-source systems.

Finally the monthly operating costs of a ground-source system would be more predictable than for an air source system. During very cold weather both the efficiency and capacity of an air-source system are degraded and much of the heating energy is provided by inefficicent electric resistance backup heaters. The heating cost of an air-source system for a very cold month is therfore significantly higher than for a month with more moderate temperatures. The monthly heating costs for a ground-source system would be much less variable and easier to budget.

Section 5

CONCLUSIONS

The report documents the successful demonstration of advanced GSHP systems designed to eliminate the need for electric resistance backup heating. Four residential sites were monitored for a full year for energy use and system performance. The analysis of these data shows that an advanced-design GSHP system can efficiently maintain comfort with minimum outdoor temperatures of -25°F and average monthly temperatures of 15°F without the use of backup resistance heat. On average, the GSHP systems provided approximately a 40 percent reduction of energy consumption and costs as well as an average demand reduction of over 12 kW, compared to a typical air-source heat pump.

The data show that the advantages of a GSHP system are most apparent during peak heating and cooling conditions when the ground loop provides a moderate temperature heating source or cooling sink as compared to outside air temperatures. For example, during peak heating conditions, the ground loop systems operated with temperatures more than 30°F warmer than outside air temperatures. This moderate-temperature source of thermal energy allows the ground source systems to operate with a higher efficiency and a higher capacity than an air-source heat pump, eliminating the need for backup heating. However, under mild conditions, the difference between outside air temperatures and ground loop temperatures is small and there are a significant number of hours during the heating season when the outside air temperature is warmer than the ground loop temperature.

The advanced GSHP systems in this demonstration included additional features such as supplemental domestic water heating, electronically commutated motors (ECMs) for the supply air fans, and zone temperature control using automatic dampers in branch zone ducts. Of these features, supplemental water heating using a desuperheater made the greatest contribution to the total energy savings. At some sites, the thermal output of the desuperheater was greater than the total thermal energy used for cooling. The advantages of ECM motors and zone controls are not clearly apparent from the data, but it appears that there is an opportunity of optimize the interaction of fan and zone damper controls.

The advanced-design GSHP systems operated reliably and there were no significant problems reported by the residents of the test sites. The only significant barrier to the adoption of this technology is the first cost of the system, in particular, the cost the ground field installation. It is anticipated that the cost of the ground field installation may be reduced if the number of experienced installers is increased. Given the considerable reduction of peak heating demand, electric utilities should consider promoting the system and providing financial incentives to increase the market penetration of this energy-efficient and environmentally clean heating and cooling technology.

Appendix A

SITE SPECIFIC INSTALLATION DETAIL

WaterFurnace International, Inc.
9000 Conservation Way
Fort Wayne, IN 46809
219-478-LOOP (5667)
FAX 219-478-3029

Don Cade/Steve Stoltz
GEOMET Technologies, Inc.
20251 Century Blvd.
Germantown, MD 20874

3-8-94

Gentlemen,

I have enclosed for your reference some additional information on each of the NYSERDA project jobsites. Blower/motor data for each unit is included.

If I can be of any further assistance please feel free to call.

Sincerely,

John Berg

John Berg
Test Engineer
WaterFurnace International, Inc.

UNIVERSAL PSC 1/2 HP MOTOR AT 230 VOLTS
(Hyde Park, NY site)

ESP	FAN TAP	RPM	WATTS	CFM
0.0	LO	757	397	993
0.5	LO	1007	305	903
0.0	MED	881	448	1162
0.5	MED	1044	337	988
0.0	HI	1050	524	1412
0.5	HI	1115	410	1131

3/15 MED SPEED TAP FOR HEATING/COOLING

ESP: external static pressure
RPM: revolutions per minute
CFM: cubic feet per minute

GE ECM 1/2 HP MOTOR AT 230 VOLTS

(Ithaca and Stillwater, NY sites)

ESP	FAN TAP	RPM	WATTS	CFM
0.0	1	291	39	669
0.5	1	698	128	594
0.0	2	322	46	766
0.5	2	727	159	714
0.0	3	362	64	887
0.5	3	711	173	854
0.0	4	387	77	955
0.5	4	723	196	927
0.0	5	423	103	1051
0.5	5	726	223	999
0.0	6	461	135	1158
0.5	6	734	253	1101
0.0	7	514	180	1301
0.5	7	760	305	1233
0.0	8	542	223	1405
0.5	8	802	364	1320
0.0	9	595	303	1545
0.5	9	755	385	1426
0.0	10	626	364	1649
0.5	10	819	475	1502
0.0	11	660	437	1767
0.5	11	831	523	1555

3/15 Currently used speed taps Stillwater 7, 9, 11
Ithaca ?

