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*Geothermal Energy Market Study
on the Atlantic Coastal Plain*

**GEOHERMAL COMMUNITY HEATING
FOR CAPE CHARLES, VIRGINIA**

CLAUDE S. LEFFEL, Jr.

This work was supported by the Department of Energy
under Interagency Agreement DE-A101-79ET27025.

THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY

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ABSTRACT

An economic feasibility study for a geothermal community heating system has been made for the residential heat load of Cape Charles, Virginia using the JHU/APL GRITS Computer Program. The effects of inflation, interest rates, wellhead temperatures, and the addition of reinjection wells are investigated. It is concluded that the utilization of geothermal energy would be feasible if well flows of 500 gal/min could be obtained and if reinjection of the geothermal fluids were not required. A comparison of the geothermal assisted community system with a coal-fired system shows that the coal-fired system may be the most attractive alternative to the heating of homes with individual oil-fired furnaces.

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1. INTRODUCTION

An investigation has been made of the feasibility for using geothermal energy by the Town of Cape Charles, Virginia. The study was begun following a visit to APL by Charles Saddler of Cape Charles and Frank Pleva of North Hampton County. The visit was the result of previous telephone conversations with APL in which some of the possibilities of using geothermal energy had been discussed. Messrs. Saddler and Pleva stated that Cape Charles is located in an economically depressed area and that, while it has a fairly good labor market, an attractive location, and adequate transportation, planning efforts for development always indicated that the principal problem of the area is the lack of an economical source of energy.

Following a discussion of the layout of Cape Charles, the expected geothermal resource, and possible uses of geothermal energy, APL agreed to attempt an economic feasibility study for the use of geothermal energy at Cape Charles with the Geothermal Resource Interactive Temporal Simulation (GRITS) computer program (Ref. 1).

2. SCOPE OF THE CAPE CHARLES STUDY

Cape Charles is an old railroad town of about 1500 independent houses constructed on a planned rectangular grid. The potential hydrothermal resource, as estimated by the Virginia Polytechnic Institute and State University (VPI&SU) (Ref. 2) is modest. Depth to basement is estimated at 3500 feet; temperature at basement is estimated to be 100°F. Because of the low expected temperature of any hydrothermal resource and the absence of any existing or expected commercial or industrial development that could use a resource of this low temperature, the present study is limited to residential heating.

The average house at Cape Charles is a two-story structure with 1800 sq. ft. of floor area located on a lot with an effective area (including street widths) of 6428 sq. ft. Thus, the housing density is about 4340 houses/sq. mi. In the GRITS program, the "single family dense" residential heat load consists of houses of 1600 sq. ft. and a density of 4495/sq. mi. The difference between the "single family dense" GRITS option and the Cape Charles housing heat load is so small, compared with other unknowns, that it is ignored in this study.

The mid-1981 prices for energy at Cape Charles as given by Mr. Pleva are given in Table 1 along with the estimated cost of a million Btu corrected by an appropriate efficiency factor.

Table 1

Energy costs at Cape Charles

No. 2 fuel oil	\$1.33/gal	\$9.78/MBtu	\$14.00/MBtu at 70% eff.
Electricity	8.23¢/kWh	\$24.11/MBtu	\$24.11/MBtu at 100% eff.
Coal	\$138/ton	\$5.31/MBtu	\$7.58/MBtu at 70% eff.

These energy costs are the costs that a hydrothermal district heating system must be compared against. The choice of the efficiency factor is somewhat arbitrary; the average oil consumption for Cape Charles is given by Mr. Pleva to be 1300 gal/yr per residence. This is equivalent to 1.25×10^8 Btu/yr at 70% efficiency. The GRITS computer program will calculate the heating load per residence to be 1.02×10^8 Btu/yr, again a reasonably good agreement, given the uncertainties in the inputs.

3. THE GRITS COMPUTER PROGRAM

The GRITS computer program calculates the cost and revenue streams for each year in the lifetime of a project that uses a hydrothermal resource of low to moderate temperature (Ref. 1). The program performs economic evaluations over a wide range of resource, demand, and financial conditions and, in addition to the yearly computations of cost and revenue streams, will compute at the end of the project life the net present value (NPV) of the project and discounted average cost (DAC) per million Btu of the energy delivered.

The 8A version of the GRITS computer program used here contains approximately 50 inputs or options. Default values are stored in the program, corresponding to a typical Atlantic Coastal Plain hydrothermal resource and energy market. Any or all of these default values can be changed at the user's option.

