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GREENHOUSE HEATING WITH LOW TEMPERATURE GEOTHERMAL WATER

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ABSTRACT

Greenhouse heating systems can be designed that supply 100% of the annual heat requirements using geothermal water with a temperature as low as 81°F. The heat is extracted using a forced air system with finned coil heaters in the air ducting. Design and evaluation was based on an energy efficient semicircular arching roof type with double polyethylene covering. The 1 acre of greenhouses were located in the LaGrande area of Oregon where 81°F water exists at a shallow depth. Three cases were considered in the economic evaluation which savings were calculated based on displacing 39,330 therms of natural gas annually. The three 20-year life-cycle cost analyses generated rates of return on capital investment of 19.7%, 27.2% and 15.5%. The highest rate of return (27.2%) is for the new greenhouse where an existing geothermal well and water disposal system exists. Lowest rate of return is for the retrofit situation where wells are needed and capital credit cannot be taken for the conventional hydronic system.

INTRODUCTION

In many areas of the western United States, low temperature geothermal water is available at relatively shallow depths. Three such areas are the Yakima Valley, of Washington, and the LaGrande and Burns areas of Oregon. For this evaluation the LaGrande area was chosen where it is known that 81°F water can be found in many locations at a depth of 800 feet. A system was developed using this 81°F water to provide the total heating requirements for one acre of a commercially available greenhouse. The system maintains a minimum inside temperature of 60°F. Capital and operating costs were developed, and savings were determined based on displacing natural gas fuel. Economic feasibility was determined for several cases including; (1) new construction with existing well and water disposal, (2) new construction with new well facilities, and (3) retrofit of existing greenhouse of identical design with new well facilities.

Heat Requirements for the Greenhouses

The greenhouses used for this study have a semicircular arching roof which is 12 feet high at the center, and 30 feet wide at the base. Two 96 foot units are connected end to end to form a pair. Then, 8 pairs are gutter connected to form an overall ground space of 192 feet by 240 feet, or 46,080 square feet. This is about 1.06 acres. The roofs are covered with 6 mil double polyethylene. Total transparent area is approximately 60,000 square feet which yields a roof/floor ratio of 1.3:1.

Figure 1 shows design peak heating requirements versus inside-outside temperature difference for single and double polyethylene covering. The curves were calculated based on one air change per hour, and a 5 mph wind. For these conditions the double polyethylene covered greenhouse requires 45% less heating than the single polyethylene covered greenhouse.

For the LaGrande area the outside design temperature was selected at 1°F. It is estimated that the temperature will be 1°F or higher 99% of the time during the three winter months of December through February. During the brief periods when the outside air temperature is less than 1°F the temperature inside would be less than 60°F unless supplemental heat is used. For instance, at an outside temperature of -10°F, and a 5 mph wind, a nighttime inside temperature of about 57°F could be expected. The peak heating required with the double polyethylene with the 59°F temperature difference is 49.4 Btu/hr ft^2 for a total requirement of just under 2.3 million Btu per hour.

Description of Heating System

Due to the low temperature of the geothermal resource a forced air system using finned tube coils was selected. Greenhouses that are air heated normally utilize 2 to 3 SCFM (standard cubic feet per minute) of air per square foot of floor space. For the geothermally heated greenhouse, 140,672 SCFM of recirculating air is needed to supply the design amount of heat. This amounts to 3.05 SCFM of air per square foot of floor. The air is supplied by 16 centrifugal fans installed in each of the outside ends. Fan discharge air enters the coil at 60°F and leaves at 75°F, and is distributed using a larger diameter plastic tube that runs overhead along the length of the greenhouse.

Table 1. gives the details of the finned tube coils. Two conditions are shown: (1) the design condition with 60°F inside air temperature and 1°F

outside , and (2) a colder condition with 57°F inside and a -10°F outside air temperature. Notice that the coil heat output increases as the inside air temperature decreases. At constant air flow and water flow the heat output increases 14%. The colder air temperatures to the coil allows a lower water discharge temperature.

