

DEMAND AND ENERGY STUDY OF HIGH EFFICIENCY HEATING AND COOLING EQUIPMENT IN GEORGIA

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INTRODUCTION

The complexity and many assumptions used in the procedures to calculate air-source heat pump seasonal energy efficiency ratio (SEER) and heating seasonal performance factor (HSPF) make it difficult to compare energy use with equipment rated under different standards. SEER and HSPF are not indicators for demand since they are seasonal values, and performance at severe conditions is not heavily weighted. The ratings for ground-source heat pumps calculated performance at a single fluid temperature (32°F) for heating coefficient of performance (COP) and a second for cooling EER (77°F). These ratings are not seasonal and reflect temperatures for an assumed location and ground heat exchanger type, and are not ideal indicators of energy use.

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) recommends a weather driven energy calculation, like the bin method, in preference to single measure methods like SEER, HSPF, EER, COP and AFUE for furnaces. The bin method permits the energy use to be calculated based on local weather data and equipment performance over a wide range of temperatures. The bin method also calculates demand at the most severe conditions.

This method was used to compare the energy use and demand of four high efficiency heat pumps in Atlanta and Macon. The heat pumps considered were a high efficiency single-speed air source, a variable-speed air source, a standard ground-source, and high efficiency ground-source.

HEAT PUMPS

Table 1 lists the rated capacities and efficiencies of the heat pumps used in this study. The single-speed unit is a split system with a piston compressor. The variable-speed (VS) unit uses a piston compressor and brushless DC motors to drive the compressor and fans. Both units are rated according to ARI Standard 210/240-89. Equations for heat pump capacity and power as a function of outdoor air temperature were developed from manufacturer's data. The units were also corrected for indoor air temperature, defrost, and auxiliary heat.

The ground-source heat pumps were rated according to ARI Standard 330-90. The standard unit has a piston compressor, conventional coils and fan. The high efficiency unit has a scroll compressor and a brushless DC indoor fan motor. Equations for capacity and power as a function of water temperature were developed. These equations were used in a computer code that also incorporated an iterative calculation for the performance of the ground heat exchanger. These heat pumps were also corrected for indoor air

temperature, pump energy, and auxiliary heat. The calculations were conducted for 600 ft. vertical ground-couplings buried in a saturated soil. The high efficiency ground-source unit is not produced in a 3-ton size, so a 3.5-ton unit is used.

Table 1. Ratings of Equipment Used in Study

Heat Pump Type	Cooling		Heating	
	Capacity Btu/h	SEER-air EER-wtr.	Capacity Btu/h	HSPF-air COP-wtr.
Air Heat Pump	34,600	10.3	35,400	7.30
VS Air Heat Pump	37,500	15.2	34,600	8.75
Std. GS Heat Pump	36,000	11.2	28,000	3.0
HE GS Heat Pump	41,000	15.2	29,400	3.4

Ground heat pumps are coupled to vertical 1" U-Bends 600 ft. of bore in total length.

Table 2 lists the conditions of the local climate and building description for which the study was performed.

Table 2. Design Temperature and Loads

Site	Cooling		Ground Temp	Heating	
	Load MBtu/h	Design Temp		Load MBtu/h	Design Temp
Atlanta, GA	34	94	64	38	17
Macon, GA	36	96	66	36	21
Indoor Temperature:	75° (Clg.), 70° (Htg.)				
Occupants:	4				
Lights:	400 Watts (Average)				
Appliances:	1000 Watts (Average)				

WATER HEATING AND COMFORT

The ground-source machines are equipped to heat water. Since the heat recovery unit is located indoors and only a few inches away from the compressor, losses can be minimized. Winter heat recovery is also effective because ground-source heat pumps have excess heating capacity in southern climates.

