

ENGINEERING

S Y S T E M S O L U T I O N S

In previous issues of *Engineering System Solutions*, we have demonstrated the importance of using energy analysis to determine optimal HVAC solutions for a building. This newsletter provides the same analysis for geothermal water source heat pump systems.

We have taken a typical HVAC system for small office and school applications and analyzed the energy savings and life cycle costs of implementing and optimizing a geothermal system. The result is a system that is significantly more efficient than alternative systems, with lower life cycle costs and a favorable payback to justify possible installed cost premiums.

Bob Koschka, our senior applications engineer for water source heat pumps, provided the technical expertise in the development of this newsletter. More information about geothermal water source heat pump systems and how to apply them can be found in our *Geothermal Heat Pump Design Manual (AG31-008)*. For a copy, contact your local McQuay representative or visit www.mcquay.com.

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Optimizing Geothermal Heat Pump Systems For Higher Efficiency, Maximum LEED Points and Lower Installed Costs

Why are Geothermal Heat Pumps So Efficient?

Geothermal heat pumps are significantly more efficient than traditional water source heat pump systems. Traditional systems use a boiler and a tower to maintain their loop temperature. When the loop temperature rises above the set point, the closed circuit cooler works to lower the temperature. When the loop temperature drops below the set point, a boiler is used to raise the loop temperature. Loop temperatures are often maintained between 60°F and 90°F.

Geothermal systems use the ground, a pond or well water to maintain their loop temperature. As a result, no fossil fuel is expended, significantly reducing the energy use of the system. Loop temperatures can range from 35°F to 100°F. The lower loop temperatures provide more efficient cooling than traditional systems, particularly at part load. Because the majority of the operating hours in most commercial applications are devoted to cooling at part load, the geothermal system will be significantly more efficient. For example, a traditional system maintaining a loop temperature above 60°F might have a performance of 22 EER. A geothermal system can have a performance as high as 36 EER.

The remaining portions of this newsletter demonstrate how these efficiencies can pay off for the building owner over the life of their geothermal HVAC system.

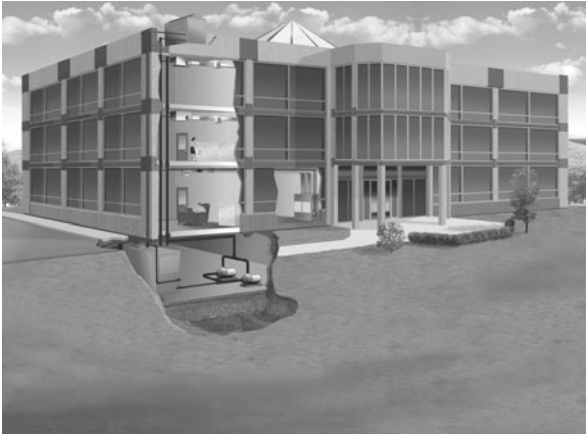
Set A Baseline Design And Compare Efficiencies

The first step in demonstrating the efficiency of a geothermal system is to set a baseline design. To do this, we followed the Informative Appendix G, Performance Rating Method, from ASHRAE Standard 90.1. Our baseline is a 5-story, 100,000 ft² office building with standard office hours, a common application for water source heat pumps and several other HVAC systems. Using McQuay Energy Analyzer™ software, we can do a quick analysis to determine the energy savings and life cycle payback of the geothermal water source heat pump system.

Our baseline HVAC system is a packaged VAV rooftop system that meets the minimum requirements of ASHRAE 90.1-2004. With the exception of the HVAC system, all other design parameters are kept the same to provide an equal comparison of the systems. The results for five different cities are shown in Table 1.

The energy rates used in this analysis are average state energy rates in accordance with the ASHRAE Standard 90.1 Informative Appendix G. These are published by the Energy Information Administration of the Department of Energy (DOE). They are updated annually and can be found at <http://www.eia.doe.gov>.