ESP: external static pressure
RPM: revolutions per minute
CFM: cubic feet per minute

GE ECM 1 HP MOTOR AT 230 VOLTS
(Rhinebeck, NY site)

ESP	FAN TAP	RPM	WATTS	CFM
0.0	1	336	48	772
0.5	1	692	151	788
0.0	2	415	86	1008
0.5	2	725	219	1061
0.0	3	493	135	1200
0.5	3	763	297	1263
0.0	4	519	162	1291
0.5	4	785	345	1369
0.0	5	557	197	1401
0.5	5	806	399	1472
0.0	6	601	243	1496
0.5	6	830	455	1569
0.0	7	652	316	1644
0.5	7	858	541	1704
0.0	8	717	430	1820
0.5	8	900	665	1860
0.0	9	811	640	2074
0.5	9	956	876	2076
0.0	10	872	816	2248
0.5	10	974	955	2142
0.0	11	-	-	-
0.5	11	-	-	-

3/15 Currently used speed taps 3, 6, 8 (may change)

ESP: external static pressure
RPM: revolutions per minute
CFM: cubic feet per minute

The field test sites selected for the NYSERDA demonstration program are as follows.

LOCATION	TYPE OF INSTALLATION	RESIDENT
Hyde Park, N.Y.	Retrofit	R. Maeder
Ithaca, N.Y.	Retrofit	S. Berg
Rhinebeck, N.Y.	New Construction	C. Freni
Stillwater, N.Y.	New Construction	B. Carpenter

All four of the units involved are Northern 36's. The blower housing, blower motor and emergency electric heat for the units varied with application.

The Control board dip switch settings for all units is as follows:

Switch No.	Position
1	Normal
2	Northern 2-Speed
3	No 2nd Stage Cooling
4	No 3rd Stage Heating
5	ACC relay with compressor (Except Ithaca site air cleaner cycling with fan)
6	Normal
7	Loop freeze protection

APPLICATION

Job Site:	Hyde Park, N.Y.
Heat Loss:	40,000
Heat Gain:	17,500
Unit:	ATVN036A110CRT / EP0007
Estimated Annual Cost:	$1,058 (based on .10/Kwh)
Ground Loop Information:	560' vertical bore 1.25" PE (2-280' boreholes)
Homeowner:	Ron Maeder (CHG&E)
Dealer:	Kool Temp (Mike Veeter)
Electric Service:	Central Hudson Gas & Electric
Emergency Heat:	10 kw

[illegible]

[illegible]

Heating Load

Cooling Load

Ground Loop

WaterFurnace® As Built Site Plan MAEDER HOME HYDE PK, NY

Company: ______________________ Date: ________

Certified GSC technician: JFB GSC number: ________

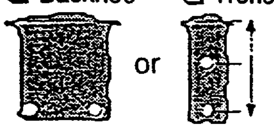
Address: ______________________

City: ________ State: ________ Zip: ________ Phone ________

Directions to job site:	Instructions
	1. Please select the type of loop installed. 2. Draw the GCL as Installed. Locate the GCL to property lines, existing structures, & or other permanent land marks. 3. Provide a profile view of the site. 4. Attach Site Survey or locate all applicable items from the Site Survey Checklist.