The task of supplying the residential heat load for Cape Charles by a geothermal district heating system is a well-defined problem, except for uncertainties about the hydrothermal resource and is well adapted for computations on GRITS. For the resource, it is necessary to specify the depth of the geothermal well, the wellhead temperature of the geothermal fluid, and the maximum flow rate. GRITS provides a choice of five types of housing for the residential heating market. As stated above, the GRITS option of "single family dense" closely matches the housing market of Cape Charles. With this option entered, along with the choice of a climate (in this case Norfolk, Virginia) that is stored in the computer, the program will compute the heating load and the length and cost of the distribution system. GRITS will perform the financial calculations in constant dollars (i.e., dollars of constant purchasing power) or in current dollars. The financial options to be entered are the interest rate, inflation rate, and the discount rate (which measures the time preference of money). The lengths of the piping systems that carry the water from the wellhead heat exchanger to the distribution system and the geothermal fluids from the heat exchanger to its disposition point (be it a reinjection well or the bay) must be specified.

GRITS provides for a fossil fuel plant that picks up the thermal load below the design temperature; that is, the ambient temperature above which the heat load is completely supplied by geothermal energy. With these entries, in the resource limited option, GRITS will compute the total heat load, the number of houses served, and the capital cost of the installation. For a

specified amortization lifetime of the components of the system, the program will compute year-by-year the annual capital and operating costs and the discounted average cost over the selected lifetime of the project. If a value is assigned to the energy supplied to the market, it will compute the net present value of the geothermal project.

To investigate the effects of varying parameters, it is convenient to set up a base case scenario. For the Cape Charles study, Table 2 lists the values of the input parameters for the base case, both with and without reinjection wells.

These input parameters were stored in GRITS under the designation CAPECH.002 and were the beginning point for all computer runs. The design temperature of 45°F was chosen because it gave, for the Cape Charles inputs, the minimum discounted average costs for the energy delivered to the market. The value assigned to the selling price of the energy delivered by the system affects only the NPV of the project and the breakeven time, defined as that year in which the NPV of the project becomes zero or positive. Since in its calculation of yearly costs, GRITS includes the cost of debt amortization, if at the end of the study period (here also the lifetime of the project) the NPV is positive or zero, then the project has paid for itself. For the Cape Charles analysis, all financial accounting is performed in constant dollars, which means that inflation reduces the cost of debt service but does not affect the cost of materials and services. GRITS provides the option of distinguishing the inflation rates for fossil fuels from the general inflation rate of the economy, but that option is not used here.

Figure 1 is a schematic of the geothermal plant for Cape Charles that corresponds to GRITS inputs of Table 2. The fossil fuel plant, which supplies the heat required when the ambient temperature falls below the design temperature, is fired by coal for this problem.

Table 2

Input parameters for Cape Charles study

	No reinjection	Reinjection wells
Production wells	1	1
Depth of production well (ft)	3500	3500
Well temperature (°F)	100	100
Reject temperature (°F)	85	85
Reinjection wells	0	1
Depth of reinjection wells (ft)	N/A	3500
Drawdown (%)	10	10
Maximum well flow (gal/min)	500	500
Transport distances to distribution system (mi)	0.2	0.2
Transport distance to reinjection (mi)	0.2	0.4
Climate area	Norfolk, VA	Norfolk, VA
System design temperature (°F)	45	45
Fraction of system in year 0 (%)	100	100
Residential, single family dense (%)	100	100
Commercial buildings	0	0
System selling price for energy (per MBtu)	\$14	\$14
Study period (yr)	20	20
Discount rate	0	0
Interest rate (%)	10	10
Inflation rate (%)	6	6
Cost of electricity (per kWh)	\$0.0823	\$0.0823
Fossil fuel cost (per MBtu)	\$5.31	\$5.31

Fig. 1 Schematic of the geothermal plant for Cape Charles corresponding to GRITS inputs in Table 2.

4. RESULTS OF COMPUTATIONS

In running GRITS, the first thing to be determined is the optimum value of the design temperature. If the values of Table 2 are entered and the design temperature varied, the DAC as a function of design temperature is given in Fig. 2 for the case of no reinjection well. The minimum DAC occurs for a design temperature of 45°F. At that design temperature, the number of houses on the system is 156; 80% of the heating load is supplied by the geothermal source and 20% by the fossil fuel plant. The DAC of the heat delivered to the houses is \$8.56/MBtu — if the delivered energy can be sold for a price greater than the DAC, the project would be economically feasible.

