WYOMING GEOTHERMAL
COMMERCIALIZATION PROGRAM;

Area Development Plans:

Fremont County, Wyoming--
Big Horn Basin, Wyoming
Converse and Natrona Counties, Wyoming

by the
Wyoming Geothermal Commercialization Office
P.O. Box 4096, University Station
Laramie, Wyoming 82071

in cooperative agreement with the
U.S. Department of Energy
Idaho Operations Office
Idaho Falls, Idaho
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FREMONT COUNTY, WYOMING
Area Development Plan

Author:
Karen Marcotte

Editor:
Rick James

Wyoming Geothermal Commercialization Office
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Introduction

Area development plans (ADPs) are comprehensive documents discussing various aspects of a geographical region in regard to its potential for geothermal development. Some of the topics included in an ADP are population and employment statistics, energy consumption figures, geothermal resource information, the resource match with energy consumers, and related data for any proposed geothermal development.

There are many steps involved in developing a geothermal resource, once a potential resource has been accurately identified and assessed. The following are all required prior to development: an adequate resource, a developer, a specific use matched with a resource of usable temperature and flow capabilities, a market or user, financial backing, and economic incentives for development. Geothermal development requires a great deal of planning effort in the preliminary stage if it is to be successful.

Many legal and environmental regulations must also be met by the potential developer. The time involved in acquiring all necessary permits and leases can range from six months to six years, depending upon the unique situation of the resource and the size and type of proposed development. Specifically, there are many more requirements regarding development on federal lands than those required for private or state lands in Wyoming. These additional permitting requirements can postpone development and generate additional planning time and effort on the part of the developer. These requirements can all be met efficiently if the developer is aware of all

prerequisites to development before project development actually gets underway. Additional information on the institutional aspects of development in the state of Wyoming can be obtained from the Geothermal Commercialization Office.

Geothermal energy is a cost-effective renewable resource, when the appropriate prerequisites are met. The cost-effectiveness of geothermal energy is a tremendous incentive for proceeding with the developmental process whenever possible. As the price of non-renewable fuel sources continues to rise dramatically, the more stable costs of a renewable fuel will become increasingly attractive. The cost of geothermal energy is already competitive with conventional fossil fuel costs in many cases. In the future, we can look towards the cost of geothermal energy becoming even less expensive in comparison to fossil fuels. It is hoped that the geothermal resource will be utilized wherever conceivable.

This ADP is an overall view of the potential for geothermal development in Fremont County, Wyoming. It considers the prerequisites to geothermal development and offers a broad look at the development potential of that region for the next forty years.

Historical and Existing Land Use

The Fremont County Area Development Plan includes all of Fremont County in westcentral Wyoming. Fremont County was created by the Wyoming Territorial Legislature in 1884. When it was initially established, the County contained over twelve and a half million acres, although subsequent action has reduced total land size to approximately six million acres. The Indians called the vast land area between the Owl Creek Mountains and

the Wind River Range the "warm valley". Shoshoni, Crow, Bannock, Sioux and Arapahoe tribes have all vied for control of this valley. Today, the Wind River Indian Reservation in Fremont County, containing 1,640,020 acres, is operated jointly by the Arapahoe and Shoshoni tribes. The first white men to enter the area were fur trappers from Canada. They were soon followed by the Lewis and Clark expedition, hunters, prospectors, surveyors, and early pioneer settlers. The total land area of Fremont County is 5,975,630 acres. Present land ownership and control is divided according to the figures shown in Table 1.

TABLE 1

<u>Land Ownership</u>	<u>Acres</u>	<u>% of County Area</u>
Private Land	808,782	13.5 %
Wind River Indian Reservation (Shoshoni and Arapahoe Tribes)	1,640,020	27.4 %
Federal Lands		
Forest Service	980,533	16.4 %
Bureau of Land Management	2,097,605	35.1 %
Bureau of Reclamation	141,980	2.4 %
Other Agencies	1,405	.02%
Total Federal Land	3,221,532	53.9 %
State and Local Governments	260,565	4.4 %
Water Surface	44,740	0.8 %
TOTAL AREA	5,975,630	100.0 %

Source: Fremont County Planning Commission, 1978.

Resource Areas

The primary geothermal resource areas which have been identified by the Wyoming Geothermal Commercialization Office in cooperation with the University of Wyoming Department of Geology are: Conant Creek Springs, Fort Washakie Hot Springs (on the Wind River Indian Reservation), Jakeys Fork Springs, Little Warm Spring, Sweetwater Station Springs, Warm Spring Creek Springs and the Countryman Well (see Figure 1). There are indications that several other geothermal resources exist in Fremont County as well, although they are inferred resources at this time.

Some of the springs in Fremont County are among those at the cooler end of the thermal spring spectrum. Still, they are geothermal waters and are representative of a potentially useful class of geothermal systems. The Fort Washakie Hot Springs are the hottest springs presently known in Fremont County and will be examined in detail in a separate report. In 1976, the temperature was 44°C. or approximately 111°F. The Countryman well also has a surface temperature of 38°C. (100°F). A more detailed description of each spring follows this development plan. Although there is a limited amount of resource data available at this time, because of the absence of geothermal test wells, the presence of the known springs in Fremont County assures distinct reasons for further studies there.

Based on the geochemical and thermal data provided by thermal springs and on heat flow and gradient data, it must be concluded that Fremont County has little indication of very hot (electrical-generating) geothermal resources. However, in terms of lower temperature waters (the type commonly found in Fremont County),

FIGURE 1

FREMONT COUNTY, WYOMING

the possibilities for space heating, industrial processing, agriculture and livestock production as well as greenhouse operation should be considered. With advances in geothermal technology and increased public interest, as well as increases in the costs of other energy forms, the use of low temperature geothermal resources will inevitably result.

Population Trends

The Geothermal Commercialization Office (GCO) surveyed growth trends in Fremont County to enable prediction of energy consumption within the area. It was discovered that the population of Fremont County is growing at about the same rate as the state of Wyoming as a whole. Population growth rate for the state of Wyoming is 2.9 per cent per year, while the growth rate for Fremont County is 2.5 per cent per year (see Figure 2).

Energy Consumption

Employment and energy consumption rates for the county indicate that the mineral industry and its related service industries, trucking and warehousing, and electric, gas and sanitary services account for the largest percentage of energy consumption for the county (Table 2 and Figure 3). There are several reasons why these activities reflect such energy intensive figures. Oil and gas extraction figures (SIC 13) include drilling and production of crude oil and natural gas as well as natural gas processing. Coal mining figures (SIC 11 and 12) include all types of mining operations and consumption (i.e., motor oil and machinery lubrication as well as diesel and other fuel oils). Iron ore mining (SIC 101) includes all mining and beneficiation operations. Uranium,

Source: U.S. Censes Data and Fremont County Planning Commission

TABLE 2

FREMONT COUNTY - ENERGY CONSUMPTION PER EMPLOYEE BY INDUSTRY

<u>SIC Code</u>	<u>Industry</u>	<u># Employees</u>	<u>Million BTU Per Employee</u>
01, 07, 09	Agricultural services, forestry, fisheries	1,482	490.0
1	Mining	2,644	
101	Iron ore mining	250-499	3,268.0
1094	Uranium, radium, vanadium ores	1,000-2,499	2,542.0
11, 12	Coal mining		1,870.0
13	Oil and gas extraction		4,003.0
15 - 17	Construction	610	368.0
2	Manufacturing	613	
24, 25	Lumber, wood products and furniture	157	277.9
27	Printing and publishing	61	95.8
28	Chemicals and allied products	20-99	2,735.5
355	Special industry machinery	100-249	180.0
2911, 31, 374, 375 379, 39	Other manufacturing and miscellaneous manufacturing industries	57	303.5
48	Communication	249	34.0
49	Electric, gas and sanitary services	128	7,494.0
50, 51	Wholesale trade	285	31.0

TABLE 2
(continued)

FREMONT COUNTY - ENERGY CONSUMPTION PER EMPLOYEE BY INDUSTRY

<u>SIC Code</u>	<u>Industry</u>	<u># Employees</u>	<u>Million BTU Per Employee</u>
52	Building materials and garden supplies	92	114.2
53	General merchandise stores	118	113.5
54	Food stores	253	135.3
55	Automotive dealers and service stations	334	79.2
57	Furniture and home furnishing stores	66	59.9
58	Eating and drinking places	528	55.7
59	Miscellaneous retail	270	65.0
60 - 62, 67	Finance	110	58.1
63, 64	Insurance	105	23.5
70	Hotels and other lodging places	194	261.6
72	Personal services	99	223.9
73	Business services	58	46.7
75, 76	Automobile and miscellaneous repair services		205.2
80	Health services	640	198.4
81	Legal services	54	36.1
82 - 89	Other services		341.4

Sources: U.S. Census Data, Wyoming Handbook, and Harvey, E.F.,
An Analysis of Energy Consumption in Wyoming.