❑ *2 Pipe*

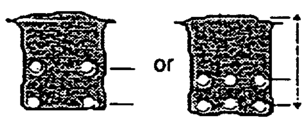
❑ Backhoe ❑ Trench



Width = ________

Depth = ________ , ________

❑ *4 Pipe or* ❑ *6 Pipe*



Width = ________

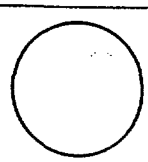
Depth = ________ , ________

❑ *Other*

Width = ________

Depth = ________ , ________

❑ *1 Pair Vertical*



Backfill = ________

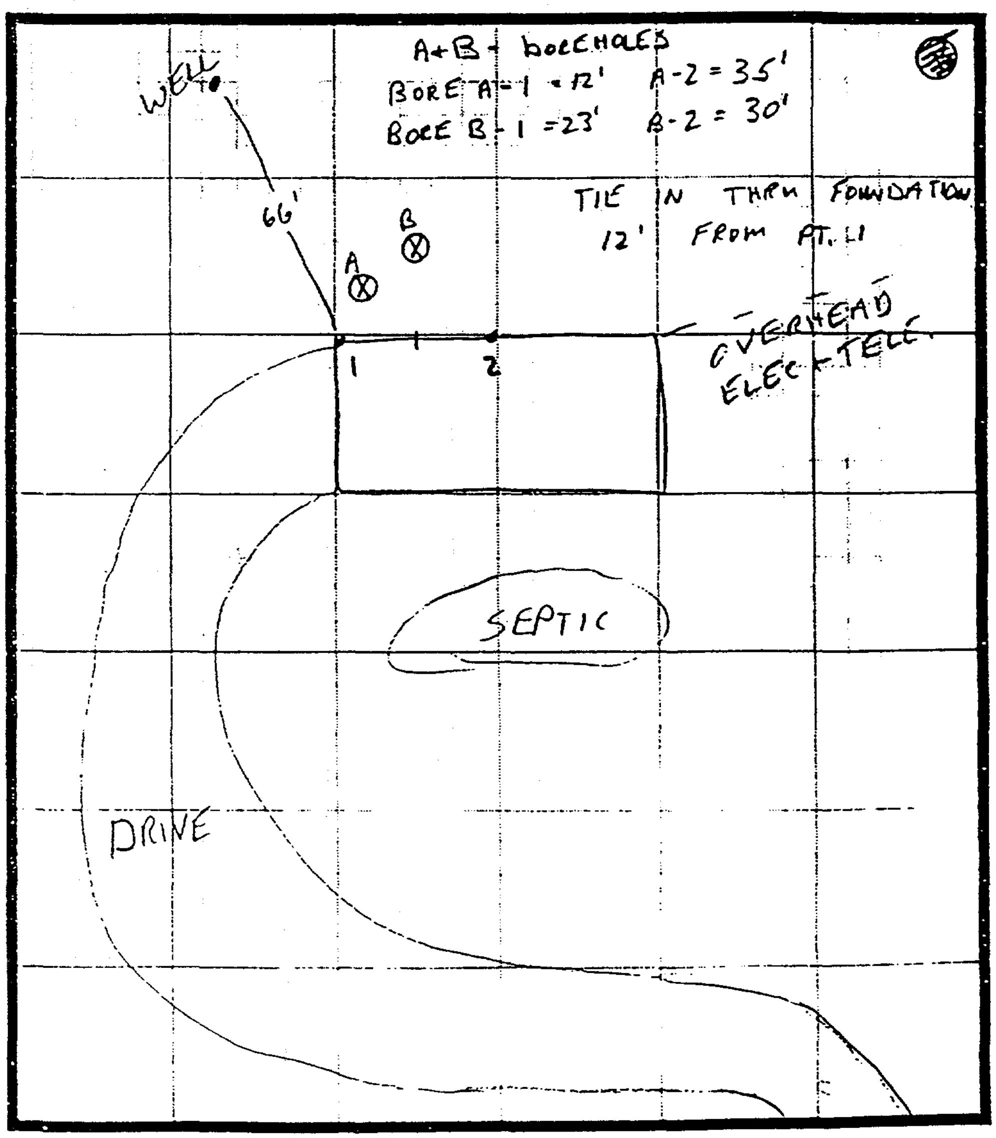
❑ *Pond*

Number of coils =

Coil length = ________

Depth installed =

Geothermal Closed Loop System
As Built Site Plan



SCALE ______ = ______

Determine:

N Profile S	W Profile E

Test Site: Hyde Park, New York EP0007

<u>Design Specifications</u>

° Model #: ATVN036A110CRT

° Serial #: EP0007

° Chassis: 45, right return, topflow

° Compressor: Copeland CTN1-0501, serial #92J52819A, WFI #34P511B01

° Air side heat exchanger: Heatcraft 3CY-1403D, 28x25, lanced fin, rifled tube, WFI #61P505C01