The 460 gpm geothermal water supply and disposal piping is polyvinyl chloride (PVC), varying in size from 1 1/4 in. to 6 in. It is not necessary to insulate, since during peak conditions the water will arrive at the furthest finned coils at a temperature above 80°F. Both production well and disposal system are located within 100 feet of the greenhouses. The new 800 ft production well is 12 in. to 150 ft with 10 in. casing, and the remainder is 8 in. with 6 in. casing. The new 800 ft injection well is 8 in. with 6 in. casing.

Operating and Capital Cost

Table 2. summarizes the capital and operating costs for the three cases that were considered, and the conventional natural gas heated greenhouse with which comparisons were made.

Economic Evaluation

Economic evaluations were made based on displacing natural gas in a conventionally heated greenhouse with a hydronic system. Using 75% efficiency, the annual gas usage amounts to 39,330 therms or $21,002.22 at $0.534 per therm.

A 20-year life-cycle cost analysis was completed for a greenhouse complex heated with natural gas versus geothermal energy. Three different cases were considered.

Case 1 evaluated natural gas versus geothermal for new construction. This included drilling a production and an injection well for the geothermal system.

Case 2 is the same evaluation as the first except that it is assumed that the geothermal system is hooked up to an existing well with effluent disposed into an existing drainage ditch. The capital investment required is only for the heating system plus a $30,000 production well pump. Both of the above cases include a $46,000 boiler for the natural gas system, making the incremental capital investment $129,000 for Case 1, and $84,000 for Case 2.

Case 3 assumes retrofit of an existing gas-fired heating system. This case includes $100,000 for the geothermal heating system, $45,000 for a production and an injection well, and $30,000 for the production well pump. Costs of the gas-fired boiler were not subtracted since it was assumed to be already in place with little or no net salvage value and therefore was assumed to be a sunk cost.

In Table 3, that follows, column two shows the 20-year forecasted costs for natural gas, inflating as follows: 9% per annum through 1984, 9.2% per annum from 1985 through 1989, 10% per annum from 1990 through 1994, and 10.2% per annum thereafter.

Column three forecasts the maintenance costs of the natural gas system inflating at 7% per annum over the 20-year life.

Column four projects insurance costs of the natural gas system inflating at 2% per annum.

Column five projects the 20-year cost of electricity associated with the natural gas system inflating at 7.9% per annum through 1987 and 9.1% per annum thereafter.

Column six shows the total annual cash flow for the natural gas system.

Column seven projects the maintenance costs for the geothermal system inflating at 7% per annum. Salaries were not included in maintenance costs for either system since they were assumed to be the same for both systems.

Column eight projects insurance costs for the geothermal heating inflating at 2% per annum.

Column nine projects the electrical costs for the geothermal system using the same inflation rates as column five.

Column ten shows the 20-year net cash flow savings of the geothermal system over the natural gas system. Notes one, two and three in this column indicate simple payback for Cases 1, 2 and 3, respectively.

Internal rates of return are shown in the lower left-hand corner of Table 3. For Case 1, a $129,000 additional capital investment required for the geothermal provides a 19.7% return on investment. Case 2 provides a 27.2% return on investment for $84,000 additional capital investment required for the geothermal system. For Case 3, $175,000 capital investment required to retrofit an existing natural gas greenhouse yields a 15.5% return on investment.