FIGURE 3

radium and vanadium ore figures (SIC 1094) reflect all mining and milling company operational consumption figures. The trucking and warehousing figure (SIC 42) is indicative of the energy intensive requirements of an industry based on fuel oil consumption and space heating. The public utilities industry (SIC 49) is the largest energy consumer (in millions of BTU per employee) for Fremont County as well as the state as a whole. This industry includes electric companies, natural gas companies and sanitary services. Electric utility figures consist of power generation, transmission and distribution. Almost all of the energy expended by Wyoming electric utilities occurs at thermal generating plants. Natural gas company figures include pipelines and distribution systems. The real estate figures (SIC 65, 66) include all forms of property management companies and their large space heating requirements.

Per Capita Energy Consumption

Fremont County as well as the state of Wyoming's high per capita energy consumption is primarily attributable to the large volume of electricity generation and distribution, predominantly energy intensive mineral industry, and the relatively cold winters. Some of the energy needs of Fremont County cannot be offset by geothermal resources, but at least six different energy consumers in the county should look toward geothermal resources to offset some of their energy demands. They are: agribusiness, gas and oil extraction industries, certain manufacturing industries, lumber industries and all industries and housing units requiring space heating.

Any of these industries that are located near one of the many geothermal resources presently known in Fremont County should seriously consider utilizing geothermal energy wherever possible to replace their high consumption levels of non-renewable energy sources.

Predictions of future resident and work populations have also been made for Fremont County by various agencies and a comparison of those figures is shown in Table 3.

CONCLUSION

There have been no wells drilled for geothermal purposes in Fremont County, therefore there are no specific geothermal site data available. However, there are data available from all the artesian geothermal springs in the county. These springs may be associated with systems which could be tapped by drilling for such uses as greenhouse operation, individual space heating and related uses. At the present time, there is no known resource with sufficient temperature or volume in Fremont County to propose a large scale project such as district heating. Certainly, however, the geothermal resource should be utilized wherever possible, even to meet small scale needs. It is obvious from looking at population and employment projections for Fremont County that the energy needs of the future will be rapidly increasing. Geothermal energy could meet some of those energy needs for the future in this county.

TABLE 3
FREMONT COUNTY

POPULATION FORECAST	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Division of Research and Statistics, Department of Administration and Fiscal Control, 1979	34,732	38,226	39,009	40,597	41,561	42,128	44,093	44,956	45,940	46,237	47,030	47,862
Above, 1978	34,185	34,611	34,783	35,706	36,458	37,283	38,222	39,588	40,661	41,695	42,743	43,014
WICHE, 1976				41,035					39,723			
State Planning Coordinators Office				33,509					36,241			
Fremont County Planning Probable Figure, 1978				39,651					47,948			
Fremont County Planning Low Figure, 1978				36,197					44,641			
EMPLOYMENT FORECAST	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Division of Research and Statistics, Department of Administration and Fiscal Control, 1979	16,081	16,432	17,107	17,481	17,649	18,475	18,766	19,105	19,091	19,373	19,665	
Above, 1978	13,705	13,799	14,114	14,370	14,650	14,970	15,469	15,819	16,150	16,498	16,851	
WICHE, 1976			14,067					13,617				
Fremont County Planning December - 1977			13,673					16,534				19,396 (1990)

SITE DATA SUMMARY

CONANT CREEK SPRINGS

Location: Sec. 26ddb, T.33N., R.94W

Elevation: 6,280 feet

Quadrangle: Blue Gulch

Ownership: Private

Access: Nine miles along the telephone line northwest from Sand Draw, then up Conant Creek 2.5 miles.

Temperature: 16°C. (10/8/76)

Flow: 300 gpm

Geologic description: Springs flow from the valley alluvium above the Phosphoria formation. Structurally, the springs are at the nose of the northward plunging Conant Creek anticline, and lie just below Beaver Rim. Geological mapping shows three faults through the spring site.

Present development status: None

Source: Breckenridge, R.M. & B.S. Hinckley, Thermal Springs of Wyoming, 1978

SITE DATA SUMMARY

JAKEYS FORK SPRING

Location: Sec. 29bda, T.41N., R.106W.

Elevation: 7,060 feet

Quadrangle: Torrey Lake

Ownership: Private - CM Ranch

Access: Three miles up Jakeys Fork off U.S. 287

Temperature: 20°C. (5/26/77)

Flow: Less than 4 gpm

Geologic description: Spring issues from a cavern at the top of a broad travertine cone, one of three such cones in the area. The spring and associated travertine occur near the base of the gently dipping Chugwater formation.

Present development status: No development has taken place, although nearby cool springs supply over ten cubic feet per second to the State Fish Hatchery downstream.

Source: Breckenridge, R.M. & B.S. Hinckley, Thermal Springs of Wyoming, 1978

SITE DATA SUMMARY

LITTLE WARM SPRING

Location: Sec. 14bbd, T.41N., R.107W.

Elevation: 7,200 - 7,240 feet

Quadrangle: Dubois

Access: Two miles southwest of Dubois on Little Warm Spring Creek Road.

Temperature: 25°C. (9/20/76)

Flow: 560 gpm

Geologic description: This site is heavily mantled by travertine and travertine cemented gravel. The lowest rocks of the Chugwater formation lie directly beneath the travertine. The subcrop relationships are confused by a fault just upstream from the spring. Upstream the rocks are deformed to near vertical.

Present development status: The spring is part of a vacation complex, creating a 6 foot deep swimming pool when headgate of stream is closed.

Source: Breckenridge, R.M. & B.S. Hinckley, Thermal Springs of Wyoming, 1978

SITE DATA SUMMARY

SWEETWATER STATION SPRINGS

Location: Sec. 15abd, T.29N., R.95W.

Elevation: 6,640 - 6,660 feet

Quadrangle: Happy Spring

Access: Four miles south of U.S. 287 on Bison Basin Road.

Temperature: 31.5°C. (10/7/76)

Flow: 500 gpm

Geologic description: There are two warm springs, occurring on a relatively flat plain. They issue from stream alluvium. Beneath the alluvium is the Miocene Split Rock formation which overlies complex Paleozoic rock structures. The springs are at the intersection of the northwest - southeast trending Mormon Trail anticline and the east - west trending Ellis fault.

Present development status: None

Source: Breckenridge, R.M. & B.S. Hickley, Thermal Springs of Wyoming, 1978

SITE DATA SUMMARY

WARM SPRING CREEK SPRINGS

Location: Sec. 32bcc, T.42N., R.107W.

Elevation: 7,400 feet

Quadrangle: Dubois

Ownership: Federal - BLM, Leasee: Bob Harrison, Wagon Bar Ranch

Access: One mile south off U.S. 287

Temperature: 29°C. (9/21/76)

Flow: Approximately 133 gpm

Geologic description: The Phosphoria formation lies beneath a travertine mantle at the spring site. It strikes N.24W. and dips 20° north, and is part of a complete Triassic-to-Precambrian section which dips north-easterly off the Wind River Mountains.

Present development status: None

Source: Breckenridge, R.M. & B.S. Hickley, Thermal Springs of Wyoming, 1978

SITE DATA SUMMARY

COUNTRYMAN WELL

Location: Sec. 15, T.31N., R.98W. of 43°N, 109°W

Ownership: Private - Countryman Ranch

Temperature: 38°C.