Conventional Boiler/Tower System



Geothermal Systems

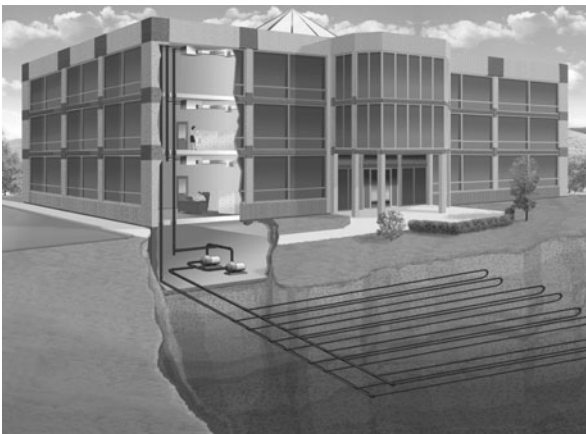


Table 1. Comparison of Baseline VAV Rooftop System and Geothermal Water Source Heat Pump System in a 5-story, 100,000 ft² Office Building.¹

City	Climate Zone	Baseline Energy Cost (USD)	Geothermal Energy Cost (USD)	Percent Savings
Philadelphia, PA	4A	136,379	114,816	15.80%
Minneapolis, MN	6A	103,246	89,954	12.90%
Helena, MO	6B	99,157	84,073	15.20%
Denver, CO	5B	102,873	94,857	7.80%
Chicago, IL	5A	117,256	106,229	9.40%

¹Actual results may vary based on occupancy and occupied hours.

In addition to energy rates, the differences in savings from Table 1 result from local requirements. For example, Philadelphia is in climate zone 4A (as defined by ASHRAE Standard 90.1-2004 and DOE climate zones) and economizers are not required for its baseline design. All other baseline designs require economizers, which lower energy costs because economizer hours reduce condensing unit hours.

Comparing the results in Table 1 to LEED 2.2 guidelines² shows that the geothermal system could earn up to two points under Energy and Atmosphere, Credit 1, depending on the energy rates and the location (Table 2).

It is important to note that we are not comparing optimized systems in our example above. The geothermal system represents a typical design used by McQuay. The baseline VAV system provides a method for quantifying the efficiency difference between systems that meet all prerequisites for LEED Energy and Atmosphere, Credit 1. Refer to Edition 20 of Engineering System Solutions (April 2004), *LEED Energy and Atmosphere, Credit 1 – Measuring Efficiency to Maximize LEED Points*, for a complete explanation of this method.

In addition, although we modeled the building energy use in this analysis, as is required by Energy and Atmosphere, Credit 1, we have only compared the energy use of two HVAC systems. We have not examined the effects of changing the lighting, envelope or miscellaneous electric loads in the building. All of these factors must be considered to maximize points for LEED Energy and Atmosphere, Credit 1.

What about costs?

The high efficiency of a geothermal system is often perceived to come at a cost premium, primarily because geothermal systems are relatively new compared to other common HVAC systems. Like many new technologies or systems, the cost premium can depend on the experience of the designer.

In Table 3, we have calculated the simple payback of the geothermal system for the five cities in North America shown in Table 1. Some assumptions are made in this calculation. First, it is generally accepted that geothermal systems cost less to maintain than standard VAV rooftop systems. In order to be fair to both systems, the maintenance cost savings versus the rooftop VAV system was given a range from \$0.02/ft² to \$0.06/ft². Second, the capital cost premium of the geothermal system was given a range from \$0.50/ft² to \$1.50/ft².

Table 2. LEED 2.2 Energy and Atmosphere, Credit 1²

Energy Cost Savings (%)	LEED Points
10.5	1
14	2
17.5	3
21	4
24.5	5
28	6
31.5	7
35	8
38	9
42	10

²At the time of this publication, the public comment period for LEED Version 2.2 had been completed but the guideline had not been published. Visit www.usgbc.org for the current version of the LEED Certification Program.

Table 3. Life Cycle Cost Comparison and Payback.

City	Annual Utility Cost Savings (\$)	Annual Maintenance Cost Savings (\$/ft ²)	Capital Cost Premium (\$/ft ²)		
			\$0.50	\$1.00	\$1.50
			Payback Period (years)		
Philadelphia, PA	21,563	\$0.02	2.1	4.2	6.4
		\$0.04	2	3.9	5.9
		\$0.06	1.8	3.6	5.4
Minneapolis, MN	13,292	\$0.02	3.3	6.5	9.8
		\$0.04	2.9	5.8	8.7
		\$0.06	2.6	5.2	7.8
Helena, MO	15,084	\$0.02	2.9	5.9	8.8
		\$0.04	2.6	5.2	7.9
		\$0.06	2.4	4.7	7.1
Denver, CO	8,016	\$0.02	5	10	15
		\$0.04	4.2	8.3	12.5
		\$0.06	3.6	7.1	10.7
Chicago, IL	11,027	\$0.02	3.8	7.7	11.5
		\$0.04	3.3	6.7	10
		\$0.06	2.9	5.9	8.8