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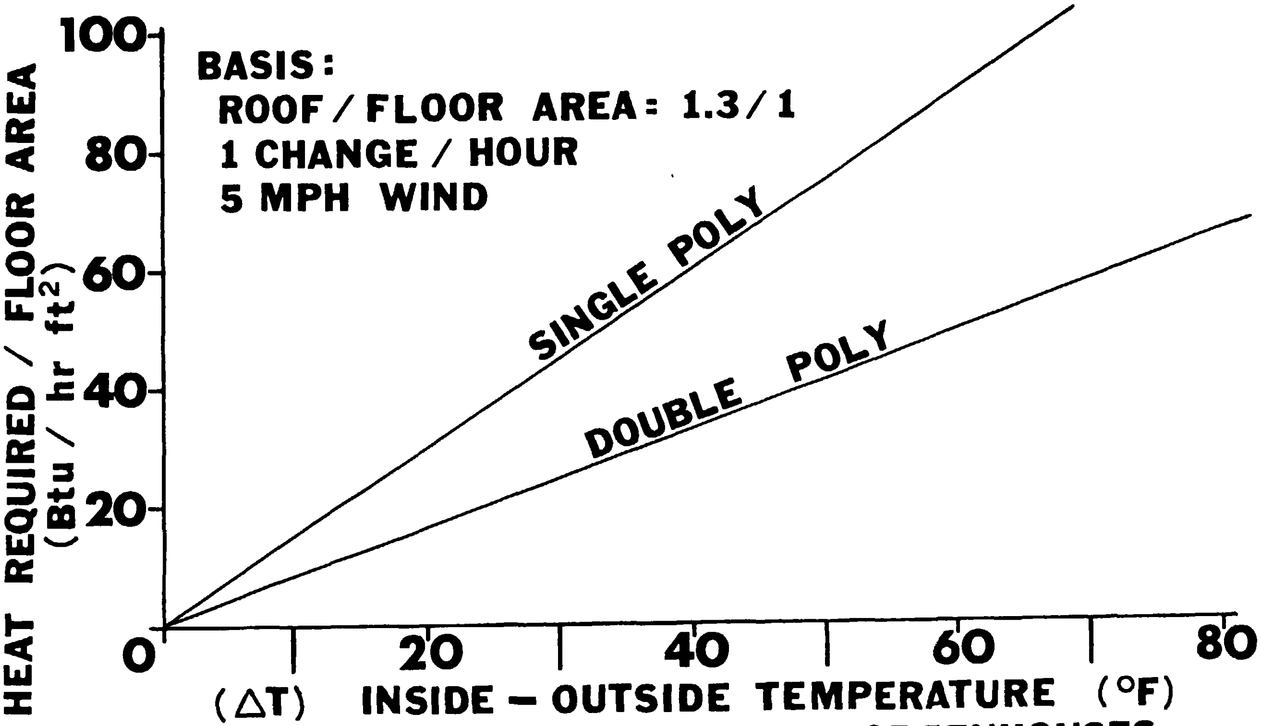

FIGURE 1. HEAT REQUIRED FOR GREENHOUSES

FINNED TUBE COILS FOR GEOTHERMAL GREENHOUSE

TABLE 1

Description:

Number required	16
Fin height (in.) x fin length (in.)	40 1/2 x 51
Face area (sq ft)	14.34
Tubes per row	26
Number of rows	5
Tube size	5/8"
Fins per inch	12
Number of feeds	13
Number of passes	10

Operating Conditions:

	Design	Alternate
Outside air temp. (°F)	1	-10
Inside (entering) air temp. (°F)	60	57.3
Leaving air temp. (°F)	75	74.3
Entering water temp. (°F)	81	81
Leaving water temp. (°F)	71	69.6
Air flow (acfm)	9,545	9,545
Air flow (scfm)	8,792	8,838
Elevation (feet)	2,755	2,755
Air velocity through coil (afm)	666	666
Heat output (Btu/hr)	143,751	163,880
Water flow through coil (gpm)	28.75	28.75
Water side pressure drop (ft H_2O)	4.63	4.63
Air side pressure drop (in. H_2O)	0.79	0.79