Flow: 500 gpm

Geologic description: Water issues from Madison limestone, perhaps from Tensleep sandstone.

Historical significance: Oldest oilwell in Wyoming - 1884

Present development status: Currently used for a greenhouse and pool with future planned development of multiple greenhouses with the potential for space heating of a housing development.

Source: James, R.W., Geothermal Energy in Wyoming: Site Data Base and Development Status, 1979

APPENDIX A

Fremont County Employment by Industry

INDUSTRY	EMPLOYMENT 1971 WICHE	EMPLOYMENT 1971 WYOMING DATA BOOK	EMPLOYMENT 1972 FREMONT CO. PLANNING	EMPLOYMENT 1975 WICHE	EMPLOYMENT 1975 WYOMING DATA BOOK
AGRICULTURE	1,350	272	1,328	1,482	328
MINING	1,713	1,711	1,919	1,864	1,867
CONSTRUCTION	856	871	562	711	701
MANUFACTURING	454	456	468	429	434
TRANSPORTATION, COMMUNICATION, & UTILITIES	379	397	407	459	541
TRADE	1,693	1,734	1,826	2,070	2,073
FINANCE, INSURANCE, REAL ESTATE	195	203	209	240	237
SERVICES	1,465	1,627	881	1,711	1,935
GOVERNMENT	2,180	2,311	1,820	2,430	2,604
OTHER		50			91
TOTAL	10,285	11,555	9,420	11,404	12,759

Source: Research and Analysis Section of the Wyoming Employment Security Commission

APPENDIX B

Fremont County Employment

	1960		1970	
	State of	Fremont	State of	Fremont
	<u>Wyoming</u>	<u>County</u>	<u>Wyoming</u>	<u>County</u>
<u>Unemployed % in</u>				
Civilian Labor Force	5.1	5.7	4.8	6.7
<u>Employed % in</u>				
Manufacturing and Industry	7.7	3.4	6.4	6.8
White Collar	40.3	36.5	46.4	21.9
Government			21.9	20.7

Source: 1960/1970 Census of Population from the U.S. Department of Commerce

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7. Morgenstern, Susan. DEPAD, Cheyenne, Wyoming.

An informative paper is only as useful as the facts that it contains. If you have any suggestions or information that you think our office should be aware of, please contact us at the following address:

Geothermal Commercialization Office
P.O. Box 4096
University Station
Laramie, Wyoming 82071

(307) 766-4820 or
Toll free in Wyoming 1 (800) 442-8334

BIG HORN BASIN, WYOMING
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Principal Authors:
James Caplan
Karen Marcotte

Editors:
Carole Aspinwall
Rick James

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Introduction

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This ADP is an overall view of the potential for geothermal development in the Big Horn Basin, Wyoming. It considers the prerequisites to geothermal development and offers a broad look at the development potential of that region for the next forty years.

Historical and Existing Land Use

The Big Horn Basin Area Development Plan covers Big Horn, Hot Springs, Park and Washakie counties in northcentral Wyoming.

This area was first visited by white men in 1742 - 1743, and was populated solely by Indians and fur traders until the 1800's. In 1807, John Colter discovered the "Boiling Spring", known as the DeMaris Hot Spring after the DeMaris family homesteaded there in 1886. Following several official expeditions into the region, gold miners entered the area and prospected near the Big Horn River and the "Stinking Water" River, now named the Shoshone River. The cattle industry arrived in this region after the gold prospectors in the 1870's, soon to be followed by sheep herders and sawmill operators. The Big Horn Basin became largely agricultural after the Carey Act of the late 1890's and the Reclamation Act of 1902. In 1916, the sugar beet industry began and shortly thereafter, large discoveries of coal, oil and natural gas were made. Thus, the Big Horn Basin has covered the complete span from fur trader to modern business corporation.

These four counties cover an area of 12,583 square miles. Federal land ownership in the four counties ranges from 40% to 69% of their total acres. Private land ranges from 23% to 35% and state owned land is in the range of 6% to 25% per county. The Wind River Indian Reservation utilizes 20.53% of the land in Hot Springs County.

Resource Areas

The primary geothermal resource areas which have been identified by the Wyoming Geothermal Commercialization Office in cooperation with the University of Wyoming Department of

Geology are near Cody (Park County) and Thermopolis (Hot Springs County). In addition, two geothermal springs have also been identified in Big Horn County (see Figure 1). The geothermal resources in the four county Big Horn Basin are:

Little Sheep Mountain Spring, Sheep Mountain Springs, Van Norman Well, Maytag Well, Sacajawea Well, McCarthy Well, Bathtub Spring, White Sulphur Spring, Railroad Springs, Piling Springs, Black Sulphur Spring, Terrace Spring, Big Spring, Wind River Canyon Spring, Buffalo Bill Reservoir Springs, DeMaris Hot Springs and some additional hot wells in Park County.

A site data summary sheet on each spring follows this report. There is little resource data available at this time for Big Horn and Washakie counties, although there is distinct reason for further studies there.

The primary resource areas of this region center on the towns of Cody, in Park County, and Thermopolis, in Hot Springs County. The preliminary report of the Wyoming State Resource Assessment Team summarizes recent research in these two important regions. A copy of the pertinent sections of this report may be found in Appendix A.

Population Trends

The Geothermal Commercialization Office (GCO) surveyed growth trends in the Big Horn Basin to enable prediction of energy consumption within the area, and discovered that the population was growing at about one-half the growth rate for

FIGURE 1

BIG HORN BASIN, WYOMING

the state of Wyoming as a whole. The population growth rate for the state of Wyoming is 2.9% per year, while the growth rate for the Big Horn Basin is 1.4% per year (Figure 2 and 3).

Employment and Energy Consumption

Employment and energy consumption rates in the Basin indicate that the mineral industry and its related service industries account for 12% of employment and 92% of energy consumption (Table 1). The top six industries in terms of energy consumption per employee are: Food Processing (SIC 200), Oil and Gas Extraction (SIC 13), Hotels and Motels (SIC 70), Service Industries (SIC 7/8), Bentonite (SIC 1452), and Medical and Health Services (SIC 80) (see Table 2).

There are several reasons why these industries reflect such energy intensive figures. The oil and gas extraction figure includes drilling and production of crude oil and natural gas as well as natural gas processing. The bentonite industry figure reflects the high energy demands of an industry based on high temperature drying. This industrial process is especially suitable to using a geothermal resource to offset some of its high energy needs. Food processing is another industry that consumes large amounts of energy during the dehydration and cooking processes. The other three high energy users are all service industries whose large energy demands primarily result from space heating of buildings during the night and day. Space heating is another applicable use for the geothermal resource.

Sources: U.S. Census Data and Department of Administration and Fiscal Control,
Wyoming Population and Employment Forecast Report, 1978.

Sources: U.S. Census Data and Department of Administration and Fiscal Control,
Wyoming Population and Employment Forecast Report, 1978.