° Liquid side heat exchanger: Koax-K60, WFI #62I507A01

° Reversing valve: Ranco V-4, WFI #33P503B01

° Expansion valve: Alco RAEB4, 20% bleed, WFI #33P534B07

° Blower housing: Morrison 9x7 regular, WFI #53P500B01

° Blower motor: Magnetek/Universal 1/2 hp psc, WFI #14P510B01

° DHW heat exchanger: Turbotec DTUSFSC-48, WFI #62I516B01

° Control box assembly: WFI #13S521B01

° Control board: Northern 2-speed

° Electric heater: 10 kw, WFI #EAM/L10

APPLICATION

Job Site:	Ithaca, N.Y.
Heat Loss:	55,000
Heat Gain:	20,000
Unit:	ATVN036A110CLTX / EP0010
Estimated Annual Cost:	$1,342 (based on .10/Kwh)
Ground Loop Information:	560' vertical bore 1.25" PE (2-280' boreholes)
Homeowner:	Stu Berg (NYSEG)
Dealer:	Kool Temp (Mike Veeter)
Electric Service:	New York State Electric & Gas
Emergency Heat:	20 kw

Test Site: Ithaca, New York

EP0010

Design Specifications

- Model #: ATVN036A110CLTX
- Serial #: EP0010
- Chassis: 45, left return, topflow
- Compressor: Copeland CTN1-0501, serial #93I03929A, WFI #34P511B01
- Air side heat exchanger: Heatcraft 3CY-1403D, 28x25, lanced fin, rifled tube, WFI #61P505C01
- Liquid side heat exchanger: Koax-K60, WFI #62I507A01
- Reversing valve: Ranco V-4, WFI #33P503B01
- Expansion valve: Alco RAEB4, 20% bleed, WFI #33P534B07
- Blower housing: Morrison 11x10 tight, WFI #53P501B01
- Blower motor: G.E. 1/2 hp ICM1, long shaft, WFI #14P503B01
- DHW heat exchanger: Turbotec DTUSFSC-48, WFI #62I516B01
- Control box assembly: WFI #13S521B01
- Control board: Northern 2-speed
- Electric heater: 20 kw, WFI #EAL20

WaterFurnace® As Built Site Plan BERG HOME ITHACA, NY

Company: ______________________ Date: ______________

Certified GSC technician: JFB ______________ GSC number: ______________

Address: ____

City: ______________ State: __________ Zip: __________ Phone ______________

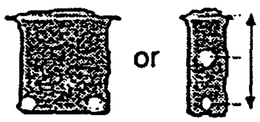
Directions to job site: ______________________________

Instructions

1. Please select the type of loop installed.
2. Draw the GCL as installed. Locate the GCL to property lines, existing structures, & or other permanent land marks.
3. Provide a profile view of the site.
4. Attach Site Survey or locate all applicable items from the *Site Survey Checklist*.