A typical hot water energy use (60 gallons/day @ 135°F) requires 4120 kWh of electrical energy without heat recovery. The HRUs reduced electrical energy requirement for hot water by 35 to 40% in the study. Water heating with high efficiency air equipment is not recommended by the manufacturers because of the low operating temperatures and heat losses that occur with the split systems.

The variable-speed air unit and the two ground-source heat pumps are well suited to meet the high dehumidification need of Georgia. The constant-speed unit has poor latent cooling capacity and discomfort is likely during mild cooling days. Winter air-delivery temperatures with the ground machines will be 98 to 102°F with the heat recovery unit operational and 100 to 106°F if it is off. The air machines will deliver air at a lower temperature.

RESULTS

Table 3 summarizes the results of the study. The single-speed air unit used the most energy in heating and cooling and had the highest demand in heating. The demand includes auxiliary electric resistance requirements. The variable-speed unit used much less cooling energy but had the highest demand. Heating energy requirement was lower than the constant-speed air unit; but, demand is about the same. Total energy was greater than either ground-source units. The standard efficiency ground-source machine had lower demand (summer and winter) and lower heating energy use than either of the air heat pumps. However, cooling energy requirement was greater than the variable-speed air unit. The high efficiency ground-source unit had the lowest energy and demand requirements. *All calculations are based on the units being properly installed. Ground-source performance is strongly influenced by ground coil type.*

Table 3. Energy and Demand for Heat Pumps

	Cooling		Heating				Water kWh	TOTAL kWh
	kWh	kW	kWh	HP	AUX	kW		
Atlanta								
ASHP ^a	3409	3.7	7397	6570	826	14.0	4120	14926
VSHP ^b	2499	4.0	5540	4947	593	13.7	4120	12159
SEGSHP ^c	2599	3.0	4237	4222	14	6.7	2620	9456
HEGSHP ^d	2079	2.7	3510	3475	35	6.7	2509	8098
Macon								
ASHP	4418	3.7	6394	5688	706	12.8	4120	14932
VSHP	3337	4.0	4736	4300	436	12.4	4120	12193
SEGSHP	3435	3.0	3641	3635	6	5.8	2420	9496
HEGSHP	2768	2.7	3014	2997	16	5.8	2338	8120

- Air-Source Heat Pumps
- Variable Speed Air Heat Pumps
- Standard Ground-Source Heat Pumps
- High Efficiency Ground-Source Heat Pumps

COSTS

The cost of operating the four different systems are compared to the cost of operating a system that uses a 10.3 SEER air conditioner, an 80% AFUE furnace, and a 78% AFUE gas water heater. Rates for Atlanta Gas Light Co. and Washington EMC, which appear to represent an average for the area, were used. Results are shown in Table 4.

Table 4. Cost of Operating Heating, Cooling, and Water Heating Equipment

Unit	Cooling	Heating	Water Ht.	Total
ASHP	\$332	\$342	\$302	\$976
VSHP	251	302	302	807
SEGSHP	258	195	177	630
HEGSHP	208	161	163	532
AC/Gas Heat	332	336*	195**	863

* Includes \$33 for electric fan energy.

** Includes \$77 for gas base charges that are not required for other units.

CONCLUSIONS

- The air heat pumps can not match the lower cost of operating typical electric/gas equipment.
- The ground-source equipment can operate with lower cost than the electric/gas equipment.
- The variable-speed heat pump would seem to be the least desirable unit for a utility to advocate since it reduces energy but increases summer demand and has little impact on reducing winter demand.
- The standard ground-source heat pump reduces demand and energy. It would appear to be a logical unit to rebate for a winter peaking utility.
- The high efficiency ground-source unit gives the greatest demand reduction and energy savings. It would seem to be the most advantageous to a summer peaking utility.

REMARKS

- Contractors are extremely reluctant to apply this technology and must be strongly encouraged.
- The added cost of a GSHP to a typical home mortgage is \$250/year which can be recovered with energy savings.
- Simple paybacks for retrofits are 6 to 8 years without rebates.