TABLE 1

REGIONAL EMPLOYMENT AND ENERGY CONSUMPTION

<u>SIC</u>	<u>Industry</u>	<u>Employees</u>	Millions of <u>BTU / Capita</u> <u>Consumption</u>	Millions of BTU <u>Total</u>
0	Agricultural Services	28	.0309	.9
1	Mining	109	.927	101.0
13	Oil and Gas Extraction	813	6000.0	4,878,000.0
138	Oil and Gas Field Services	266	.927	246.6
1452	Bentonite	239	5300.0	1,266,700.0
1	Contract Construction	373	3.0	1,119.0
15	General Construction	110	3.0	330.0
17	Special Construction	109	3.0	327.0
2	Manufacturing	803	2.08	1,670.2
200	Food Processing	54	285.19	15,400.0
2063	Beet Sugar	200	79.0	15,800.0
29	Petroleum and Coal Products	200	3.0	600.0
5	Wholesale Trade	397	28.0	11,116.0
508	Machinery and Equipment	28	28.0	784.0
5	Retail Trade	507	95.0	48,165.0
52	Building Materials	164	100.0	16,400.0
53	General Merchandise	125	95.0	11,875.0
54	Food Stores	105	100.0	10,500.0
541	Grocery Stores	4	100.0	400.0
55	Automotive Dealers	309	76.0	23,484.0
554	Gas Stations	152	100.0	15,200.0
56	Apparel Stores	46	20.0	920.0
58	Eating and Drinking	515	38.0	19,570.0
59	Miscellaneous Stores	180	55.0	9,900.0
6	Finance, Insurance, Real Estate	377	95.0	35,815.0
7/8	Services	564	200.0	112,800.0
70	Hotels	233	270.0	62,910.0
72	Personal Services	63	200.0	12,600.0
80	Medical and Health	305	195.0	59,475.0
81	Legal	25	100.0	2,500.0
86	Non-Profit Organizations	226	100.0	22,600.0
869	Non-Profit Organizations NEC	140	100.0	14,000.0
89	Miscellaneous Organizations	43	100.0	4,300.0
TOTALS		8,460		6,667,104.7

Sources: Wyoming Directory of Manufacturing and Mining,
1978 Data from DEPAD, and U.S. Census Data.

TABLE 2

Source: U.S. Census Data, and Harvey, E.F., An Analysis of Energy Consumption in Wyoming.

Predictions of future resident populations were also made for the Basin and are shown in Figures 2 and 3. It is obvious that the energy demands for the area and the number of employees available for work will be rapidly increasing in the future. The development of geothermal resources can both provide jobs and replace the use of nonrenewable resources in many instances.

Proposed Applications of the Geothermal Resource

The principal work has been conducted on resource information for Cody and Thermopolis. The proposed application in each case is for geothermal district heating. The two communities are quite similar economically and in size. Therefore, in the broad context of this plan, they are considered equal, with the exception of specific energy demands made by unique industries in each community. There are also lower temperature geothermal waters in the Big Horn Basin. These resources are particularly adaptable for use in smaller scale space heating projects, industrial and food processing procedures, agricultural and livestock production, and greenhouse operation. With advances in geothermal technology and increased public interest, as well as increases in the cost of other energy forms, the use of both high and low temperature geothermal resources will probably become a reality in the Big Horn Basin.

Six wells have been drilled for geothermal purposes in the vicinity of Cody. These shallow wells range in depth from 320 feet to 411 feet, with temperatures up to 100°F at less than 400 foot depths. There have also been some oil

well log data obtained from Park County which indicated bottom-hole temperatures of 104°F and above at varying depths.

There are also data available from the nearby DeMaris Hot Springs. These springs may be associated with a much larger system that could be tapped by drilling in Cody. It should also be noted that in northeastern Park County, residents of the small town of Frannie have encountered well water that is 90°F. There is potential for district heating there with the application of heat pumps.

The Thermopolis district heating potential has been considered for years, but some problems are associated with its development. Hot Springs State Park in Thermopolis is the most famous thermal area in Wyoming outside of Yellowstone. Some of the springs in the area are part of the Park and, based on original ownership restrictions, cannot be developed except for recreational uses. However, there is presently some development associated with Big Spring in the State Park. The following areas utilize these geothermal waters:

1. Holiday Inn - located near Hot Springs State Park, utilizing hot mineral waters piped from Big Spring for bathing and a steam room.
2. Plaza Hotel - located directly across the street from the State Park. This hotel provides eight large tubs for bathing in hot mineral waters (114 - 117°F. before cooled) and a steam room heated by Big Spring waters.
3. Pioneer Home - is a home for the elderly near the park and provides whirlpool bathing with geothermal water.
4. Gottsche Rehabilitation Center and Memorial Hospital - utilizes Big Spring waters for whirlpool bathing.

5. Teepee Spa - located within boundaries of Hot Springs State Park providing three swimming pools with Big Spring waters cooled to various temperatures.
6. Star Plunge Spa - located in the State Park, utilizing Big Springs waters for indoor and outdoor swimming and a steam room.
7. State Bath House - operated by Hot Springs State Park, utilizing Big Spring waters for an indoor pool, indoor and outdoor soaking pools and individual bathtubs. The State Bath House does not charge a fee for the use of its facilities.

The privately owned wells in the Thermopolis area offer significant space heating potential. Three wells have been used to heat the homes and swimming pools of the owners in the past. If we were to apply a reasonable ΔT (amount of heat which can be extracted) such as 30°F., we can realize significant space heating potential as indicated in Table 3.

TABLE 3

<u>Well</u>	<u>Ownership</u>	<u>°F. Temp.</u>	<u>°F. ΔT</u>	<u>BTU / Hr.</u>	<u>Flow Gpm</u>	<u>Number* of Homes Heated</u>
Maytag	Private	129°	30	8,085,000	539	231
Sacajawea	Private	125°	30	18,300,000	1,220	523
McCarthy	Private	129°	30	8,745,000	583	250

*Estimated number of homes which could be heated by direct use given an area of approximately 1,000 square feet per home. No consideration has been given in the estimation for other contributing factors such as a distribution system, etc.

Economic Analysis of Proposed District Heating Systems

Preliminary economic analysis has been conducted for the proposed geothermal district heating systems for Cody and Thermopolis by the Physical Science Laboratory of the New Mexico Institute (PSL-NMEI) and by Western Energy Planners, Ltd. (WEPL). Summaries of their initial economic studies appear in the Appendix of this report.

The reader will note that the price per MMBTU for the geothermal fuel covers a large range of values in the examples included in the Appendix. There are also many discrepancies between drilling, investment and distribution costs over the six studies included. This is presumably due to the number of assumptions and "best - guess" estimates that were made by PSL-NMEI and WEPL whenever actual data were lacking.

A Site Specific Development Analysis (SSDA) for the Thermopolis region will be completed in the near future. Specific data will be provided to PSL-NMEI and WEPL for this analysis by the GCO. It is hoped that cost studies will then be generated that more accurately describe the physical and economic realities of the Thermopolis region.

SITE DATA SUMMARY

LITTLE SHEEP MOUNTAIN SPRING

Location: Sec. 17aaa, T.55N., R.94W.

Elevation: 3,675 feet

Quadrangle: Spence, Big Horn County

Ownership: Federal - BLM

Access: South off U.S. 14-A, then along railroad into Little Sheep Canyon

Temperature: 18° and 20°C. (8/17/77)

Flow: 1800 gpm

Geologic description: Spring issues from a fine-grained, light brown zone of the Madison limestone. The Madison is exposed here, at the core of the Little Sheep Mountain Anticline, where the Bighorn River has cut across the structure. In this area the exposed limestone has large cracks and caverns, as well as contorted bedding.

Present development: None

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

SHEEP MOUNTAIN SPRINGS

Location: Sec. 35dbd, T.54N., R.94W.
Sec. 35cdc, T.54N., R.94W.

Elevation: 8,350 feet

Quadrangle: Sheep Canyon

Ownership: Federal - BLM; Private - Burlington Northern Railroad

Access: East off U.S. 310, north along the railroad into Sheep Canyon,
east across the river from the railroad.

Temperature: 21°C. (8/16/76)

Flow: Total 450 gpm

Geologic description: The principal source of the three springs is a six foot deep cavity along a bedding plane crack, 20 feet above the river. The outcrop is dark brown, medium crystalline, silty Madison limestone. There are abundant fractures parallel to bedding (approximate dip = 20° SW) and a conspicuous vertical fracture zone runs nearly the full height of the cliff 150 feet north of the spring.

Present development: None

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

VAN NORMAN WELL

Location: Sec. 24cd, T.43N., R.95W.

Quadrangle: Thermopolis, Hot Springs County

Ownership: Private - Van Norman owner, Thermopolis

Access: 10 yards west of U.S. 20, just south of Red Lane Gulch

Temperature: 51°C. (9/2/76)

Flow: Controlled artesian well

Depth: Unknown

Present development: The well waters are used to heat the Van Norman home and are delivered to subfloor units through a plastic pipe. The well water is also used for local irrigation.