SUMMARY OF CAPITAL AND OPERATING COST - TABLE 2

Item	CASE I New, with New Well & Wtr Disposal	CASE II New, with Existing Well & Wtr Disposal	CASE III Retrofit, with New Well & Wtr Disposal	CONVECTIONAL Natural Gas Fired Hydronic System
CAPITAL COST				
Production well	24,000	-	24,000	-
Injection well	21,000	-	21,000	-
Turbine pump	30,000	30,000	30,000	-
Piping	18,000	18,000	18,000	-
Centrifugal fans	27,000	27,000	27,000	-
Finned coils & ducting	29,000	29,000	29,000	-
Misc. mechanical & electrical	6,000	6,000	6,000	-
Subtotal	155,000	110,000	155,000	
Contingency & Engr. fee	20,000	20,000	20,000	
Total Capital Cost -	$175,000	$130,000	$175,000	$ 46,000(1)
OPERATING COST (FIRST YEAR)				
Maintenance:				
Piping & finned coils	243.75	243.75	243.75	-
Centrifugal fans	1,012.50	1,012.50	1,012.50	-
Pump	1,500.00	1,500.00	1,500.00	
Remainder	875.00	875.00	875.00	
	$3,631.25	$3,631.25	$3,631.25	$1,380.00(2)
Taxes & insurance	500.00	500.00	500.00	230.00
Electric power @ $.038/kWh	4,892.99	4,892.99	4,892.99	302.16
Total Operating Cost (First Year)	$9,024.24	$9,024.24	$9,024.24	$1,912.16

(1) Based on $\$1.00/ft^2$
(2) 3% of $46,000

LIFE CYCLE COST ANALYSIS FOR GREENHOUSE HEATING SYSTEMS: TABLE 3
NATURAL GAS VS. GEOTHERMAL

1 YEAR	2 NATURAL GAS PER ANNUM	3 MAINT. COSTS PER ANNUM	4 INS. COSTS PER ANNUM	5 ELEC. COSTS PER ANNUM	6 TOTAL CASH FLOW NATURAL GAS	7 MAINT. COSTS PER ANNUM	8 INS. COSTS PER ANNUM	9 ELEC. COSTS PER ANNUM	10 NET SAVINGS
	21,002.22	1,380	230	302.16		3,631.25	500	4,892.99	
1982	22,892	1,477	235	326	24,930	3,885	510	5,280	15,255
1983	24,953	1,580	239	352	27,124	4,157	520	5,697	16,750
1984	27,198	1,691	244	380	29,513	4,448	531	6,147	18,387
1985	29,701	1,809	249	410	32,168	4,760	541	6,632	20,235
1986	32,433	1,936	254	442	35,067	5,093	552	7,156	(2...22,263
1987	35,417	2,071	259	477	38,224	5,450	563	7,722	24,490
1988	38,675	2,216	264	520	41,676	5,831	574	8,424	(1...26,846
1989	42,234	2,371	269	568	45,442	6,239	586	9,191	29,426
1990	46,457	2,537	275	619	49,888	6,676	598	10,027	(3...32,587
1991	51,103	2,715	280	676	54,773	7,143	609	10,940	36,081
1992	56,213	2,905	286	737	60,141	7,643	622	11,935	39,941
1993	61,834	3,108	292	804	66,038	8,178	634	13,021	44,204
1994	68,018	3,326	298	877	72,518	8,751	647	14,206	48,914
1995	74,955	3,558	303	957	79,774	9,363	660	15,499	54,252
1996	82,601	3,807	310	1,044	87,762	10,019	673	16,909	60,161
1997	91,026	4,074	316	1,139	96,555	10,720	686	18,448	66,701
1998	100,311	4,359	322	1,243	106,235	11,470	700	20,127	73,938
1999	110,543	4,664	328	1,356	116,891	12,273	714	21,958	81,945
2000	121,818	4,991	335	1,479	128,623	13,133	728	23,957	90,806
2001	134,243	5,340	342	1,614	141,539	14,052	743	26,137	100,608
TOTAL					1,334,878				903,790

Internal Rate of Return: (1) 19.7%, (2) 27.2%, (3) 15.5%