❑ *2 Pipe*

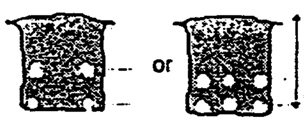
❑ Backhoe ❑ Trench



Width =

Depth = ______ ______

❑ *4 Pipe or* ❑ *6 Pipe*



Width = ____________

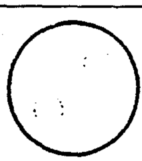
Depth =

❑ *Other*

Width =

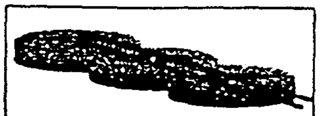
Depth =

❑ *1 Pair Vertical*



Backfill =

❑ *Pond*

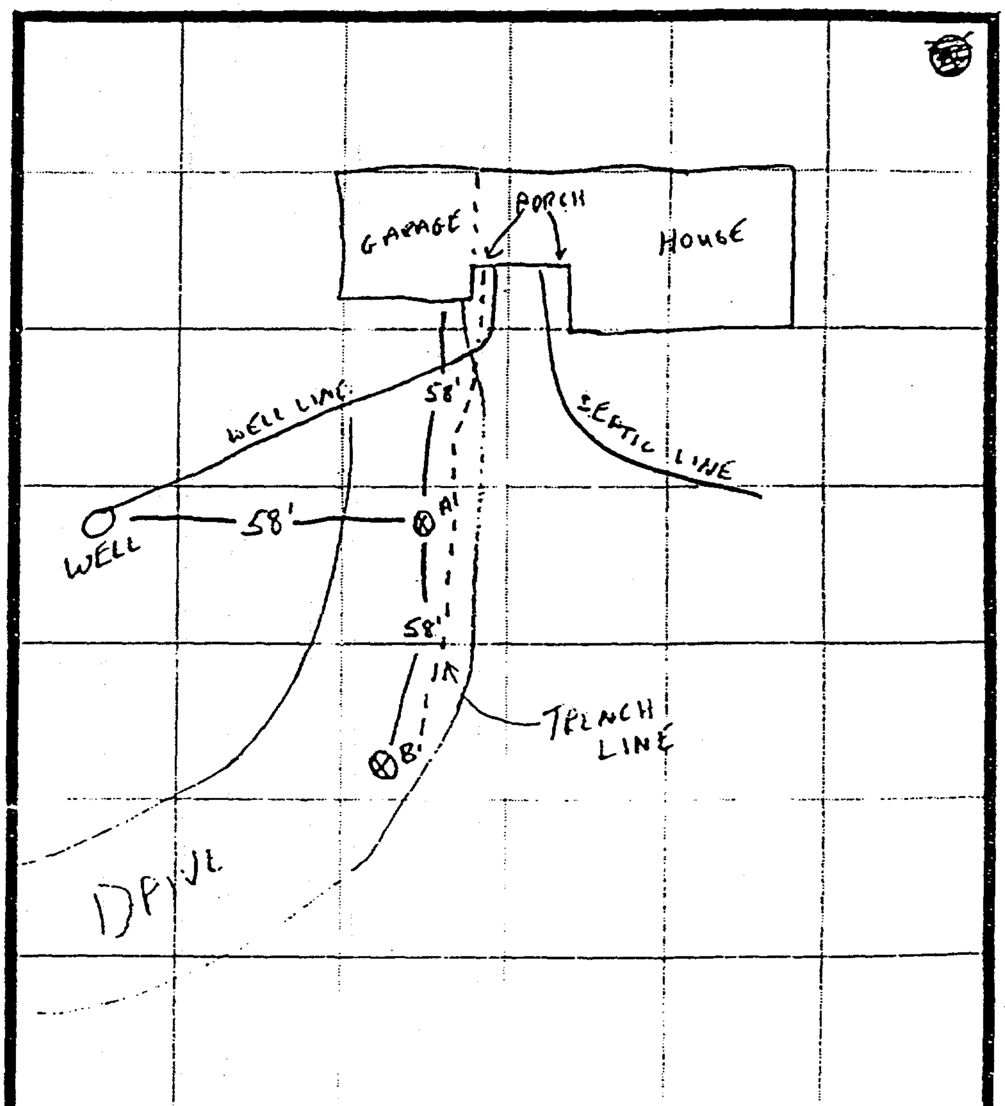


Number of coils =

Coil length = ____________

Depth installed =

Geothermal Closed Loop System
As Built Site Plan



SCALE ______ = ______

Determine:

N Profile S	W Profile E

APPLICATION

Job Site:	Rhinebeck, N.Y.
Heat Loss:	43871 (Main & second level, excluding basement)
Heat Gain:	31216
Unit:	ATVN036A110CLTX / EP0006
Estimated Annual Cost:	$1,221 (based on .10/Kwh)
Ground Loop Information:	480' of horizontial slinky at 5'-6' depth
Homeowner:	Charlie Freni (CHG & E)
Dealer:	Kool Temp (Mike Veeter)
Electric Service:	Central Hudson Gas & Electric
Emergency Heat:	20 kw

NOTES:

The 580' of 6-pipe trench would have resulted in 3480' of 3/4" pipe in the trench. Site layout would not allow this much length of trench so a horizontally-layed slinky loop was installed. Trench length was shortened to 480', however the 3/4" pipe length was increased to 4800'. Soil consisted of a wet sand/clay mixture, which is ideal for a slinky installation.