All alternative energy sources that are capital intensive are more attractive economically if the inflation rate is high and the interest rate is low. This is shown in Fig. 3 where the DAC is plotted versus the inflation rate for a fixed interest rate and versus the interest rate for a fixed inflation rate for the case where no reinjection well is required. In this particular case, it is observed that the cost of delivered energy is competitive even at the zero inflation rate.

The addition of a reinjection well to take care of the disposal of the geothermal fluids after the heat has been extracted increases both the capital costs and the operating expenses. This significantly increases the DAC of the delivered energy. For this case, Fig. 4 shows the effect of the inflation and interest rate on the DAC. The DAC for zero inflation and a 10% interest rate is observed to be \$16.55/MBtu. Figures 3 and 4 are independent of the price at which the project sells its energy; however, they do indicate what the minimum price must be to make the project feasible.

The major technical and financial results of the GRITS computer runs for the inputs of Table 2 are listed in Table 3. Annual costs are given for the first year of the project; in constant dollars the cost of debt service will decline in time but the costs of fuel, electricity, and operation will remain constant. For the base cases calculated in Table 3, the price charged for heat delivered to residences is \$14.00/MBtu, which is about the effective cost of heating with No. 2 fuel oil at Cape Charles. At this price for delivered energy, both cases are economically feasible, but for the case where a reinjection well must be used, the project will not be economically feasible unless the price of delivered energy is set at \$12.00/MBtu or higher.

Fig. 2 Cape Charles base case with design temperatures varied; no reinjection wells.

Table 3

Results of GRITS run for Cape Charles, base case.

	No reinjection well	Reinjection well
Design temperature (°F)	45	45
Number of houses	156	156
Total Btu (millions)	15911	15911
Geothermal Btu (millions)	12805	12805
Service geothermal (%)	80.5	80.5
Capital costs (thousands of dollars)		
Wells	272.4	544.9
Distribution system	229.0	229.0
Heat exchanger	18.2	18.2
Pumps	28.5	35.4
Hookups	134.0	234.0
Peaking boiler	140.0	140.0
Transport system	126.0	294.3
Storage tank	79.5	79.5
Total	1128.3	1575.
Annual cost, first year		
Capital (debt) (thousands of dollars)	132.5	185.1
Pump overhaul	4.6	4.6
Pumping costs	17.9	35.9
Fossil fuel costs	21.9	21.9
O and M cost	11.3	15.7
Total	188.2	263.3
Financial summary		
Net present value (thousands of dollars)	1729.6	63 .6
DAC/MBtu	\$8.56	\$11.99
Breakeven year	0	9

Fig. 3 Cape Charles base case with inflation and interest rates varied; no reinjection wells.

Fig. 4 Cape Charles base case with inflation and interest rates varied; with reinjection wells.

The effects of varying the financial variables such as the inflation rate or the interest rate (cost of money) are shown in Figs. 3 and 4. Adding a discount rate increases the DAC, but the effect is not large; a discount rate of 4% increases the DAC of energy from \$8.56 to \$8.94/MBtu for the base case with no reinjection well. Whether the discount rate (which measures the time preference of money) is significant for a municipal or county development is a question beyond the scope of this report.

While the results of Table 3 show that geothermal energy is competitive with heating oil, several very optimistic assumptions were made in Table 3 and in the computations to achieve these results.

First, the well yield is entered as 500 gal/min. There is little reason to suppose this yield can be realized. The yield at Crisfield, Maryland was estimated to be 140 gal/min (Ref. 3). If at Cape Charles, the well yield is reduced to 300 gal/min (still an optimistic value), the number of houses served by one well drops to 93 and the DAC increases to \$14.86/MBtu for the case with an injection well. To serve 800 houses, using the inputs of Table 2, five wells with a maximum output of 2560 gal/min would be required. Assuming that the lengths of the transport system do not change (which would probably result in an unacceptable density of wells) the DAC would only drop slightly to \$11.76/MBtu.

Second, while disposing of the spent geothermal fluid directly into the bay and omitting the reinjection well increases the financial attractiveness of the project, it is very questionable that this disposal method will be acceptable for significant fluid flows. Even if the chemical composition of the geothermal fluids are close to that of sea water, disposing of the fluids in this manner would unquestionably run into serious environmental obstacles not to mention the effect on the reservoir itself.

Third, the GRITS program as run here allows a hook-up cost per house of \$1500. No allowance is made for the expense of conversion inside the house to a hot water system with low temperature water. To estimate more accurately the cost of the wellhead heat exchangers and the internal radiators that would be necessary to utilize 100°F geothermal fluids is an engineering effort that has not been performed in this study.