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

MAYTAG WELL

Location: Sec. 24dc, T.43N., R.95W.

Quadrangle: Thermopolis

Ownership: Local irrigation district

Access: Between U.S. 20 and Burlington Northern Railroad tracks on Red Lane Gulch

Temperature: 54°C. (1/2/76)

Flow: 539 gpm

Geologic description: This ten inch well was drilled to 900 feet in 1919. Water now rushes turbulently into a ten foot diameter masonry pool from which it is ditched.

Present development: Used mainly for irrigation. A small flow is diverted to the home of Fred Baines where it is used for domestic purposes after treatment in a settling pond.

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

SACAJAWEA WELL

Location: Sec. 25ab, T.43N., R.95W.

Quadrangle: Thermopolis

Ownership: Private - Oscar and Etta Payne, Thermopolis

Access: Between U.S. 20 and Burlington Northern Railroad tracks 1.5 miles
north of Thermopolis

Temperature: 52°C. at 12 feet from source (9/2/76)

Flow: 1220 gpm

Geologic description: The well was drilled to 900 feet in 1918 in an attempt
to find oil. A five foot high mineral cone has developed around the
well.

Present development: The well has been managed as a mineral swimming pool
for many years.

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

MCCARTHY WELL

Location: Sec. 30cb, T.43N., R.94W.

Quadrangle: Thermopolis

Ownership: Private - Scott Taylor, Thermopolis

Access: One-third mile north from the end of Park Loop

Temperature: 54°C. (9/2/76)

Flow: 583 gpm

Geologic description: This well has drilled to a depth of 510 feet in 1920.

Water is produced from the Phosphoria formation. Flowing under artesian pressure from 6-5/8 inch casing, it has built up a small cone.

Present development: Well waters are used to heat an addition to the Scott Taylor home.

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

BATHTUB SPRING

Location: Sec. 25dd, T.43N., R.95W.

Quadrangle: Thermopolis

Ownership: Hot Springs State Park, State of Wyoming

Access: Between Burlington Northern Railroad and Bighorn River, downhill
from U.S. 20

Temperature: 53°C. (9/2/76)

Flow: 2 gpm

Geologic description: This spring issues from the base of a relict travertine terrace, 15 feet above the level of the Bighorn River. Spring waters flow under the railroad. A fan shaped travertine terrace (25 feet maximum width) forms where they enter the river.

Present development: State Park

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

WHITE SULPHUR SPRING

Location: Sec. 30ccb, T.43N., R.94W.

Quadrangle: Thermopolis

Ownership: Hot Springs State Park, State of Wyoming

Access: Park Loop

Temperature: 53°C.

Flow: 206 gpm

Geologic description: The spring presently issues from a deep cavity at the base of a travertine complex, approximately six feet above the level of the Bighorn River. A ten foot wide travertine fan has formed between the vent and the river.

Present development: State Park

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

RAILROAD SPRINGS

Location: Sec. 36aad, T.43N., R.95W.

Quadrangle: Thermopolis

Ownership: Hot Springs State Park, State of Wyoming

Access: Between Burlington Northern Railroad and Bighorn River, in the cut
above the footbridge

Temperature: Not measured

Flow: Less than 3 gpm

Geologic description: These springs are recent, and result from the excavation
of the railroad cut in which they occur.

Present development: State Park

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

PILING SPRING

Location: Sec. 36ac, T.43N., R.95W.

Quadrangle: Thermopolis

Ownership: Hot Springs State Park, State of Wyoming

Access: Ten yards east of U.S. 20

Temperature: 35°C. (9/2/76)

Geologic description: This minor spring flows from a recess under part of the road bed of U.S. 20. The cavern was apparently shored with pilings. Outflow occurs on an area of seeps immediately downhill.

Present development: State Park

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

BLACK SULPHUR SPRING

Location: Sec. 31bc, T.43N., R.94W.

Quadrangle: Thermopolis

Ownership: Hot Springs State Park, State of Wyoming

Access: On the Park Loop

Temperature: 55°C. (9/2/76)

Flow: Little or none

Geologic description: Apparently inactive since 1959, the spring forms a five by twelve foot pool in a 20 foot deep cavern with no surface outlet. The pool presumably experiences some flow through to maintain its high temperature. Trace dye tests have been conducted which show that Terrace Spring is a direct outlet for Black Sulphur pool.

Present development: State Park

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

TERRACE SPRING

Location: Sec. 36aad, T.43N., R. 95W.

Quadrangle: Thermopolis

Ownership: Hot Springs State Park, State of Wyoming

Access: Just above river level at the base of the main terraces, north of footbridge, difficult to reach except by boat

Temperature: Not measured

Flow: 10 gpm

Geologic description: Flowing a one-and-one-half inch diameter spout of water, this spring is located on the apparent contact of modern and older travertine masses. It is believed that Terrace Spring is the diverted flow of Black Sulphur Spring.

Present development: State Park

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

BIG SPRING

Location: Sec. 31bc, T.43N., R.94W.

Quadrangle: Thermopolis

Ownership: Hot Springs State Park, State of Wyoming

Access: On the Park Loop

Temperature: 56°C. (9/2/76)

Geologic description: Big Spring is by far the largest and most impressive feature in the area. It produces a large stream at scalding temperatures, feeds an extensive terrace complex and supplies several pools and bathhouses. Big Spring enters a 25 foot diameter pool through vents in the pool bottom.. Inflow is accompanied by constant gas bubbling. Two manmade ditches and buried pipeline accomodate outflow, which eventually enters the Bighorn River.

Present development: State Park, use of waters for mineral water bathing at several sites.

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

WIND RIVER CANYON SPRING

Location: Sec. 25bc, T.42N., R.95W.

Elevation: 4,370 feet

Quadrangle: Wedding of the Waters, Hot Springs County

Ownership: Private

Access: Ten yards east of U.S. 20 at the mouth of Wind River Canyon

Temperature: 22°C. (9/1/76)

Flow: 989 gpm

Geologic description: This relatively cool spring fills a rock-lined 10 x 15 foot, 12 foot deep pool from which it flows under Highway 789 and into the Bighorn River. This spring issues from a chert zone in Phosphoria limestone. The presence of the spring seems to indicate that groundwaters move to some degree between most of the upper Paleozoic rocks.

Present development: None

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

BUFFALO BILL RESERVOIR SPRINGS

Location: Sec. 14ac, T.52N., R.103W.

Elevation: 5,369 feet

Quadrangle: Devils Tooth, Park County

Ownership: Federal - U.S. Bureau of Reclamation

Access: Under water

Temperature and Flow: Warm and voluminous enough to keep an area ice free throughout the winter

Geologic description: These springs were covered by the waters of Buffalo Bill Reservoir in 1907. As mapped, the springs issue from the Phosphoria formation on the southwest flank of the Rattlesnake anticline. The anticline is bounded on the southwest by a number of steeply dipping faults which have left strata vertical or overturned.

Present development: None as they are under water

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

DE MARIS HOT SPRINGS

Location: Sec. 3bc, T.52N., R.102W.

Elevation: 4,960

Quadrangle: Cody, Park County

Ownership: Private - Kit Cody, Wyoming, owner

Access: Across river on private road off U.S. 14 - 20, two miles west of Cody

Temperature: 27 - 36°C. (varies between vents, 8/1/76)

Flow: Approximately 1700 gpm

Geologic description: Seven distinct vents have been counted, although many more probably issue through the river bottom. Some springs bubble up through the sand and others pour from deep cracks, up to two feet wide, in the canyon wall. All the DeMaris springs issue from the Permian Phosphoria formation, an interbedded sequence of massive limestone beds and thin shaley layers at this site. Here, on the northeast limb of the Rattlesnake anticline, the strata dip 16° off of the mountain.