WaterFurnace® As Built Site Plan FREN' HOME RHINEBECK, NY

Company: ____________ Date: ____________

Certified GSC technician: JFB GSC number: ____________

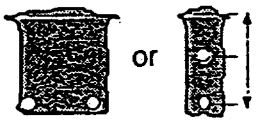
Address: ____________

City: ____________ State: ____________ Zip: ____________ Phone ____________

Directions to job site:	Instructions
	1. Please select the type of loop installed. 2. Draw the GCL as Installed. Locate the GCL to property lines, existing structures, & or other permanent land marks. 3. Provide a profile view of the site. 4. Attach Site Survey or locate all applicable items from the Site Survey Checklist.

☐ *2 Pipe*

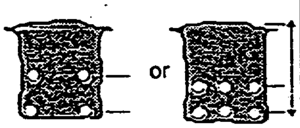
☐ Backhoe ☐ Trench



Width = ______

Depth = ______ , ______

☐ *4 Pipe or* ☐ *6 Pipe*



Width = ______

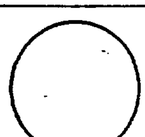
Depth = ______ , ______

☐ *Other*

Width = ______

Depth = ______ , ______

☐ *1 Pair Vertical*



Backfill = ___

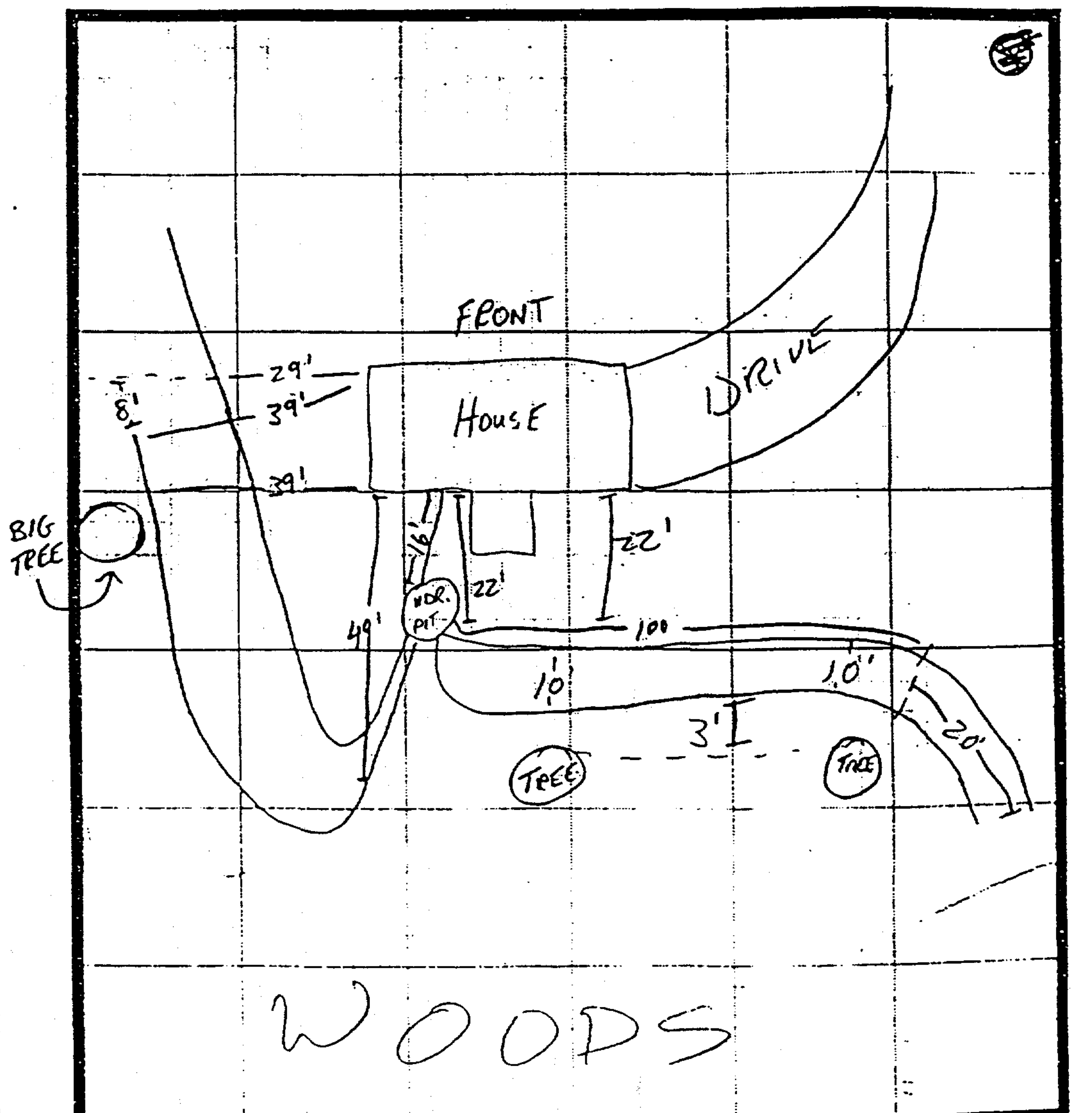
☐ *Pond*

Number of coils =

Coil length = ______

Depth installed =

Geothermal Closed Loop System
As Built Site Plan



SCALE ____ = ____

Determine:

N Profile S	W Profile E

Test Site: Rhinebeck, New York EP0006

Design Specifications

° Model #: ATVN036A110CLTX

° Serial #: EP0006

° Chassis: 45, left return, topflow

° Compressor: Copeland CTN1-0501, serial #92L22214A, WFI #34P511B01

° Air side heat exchanger: Heatcraft 3CY-1403D, 28x25, lanced fin, rifled tube, WFI #61P505C01