The most obvious parameter that would favorably affect the feasibility of geothermal use at Cape Charles would be an increase in the temperature of the resource. If, for the base case of Table 3, the wellhead temperature is increased to 105°F, the DAC drops to \$10.12/MBtu and the number of houses served per well increases to 208 (compared to \$11.99/MBtu and 156 for 100°F in Table 3).

An interesting option in the GRITS program is replacing the geothermal-fossil fuel plant with a 100% fossil fuel plant. If that is done for a coal fired district heating plant, the results are as shown in Table 4.

Table 4
Comparison of geothermal and fossil fuel
district heating system

	Geothermal and fossil, no reinjection well	Geothermal and fossil, reinjection well	Fossil fuel only (coal)
Number of houses	156	156	156
Capital cost (initial) (thousands of dollars)	1128.3	1575.9	823.2
Annual fossil fuel cost (thousands of dollars)	21.9	21.9	112.4
Annual pumping costs (thousands of dollars)	17.9	35.9	1.3
DAC (\$/MBtu)	8.56	11.99	11.36

The DAC for energy delivered by the fossil fuel district heating system does not depend very much on the number of houses served; it varies from \$11.52/MBtu for 120 houses to \$10.78/MBtu for 800. It may be observed from Table 4 that the geothermal-fossil fuel plant has a lower DAC only for the case where no reinjection well is required.

5. CONCLUSIONS

Both of the cases considered above would appear to be economically attractive versus a real residential heat cost of \$14.00/MBtu. However, the flow of geothermal fluid required is much larger than can be expected on the basis of available information. Even assuming that the required flow can be obtained, a more realistic estimate must be made of the costs of converting the houses to the use of hot water heating in the 90 to 95°F range.

The installation of a coal-fired district heating plant would appear more attractive on several counts. First, there is no geothermal risk factor involved. Second, it appears to be more economical than a geothermal system with reinjection wells. And third, there would be less of a problem in converting the radiation system within the houses to a hot water source in the conventional 180°F range. Burning coal may present an environmental problem, but this must also be faced with a fossil-fuel-assisted geothermal plant. If coal is to replace oil, a district heating system is, from the environmental point of view, the most attractive method of doing it.

In conclusion, Cape Charles should seriously consider the installation of a district heating system. Geothermal energy will be useful to the system only if the yields and temperature of geothermal fluids are of the magnitude discussed in this report.

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2. Private Communication, Virginia Polytechnic Institute and State University to Mr. Frank Pleva, Cape Charles, Virginia.
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Energy Exploration, Inc.	Research Triangle Park, NC	R. H. Stratemeyer	1
Energy Systems, Inc.	Anchorage, AK	R. Schulz	1
General Ener-Tech., Inc.	San Diego, CA	M. Beam	1
Gipe Associates,		W. Ogle	1
Consulting Engineers	Timonium, MD	C. R. Possell	1
Gruy Federal, Inc.	Arlington, VA		1
Kidde Consultants, Inc.	Newark, DE	J. Renner	1
Malone and Williams, Architects	Salisbury, MD	R. R. Ruggis	1
Nabisco, Inc.	East Hanover, NJ	J. H. Sprinkle	1
Pamlico Refineries, Inc.	Raeford, NC	Manager of Tech.	1
Raytheon Company	Burlington, MA	F. Clark, Jr.	1
R. G. Jacques Associates	Albany, NY	A. Slater	1
Resource Communities, Inc.	Santa Fe, NM	C. A. Hall	1
Salisbury Wicomico Economic Development Corp.	Salisbury, MD	J. Estoque	1
Standard Brands Inc.	Wilton, CT		1
Shore Engineering	Melfa, VA	R. L. Kiley	1
Solar Energetics	Wilmington, DE	W. B. Sharp	1
Sperry Vickers	Jackson, MS	A. Grothous	1
Sydnor Hydrodynamics, Inc.	Richmond, VA	B. Weber	10
Systems Development Corp.	Santa Monica, CA	D. J. Tearpock	1
The Armfield Organization	Winston Salem, NC	E. Henely	1
The Mitre Corp.	McLean, VA	F. Zimmerman	1
United Indian Planners Assoc.	Washington, DC	W. A. Armfield, Jr.	1
USS Agri-Chemical	Atlanta, GA	D. Entingh	1
Westinghouse Elec. Corp.	Staunton, VA	D. Larson	1
Worthington Pump Corp.	Washington, DC	R. F. McFarlin	1
		R. C. Neiss	1
		R. L. French	1
FOREIGN INSTITUTIONS			
Sunderland Polytechnic	Great Britain	R. Harrison	1