Present development: It is reported that 850 tons of sulphur associated with the hot springs was produced in 1906. This involved constructing a mill and processing 2,833 tons of ore. Sulphur was mined here intermittently until 1917. The springs themselves are named for Bill DeMaris who developed them for swimming and bathing. At DeMaris' death, the springs and facilities were purchased for the Bronze Boot (a supper club) and in turn, were sold to Kit Cody around 1970 when the facility was moved away from the spring site. The springs are now abandoned, and Mr. Cody uses the access road to stage commercial float trips. The Bronze Boot Spa, located on the terrace across from the springs, pumps 208 gpm from a 168 foot deep well to supply a commercial pool, obviously tapping the same supply.

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

ADDITIONAL GEOTHERMAL EVIDENCE IN PARK COUNTY

There are some well logs available for the area near Cody which show measured temperatures greater than those of the springs. While well temperatures are often depressed by drilling fluids and drilling disruptions, it is reasonable in most cases to assume that they represent minimum formation temperatures.

Well Log Data

1. Sec. 13, T.52N., R.102W., Tensleep formation waters have been measured at 47°C.
2. Sec. 24, T.52N., R.102W., Tensleep formation waters have been measured at 40°C.
3. Further west in R103 - 105W, temperatures of 41°C. to 46°C. were encountered in the Tensleep and Madison formations from 4000-6000 feet deep.
4. Sec. 31, an artesian well produces 69°C. water from 1476 feet in the Tensleep formation.

Source: Breckenridge, R.M. and B.S. Hinckley,
Thermal Springs of Wyoming, 1978.

APPENDIX A

AREAS WITH INDICATED LOW-TEMPERATURE RESOURCES

The Thermopolis Area

Temperatures, gradients, and regional geology have been compiled for a 1800 - 1900 mi² area that is roughly centered on the Thermopolis hot springs. The results demonstrate that the thermal anomaly occurs all along the central part of the Thermopolis anticline, occupying a 20 - mi long by 3 - mi wide area that strikes west-northwest between the southwestern part of T. 43 N., R. 93 W. and the southeastern part of T. 44 N., R. 96 W.. Within this zone, calculated gradients are in the range 43-300°F/1000 ft (78-547°C/km) and tabulated bottom hole temperatures range from 90°F (32°C) to 160°F (70°C) at depths less than 2000 ft (~.6 km). Inasmuch as downward continuation of the lower gradients predicts 140°F (60°C) temperatures at depths between 3500 and 4000 ft (1.1 - 1.2 km), we consider all of the region to be a "viable" low temperature, hydrothermal resource area.

The Red Springs Anticline area in T. 43 N., R. 93 W. may be a "marginal" resource area. Here the calculated gradients are in the range 24 - 59°F/1000 ft (43-107°C/km). Consequently, 140°F (60°C) waters might be encountered at 3900 - 4500 ft depths (1.2 - 1.3 km) here.

The narrow boundaries of the Thermopolis-Red Springs anticlines anomaly suggest that "thermal waters" would be at shallow depths. The best examples are the changes from 43 - 300°F/1000 ft (78 - 547°C/km) gradients from the Thermopolis anticline to the 11 - 23°F/1000 ft gradients about 5 - 6 miles (8 - 10 km) to the north - northwest. The 10 - 25°F/1000 ft (18 - 46°C/km) gradients at five sites 5 - 10 miles (8 - 16 km) southwest of the anticline also suggest that shallow sources are responsible for the increased gradient in the middle part of the structure.

A tightly folded syncline is located immediately south of the Thermopolis anticline. We believe that waters from the Owl Creek Mountains are heated at the bottom of this syncline. Subsequent upward movement of these waters along the northern flanks of the syncline could explain the high gradients in the anticline. The thermal waters are most likely to be in the Tensleep and / or Madison Formations--two formations with porosities and permeabilities sufficient to yield the flow rates (~2800 gpm; Breckenridge and Hinckley, 1978) of the spring system in Hot Springs State Park. Within the central part of the anticline, the "tops" of the Tensleep and Madison range from 200 - 2800 ft (.06 - .85 km) and 800 - 3450 ft (.24 - 1.08 km), respectively. It is possible, therefore, that these aquifers could be reached with economical drilling in some parts of the structure.

APPENDIX A (continued)

Referring to "practical" aspects of resource development, one question that must be answered is whether drilling and large scale development would change temperatures and flow rates of the Thermopolis hot springs. Lack of data on porosities and permeabilities of the regional subsurface units also could impede development, as could the data for the springs which suggest that regional thermal waters would contain large amounts of total dissolved solids (2300 ppm; Breckenridge and Hinckley, 1978). Finally, minor structures along the crest of the anticline should be carefully considered during drill site selection; for example, numerous faults cross cut the northwest-southwest trend of the anticline, and a heretofore unmapped fault is evident on air photos of the structure.

The Cody-Horse Center Anticline System

This potential resource area seems to be bounded by the DeMaris hot springs (27-36°C, 1700 gpm) just west of Cody and the Horse Center anticline about 7 miles to the south. The first evidence for a low-temperature resource was provided by the 49-205°C/km gradients calculated using bottom hole temperatures in eleven dry oil wells in the anticline. Recent down hole measurements by Wyoming personnel agree with the oil well data. For example, least-squares gradients and maximum temperatures based on measurements in five shallow wells are in the ranges 96-190°C/km and 38.4-47.5°C, respectively, at subsurface depths in the range 185-500 m.

The Rattlesnake anticline is between Cody and the Horse Center anticline. As seems to be the case elsewhere in the area, the Chugwater Formation in this anticline appears to be an impermeable cap rock that overlies porous, permeable and perhaps water-bearing units in the Tensleep and Madison Formations. From recent detailed geologic mapping, we believe that ~60°C waters might be encountered at ~300 m depths in the vicinity of the southeastern flank of this structure. Confirmation of a reservoir at such temperatures and depths with adequate flow rates is a great local interest because the resource could be used in two possible projects--a housing development or an alcohol plant.

The inferred most promising area is presently being examined with a drilling program that started in January of 1980. From measurements in four ~100 m drill holes, the gradients off the flank of the Rattlesnake anticline are in the range 130 to 200°C/km. Concomitant bottom hole temperatures at these depths are in the range 20 to 29°C. We hope to complete at least one 300+ meter hole in the Madison Formation by the end of the first week in March, 1980. Observed temperature, water geochemistry and flow

APPENDIX A
(continued)

rate studies for this locality would provide data on the base temperature and other important characteristics of the indicated system.

The Big Horn Basin, Excluding the Thermopolis and Cody-Horse Center Systems

Bottom hole temperature data have been compiled and analyzed for ~150 oil wells that are within a triangular area bounded by Worland, Meeteetse and Thermopolis in the southern part of the Big Horn Basin. The widely scattered data points cannot be interpreted in detail, but one general conclusion is that the geothermal gradients increase between Worland and the Absaroka, Wind River and Owl Creek Mountains to the west, southwest, and south, respectively. Confirmation of this regional variation(?) would be important because it suggests that any low-temperature reservoirs are most likely to exist along the flanks of these mountains.

A new heat flow value of 1.78 HFU has been determined for Meadow Creek Basin in the eastern part of the Absaroka Mountains. This flux and Blackwell's (1969) 1.8 HFU value near Kirwin about 20 km to the south suggest that a large part of the Absarokas is a zone of high flux like the western Great Basin. Additional evidence for Basin and Range type flux in these mountains, in turn, would suggest that low-temperature reservoirs could occur in this part of north-western Wyoming.

Temperatures have been measured in 15 drill holes in the Bridger Mountains. Although some of the observed gradients (5.3-12.8°C/km) are consistent with local hydrologic disturbances in these mountains, the most reliable values of 19.0-22.6°C/km support earlier suggestions that the Lysite-Bridger Mountain area is a zone of above-normal heat flow (see Decker and others, 1980). Like the elevated flux in the Absarokas to the northwest, the above-normal regional heat flow may imply the presence of hydrothermal reservoirs locally in the Bridger Mountains.

Note: Throughout the text, temperatures are given in °F or °C and geothermal gradients are given in °F/1000 ft or °C/km. The heat flow unit is abbreviated to HFU, where 1 HFU = 1×10^{-6} cal/cm² sec = 41.8 mW/m².