° Liquid side heat exchanger: Koax-K60, WFI #62I507A01

° Reversing valve: Ranco V-4, WFI #33P503B01

° Expansion valve: Alco RAEB4, 20% bleed, WFI #33P534B07

° Blower housing: Morrison 11x10 tight, WFI #53P501B01

° Blower motor: G.E. 1.0 hp ICM1, WFI #14P501B01

° DHW heat exchanger: Turbotec DTUSFSC-48, WFI #62I516B01

° Control box assembly: WFI #13S521B01

° Control board: Northern 2-speed

° Electric heater: 20 kw, WFI #EAL20

APPLICATION

Job Site:	Stillwater, N.Y.
Heat Loss:	61098 (including basement)
Heat Gain:	42431
Unit:	ATVN036A110CLTX / EP0011
Estimated Annual Cost:	$1,456 (based on .10/Kwh)
Ground Loop Information:	700' horizontal 6-pipe *
Homeowner:	Bill Carpenter (home-builder)
Dealer:	Kool Temp (Mike Veeter)
Electric Service:	New York State Electric & Gas
Emergency Heat:	20 kw

NOTE:

Trench length was increased from 580' up to 700' after the trench was observed to be dryer than expected.

STILL WATER

WaterFurnace® As Built Site Plan Carpenter Mechanicville, NY

Company: ______ Date: ______

Certified GSC technician: JFB GSC number: ______

Address: ______

City: ______ State: ______ Zip: ______ Phone ______

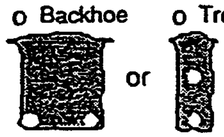
Directions to job site: ______

Instructions

1. Please select the type of loop installed.
2. Draw the GCL as installed. Locate the GCL to property lines, existing structures, & or other permanent land marks.
3. Provide a profile view of the site.
4. Attach Site Survey or locate all applicable items from the Site Survey Checklist.