Table 4. Energy and Cost Comparison of 85°F and 95°F loops

City	Energy Used 85°F loop (\$)	Loop Size 85°F (ft)	Energy Used 95°F Loop (\$)	Loop Size 95°F (ft)	Capital Cost Difference in Loop Size (\$10/ft)	Energy Savings (\$)	Payback (years)
Philadelphia, PA	113,619	57,170	114,816	45,490	116,800	1,197	98
Minneapolis, MN	89,155	44,640	89,954	37,060	75,800	799	95
Helena, MO	83,365	38,910	84,073	32,300	66,100	708	93
Denver, CO	93,865	44,550	94,857	35,310	92,400	992	93
Chicago, IL	105,188	51,400	106,229	41,860	95,400	1,041	92

Table 5. Constant Flow Versus Variable Flow Using VFDs

City	Utility Cost Savings (\$)	Capital Cost Premium (\$)		
		\$6,000	\$8,000	\$10,000
		Payback Period (years)		
Philadelphia, PA	10,703	0.56	0.75	0.93
Minneapolis, MN	7,897	0.76	1.01	1.27
Helena, MO	7,206	0.83	1.11	1.39
Denver, CO	8,349	0.72	0.96	1.2
Chicago, IL	9,659	0.62	0.83	1.04

As you can see from Table 3, the payback for the cost premium of a geothermal system ranges from less than 2 years to 15 years, depending on the utility and maintenance cost savings, and the capital cost premium. The cost premium for a geothermal system is easily overcome by cumulative energy savings in some climates and applications. Note that simple payback only looks at first year cost savings. Rising costs for natural gas and electricity in many areas of the United States can reduce the payback period.

Optimizing Geothermal Systems

There are three parameters that should be considered in optimizing a geothermal design: The effect of raising the loop temperature on operating and capital costs, using Variable Frequency Drives (VFDs) on the pumps, and using energy recovery ventilators (ERV) for the make-up air. Each has been incorporated in the design of our geothermal system in this newsletter.

Loop Temperature Versus Operating Costs

The loop temperature of a geothermal system affects its efficiency and capital cost. A smaller geothermal loop will run at higher temperatures and decrease the efficiency of the water source heat pump units. However, a smaller loop results in significant capital cost savings. Table 4 compares the energy use and capital cost of geothermal systems with loops designed at 85°F and 95°F.

From this chart you can see that the energy penalty for the smaller loop is very small and may justify the capital cost savings of using a smaller loop.

Adding VFDs to the Pumps

The pumps serving geothermal systems are small, but they provide constant flow and run continuously. These small pumps can use a significant amount of energy over the course of a year. Adding VFDs to the system to provide variable flow can reduce this energy consumption considerably. In recent years, VFD costs have been reduced so that the payback (in energy cost savings) is worth the capital cost premium for installing a VFD (Table 5).

Energy Recovery of Ventilation Air

In many parts of the United States, make-up air must be conditioned before it enters the building. Water source heat pump units are generally not suitable for handling ventilation loads because they cycle on and off. In the off cycle, dehumidification does not occur and humid air can enter the space. We modeled a standard make-up air unit and an energy recovery ventilation (ERV) unit to supply ventilation air for our geothermal system. Using a range from \$0.50/CFM to \$1.50/CFM capital cost premium for an ERV system, Table 6 shows the climates that are most favorable for an ERV system supplying 18,000 cfm of outdoor air.

Table 6. Energy Recovery Ventilation Payback

City	Utility Cost Savings (\$)	Capital Cost Premium (\$/CFM)		
		\$0.50	\$1.00	\$1.50
Payback Period (years)				
Philadelphia, PA	3,288	2.74	5.47	8.21
Minneapolis, MN	5,252	1.71	3.43	5.14
Helena, MO	4,612	1.95	3.9	5.85
Denver, CO	1,566	5.75	11.49	17.24
Chicago, IL	3,842	2.34	4.69	7.03

Conclusion

Geothermal water source heat pump systems are ideal for achieving high efficiency that pays back year after year in energy cost savings for building owners. While the installed cost of the system can

be higher than more conventional systems, the payback is often very favorable for achieving lower life cycle costs. For more information on geothermal design, contact your local McQuay representative or visit www.mcquay.com.

The data and suggestions in this document are believed current and accurate at the time of publication, but they are not a substitute for trained, experienced professional service. Individual applications and site variations can significantly affect the results and effectiveness of any information. The reader must satisfy him/herself regarding the applicability of any article and seek professional evaluation of all materials. McQuay disclaims any responsibility for actions based on this document.

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