Source: Appendix A is entirely and directly quoted from Decker, E.R., Heasler, H.P., and J.K. King, 1980. "Hydrothermal Resources in Wyoming: A Preliminary Report on the University of Wyoming's Research in 1979", Department of Geology, University of Wyoming, Laramie, Wyoming, 82071. (In press)

APPENDIX B

THERMOPOLIS / CODY COMMERCIAL DISTRICT HEATING SYSTEM

A. Capital Cost Assumptions

1. Reservoir System	
a. Exploration	\$ 25,000
b. Well System - Intangibles	
i. Wells and Casings	
2 - Production wells (3000 feet @\$100/ft.)	\$ 600,000
1 - Reinjection well (2500 feet @\$ 75/ft.)	\$ 187,500
ii. Pump tests	\$ 10,000
iii. Geologist (5 days at well site)	\$ 1,500
iv. Contingency (10%)	\$ 80,000
v. Engineering Fee (15%)	\$ 131,850
Subtotal	\$ 1,010,850
c. Well System - Tangibles	
i. Submersible pumps (2)	\$ 80,000
ii. Well Head Equipment and Pad	\$ 15,000
iii. Powerline, etc.	\$ 2,000
iv. Contingency (10%)	\$ 9,700
v. Engineering Fee (15%)	\$ 16,005
Subtotal	\$ 122,205
2. Transmission System (to point of distribution)	
a. Pipeline (2 miles x 16" diameter)	\$ 528,000
b. Circulation pump	\$ 10,000
c. Power Lines	\$ 2,000
d. Controls and valves	\$ 5,000
e. Contingency (10%)	\$ 54,500
f. Engineering Fee (15%)	\$ 90,000
Subtotal	\$ 689,500
3. Distribution Network (for 1 mile x 1/3 mile network)	
a. Supply pipeline (8" diameter x 21,120 feet	\$ 316,800
& 16" diameter x 1,320 feet)	\$ 66,000
b. Return pipeline (same dimensions as above)	\$ 382,800
c. Curb to building lines (20)	\$ 80,000
d. Building retrofits (20)	\$ 100,000
e. Return pipeline to reinjection well	
(16" diameter x 0.5 mile)	\$ 132,000
f. Reinjection pump	\$ 35,000
g. Circulation pumps (4)	\$ 20,000
h. Power lines	\$ 2,000
i. Controls and valves	\$ 2,000
j. Contingency (10%)	\$ 113,960
k. Engineering Fee (15%)	\$ 188,034
Subtotal	\$ 1,441,594
4. Regulatory Costs (institutional costs)	\$ 10,000
5. Total Capital Cost	\$ 3,299,649

APPENDIX B
(continued)

THERMOPOLIS / CODY COMMERCIAL DISTRICT HEATING SYSTEM

B. Other Cost Assumptions

1. Working Capital (2.5% of Capital Costs) \$ 82,500
2. Operating and Maintenance Costs
 - a. Case A - 6% per year of Capital Costs \$ 197,979 / yr.
 - b. Case B - 3% per year of Capital Costs \$ 98,989 / yr.
3. O & M Cost Escalation Rate 10% per yr.
4. Municipal Bond Interest Rate 8% per yr.
5. Rate of Return to Municipality
 - a. Case 1 - 8% per year
 - b. Case 2 - 3% per year
6. Replacement Fuel: Natural Gas
 - a. Current (1980) Price \$ 3.13 / MMBTU
 - b. Escalation Rate 11% per yr.
 - c. Amount of Fuel required 55,000 MMBTU / yr.
7. Life Cycle Duration 25 years
8. Bond Issuances
 - A - Bonds: \$ 3,299,650 (CC) plus \$ 82,500(WC) issued at beginning of year 0, to provide capital for construction during year 0 (full operation begins at beginning of year 1, end of year 0); 26 year issuance with equal annual P & I payments.
 - B - Bonds: \$ 264,000 issued at beginning of year 1 to pay interest due on A - Bonds at end of year 0; 5 year issuance with equal P & I payments.

C. Result of SEER Calculations

1. Three Cases Evaluated:

	<u>Discount Rate (ROR)</u>	<u>O & M Costs</u>
Case 1	8%	6% of Capital
Case 2	3%	6% of Capital
Case 3	3%	3% of Capital

2. Items Calculated:

DCFROR = Discounted cashflow rate of return

NPV = Net present value (at minimum rate of return to municipality)

Dis. Payback = Discounted payback period

Annualized Revenue = Actual escalated dollar revenue required
each year for 25 years

Energy Price = Annualized Revenue divided by 55,000 MMBTU

Source: Western Energy Planners, Ltd., 1980.

ASSUMPTIONS OF APPENDIX B

1. Capital costs were assumed at 100% borrowing with no grants. In the case of East Thermopolis, a UDAG grant would probably be available. This table also does not account for federal programs such as the User-Coupled Drilling Program or the Geothermal Loan Guarantee Program.
2. Heating demand may be innaccurate as it is based on square footage figures that are much higher at an averaged rate than those actually found in most cities in Wyoming. Figures that more accurately reflect actual heating demand will be used in the Thermopolis Site Specific Development Analysis (SSDA).
3. Drilling and pump costs may be inaccurate for Thermopolis, although they resemble the real life situation of Cody pretty well. In Thermopolis, there is a good chance that artesian flow could be achieved, as well as finding a good production well (with adequate temperature and flow rates) at depths much less than 3000 feet. This would significantly reduce the Capital Costs.

APPENDIX C

THERMOPOLIS DISTRICT HEATING SYSTEM

INVESTMENT COSTS

<u>CATEGORY</u>	<u>NET PRESENT VALUE (1980 - 2010)</u> <u>DISCOUNTED AT COST OF CAPITAL</u>
Research Investment	\$ 334,957
Design	\$ 816,675
Management Fees	0
Wells	\$ 2,907,342
Transmission	0
Distribution:	
Residential Retrofit	\$ 1,095,403
Residential Hookup	\$ 380,606
Commercial Conversion	\$ 771,424
Industrial Conversion	0
Heat Exchangers	\$ 242,329
Central System	\$ 3,381,197
Total	\$ 9,929,934

Price per MMBTU: \$ 4.94
Year on line: 1989

COST AND BENEFIT SUMMARY (1980 - 2010), DISCOUNTED

Federal Factors:	<u>Fed. Tax</u>	<u>Tax Credit</u>	<u>Royalty</u>
	\$ 3,506,177	\$ 2,002,477	\$ 563,317
State Factors:	<u>State Tax</u>	<u>Sales Tax</u>	<u>Property Tax</u>
	\$ 0	\$ 0	\$ 1,371,539
Net Savings Through Year:	<u>1990</u>	<u>2000</u>	<u>2010</u>
	\$ 246,000	\$ 3,734,000	\$ 7,370,000

EVALUATION OF INVESTMENT (NET PRESENT VALUE)

Investors return on investment:	\$ 5,350,511
Equity Investment:	\$ 3,435,983
Equity Portion:	0.3
Economic Judgement:	\$ 1,914,529
Ratio of Rate of Return to Investment:	1.6
Investors Break-Even Year:	1999
Total Project Break - Even Year:	2008
Price of Geothermal:	\$4.94 / MMBTU
Price of Natural Gas:	\$3.30 / MMBTU (\$ 5.16 by 1987)
Year on Line:	1989

APPENDIX C
(continued)

REQUIRED FLOW RATE

Available Flow:	5000 GPM
Required Flow Rate:	4883 GPM
Spare Flow Rate:	117 GPM

Source: NMEI printout from BTHERM computer model, May, 1980.