o *2 Pipe*

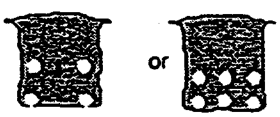
o Backhoe or o Trench



Width =

Depth =

o *4 Pipe* or o *6 Pipe*



Width =

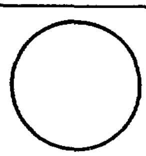
Depth =

p *Other*

Width =

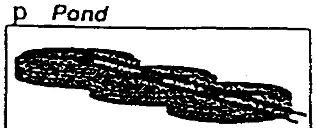
Depth =

p *1 Pair Vertical*



Backfill =

p *Pond*

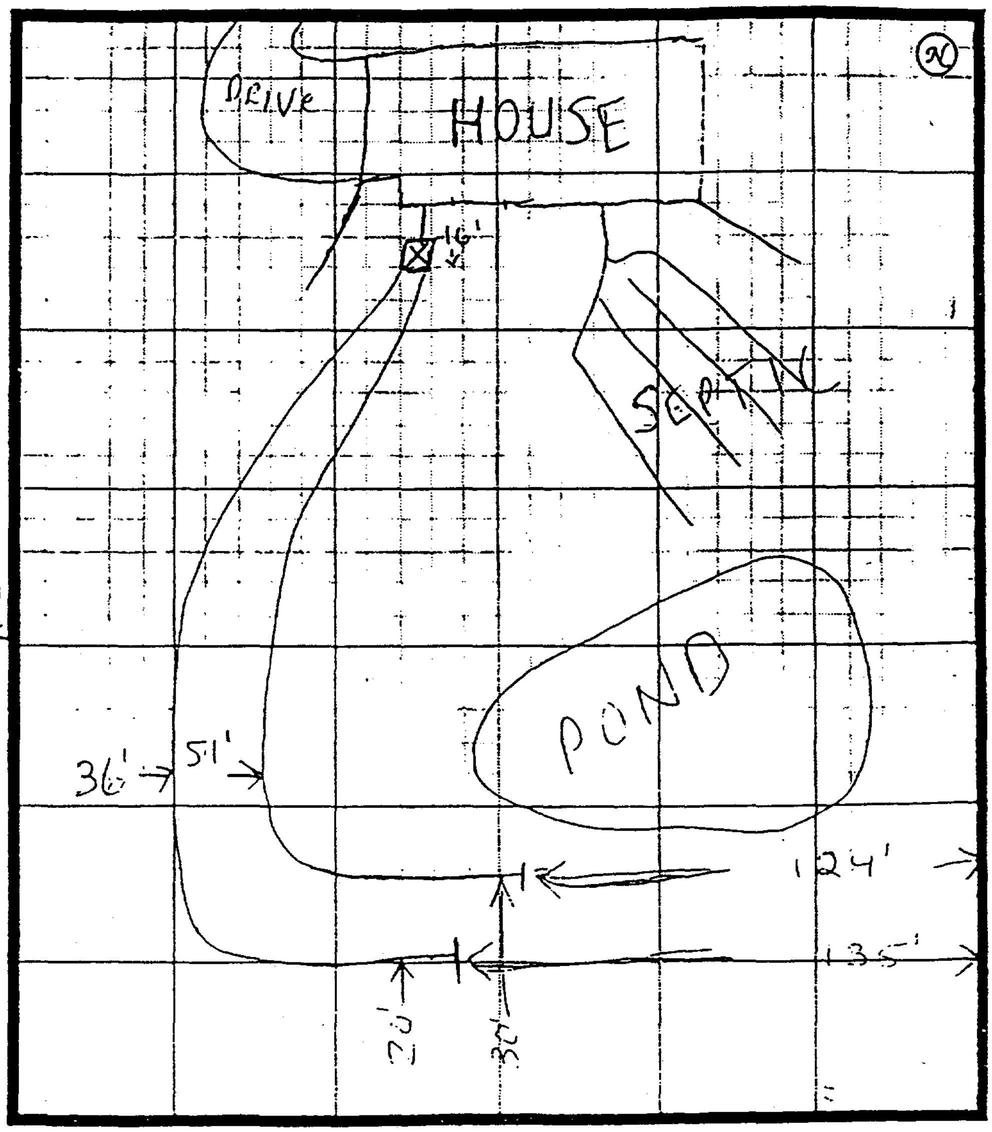


Number of coils =

Coil length =

Depth installed =

Geothermal Closed Loop System
As Built Site Plan



SCALE ____ = ____

Determine:

N Profile S W Profile E

Test Site: Stillwater, New York EP0011

Design Specifications

- Model #: ATVN036A110CLTX
- Serial #: EP0011
- Chassis: 45, left return, topflow
- Compressor: Copeland CTN1-0501, serial #93I03883A, WFI #34P511B01
- Air side heat exchanger: Heatcraft 3CY-1403D, 28x25, lanced fin, rifled tube, WFI #61P505C01
- Liquid side heat exchanger: Koax-K60, WFI #62I507A01
- Reversing valve: Ranco V-4, WFI #33P503B01
- Expansion valve: Alco RAEB4, 20% bleed, WFI #33P534B07
- Blower housing: Morrison 11x10 tight, WFI #53P501B01
- Blower motor: G.E. 1/2 hp ICM1, long shaft, WFI #14P503B01
- DHW heat exchanger: Turbotec DTUSFSC-48, WFI #62I516B01
- Control box assembly: WFI #13S521B01
- Control board: Northern 2-speed
- Electric heater: 20 kw, WFI #EAL20