ASSUMPTIONS MADE IN APPENDIX C

1. Research investment includes first production and injection well, in addition to engineering and geophysical studies.
2. Design is 10% of initial pre-production investment.
3. Management fees are included only for municipal development.
4. Transmission is pipeline cost from field to central distribution system.
5. Well costs indicate any wells required over initial well included in research investment, and all pumps, royalties or other associated well costs.
6. Developer's share of money was assumed at 75%.
7. Degree days were assumed at 7200. The actual figure for Thermopolis is 7248.
8. Depth of resource was assumed at 3500 feet. This is a "worst-case" figure. Satisfactory temperatures might be achieved at significantly shallower depths.
9. Shipping distance was assumed at 0 miles.
10. Temperature of geothermal fluid was assumed to be 140°F (60°C).
11. This computer run assumed a sales tax of 0. Wyoming actually has a 3% sales tax at the present time.
12. There are many other assumptions made by the BTHERM Base Case inputs that will not be elaborated on in a report of this scope. Data will be provided to NMEI in the future that will provide a more accurate reflection of Thermopolis district heating potentials than base case figures.

APPENDIX D

THERMOPOLIS / CODY DISTRICT HEATING SYSTEM

	<u>PRICE / MMBTU (GEOTHERMAL)</u>	<u>INVESTMENT COST</u>	<u>25 YEAR DISCOUNTED FUEL SAVINGS</u>	<u>25 YEAR DISCOUNTED RETURN ON INVESTMENT</u>
Case 1	\$ 5.02	\$ 2,458,855	\$ 743,000	0
Case 2	\$ 6.27	\$ 2,458,855	\$ 306,000	\$ 636,551
Case 3	\$ 8.20	\$ 2,704,740	\$ 114,000	\$ 700,203
Case 4	\$ 12.30	\$ 3,748,764	0	\$ 749,753

Source: January, 1980 data provided by PSL - NMEI in personal letter.

ASSUMPTIONS FOR APPENDIX D

Case 1: Interest rate (0.08), time (25 years), distance from resource (8 miles), temperature (122°F or 50°C), depth (4000 feet), annual commercial heat demand (55,000 MMBTU/yr.), operating cost (2% of investment), alternative fuel price (\$3.13/MMBTU), with real annual growth rate in conventional energy price of 6.6% for 10 years, and 5% per year for the following 30 years. The following financial factors were all set to zero: rate of return on investment, Federal and State taxes, royalty rates, depletion allowances and investment credits.

Comments of Case 1: This is the most unrealistic of the four cases and was completed to illustrate how the model can be played with rather than to provide any real information. Resource distance, temperature and depth are all worst case values. The financial factors are impractical from a developers standpoint.

Case 2: The assumptions are identical to Case 1, except that it is a private developer who must earn a rate of return on investment, who must pay taxes and who will receive credits and allowances. This developer has 20% equity financing.

Case 3: The assumptions are identical to Case 2, except a design cost equal to 10% of other investment has been included.

Case 4: The assumptions are the same as Case 3, except it contains PSL - NMEI standard cost estimates for wells, well casings and pumps. These costs are for a 500 gpm, 4000 foot well with accessories. The PSL - NMEI costs are unspecified in this case. It is assumed that GCO well costs were used in the other three cases.

APPENDIX D
(continued)

General Comments on Assumptions:

Most of the variables and assumptions that are usually described in an economic analysis are lacking in this one. It is not known what other estimates have been made other than those specifically listed above. This table is only included to show the broad range of values that the GCO has received for geothermal price per MMBTU for the Thermopolis / Cody system.

Appendix E

Figures for the Big Horn Basin, Wyoming. Source: NMEI printouts dated December, 1979.

Appendix F

Figures for the Big Horn Basin, Wyoming. Source: NMEI printouts dated December, 1979.

Appendix G

Figures for the Big Horn Basin, Wyoming. Source: NMEI printouts dated December, 1979.

Appendix H

Figures for the Big Horn Basin, Wyoming. Source: NMEI printouts dated December, 1979.

Appendix I

Figures for the Big Horn Basin, Wyoming. Source: NMEI printouts dated December, 1979.

Appendix J

I=INFERRED P=POTENTIAL C=INF. PLUS POT.

STATE: WYOMING APPLICATION: COMBINED INDUSTRIAL AND RESIDENTIAL CITY UTILITY

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An informative paper is only as useful as the facts that it contains. If you have any suggestions or information that you think our office should be aware of, please contact us at the following address:

Geothermal Commercialization Office
P.O. Box 4096, University Station
Laramie, Wyoming 82071

(307) 766-4820 or
Toll free in Wyoming 1 (800) 442-8334

CONVERSE AND NATRONA COUNTIES, WYOMING
Area Development Plan

Principal Authors:
John MacDonald
Karen Marcotte

Research Assistance:
Keith Bray

Editor:
Rick James

Wyoming Geothermal Commercialization Office
in cooperative agreement with
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iv

Introduction

The goal of Area Development Plans (ADP) is the inventory of potential geothermal sites and the feasibility of geothermal energy development in the ten major planning regions in Wyoming. Although utilization of a geothermal resource will require site specific analysis, it is the focus of the ADP to provide enough general information to encourage interest in areas of likely success and to suggest possible uses. An ADP for the Converse/Natrona region is encouraged due to the vast quantities of water stored in the Madison limestone which probably possess low-temperature geothermal waters. Temperature readings of geothermal waters from existing wells indicate the feasibility of utilization of the Madison waters, especially in the Midwest area of Natrona County.

Development of geothermal resources, as with other alternative energy uses, is necessitated by the need for reduction in the consumption of petroleum and natural gas. Although by no means a complete panacea to this country's energy requirements, geothermal energy use is a step in the direction of alternative energy use and national self-sufficiency in energy requirements.

The Natrona/Converse Area Development Plan includes all of Natrona and Converse counties in eastcentral Wyoming. The northern two-thirds of the region is part of the Powder River Basin, an extension of the Great Plains. The southern tier rises into several geomorphic uplifts, from the Laramie Mountains in the southeast, through the Rattlesnake Hills and Granite

Mountains in the southwest, to the Big Horn Mountains in the northwest of Natrona county. Major drainage through the region is via the Platte river which flows eastward, and by several smaller streams draining northward into the Powder River Basin.

Area Ownership

These two counties cover an area of 9,949 square miles, more than 10% of the state. Private ownership encompasses 57% of the area of 5,671 square miles, while Federal control extends over 33%, with State lands covering the remaining 10% (Figure 1).

History of Region

Native americans of the Crow, Cheyenne, Ogallala and Brule Sioux inhabited the region before the immigration of white pioneers. Most of the Indian activity was concentrated along the Sweetwater, Powder, and North Platte Rivers. Although trappers and explorers passed through as early as 1808, heavy pioneer traffic didn't commence until 1843 along the Oregon Trail. Founded in 1867 as a stopping point along the Trail, Fort Fetterman in present day Converse County, was the center of early community activity. Population growth in the region was aided by the extension of the Union Pacific Railroad through the area between 1886 and 1888. Most of the region remained agricultural into the mid-twentieth century with the exception of Casper which is the business center of Wyoming and its largest city.

Figure 1: Converse/Natrona ADP Region

Early mineral development in the region focused on petroleum and gas extraction which continues today, especially in the Salt Creek area of Natrona County. It was in this area that the Teapot Dome leasing scandal brought notoriety to the state in the 1920's. Recent mining activities have focused on coal and uranium which underlie much of the area of the Powder River Basin.

Population

The GCO surveyed growth trends in the region to aid in prediction of energy consumption. Population growth in the region grew 50.4% between 1970 and 1980, after an increase of only 2.2 percent in the 1960-1970 decades. Forecasts for the 1980's indicate a slowdown to 35.3 percent. The population increase for the state has been 2.9 percent annually or 29 percent for the last decade. During the 1970's the growth rate for Natrona county was 37.9 percent, while that of Converse jumped 158.1 percent. These figures are indicative of the mineral extractive boom economy in this impacted area. Traditional socio-economic patterns in the region have been drastically affected by the increased development of coal, oil, natural gas, and uranium mines, as well as power plant construction (Figures 2 and 3).

Figure 2

NATRONA COUNTY POPULATION

— HISTORICAL

- - - PROJECTIONS

A-Natrona County Planning
B-Wyoming Dept. of Administration and
Fiscal Control
C-U.S. Census

Figure 3
CONVERSE COUNTY POPULATION

Table 1
POPULATION CHANGE

	Natrona <u>County</u>	<u>Casper</u>	Converse <u>County</u>	<u>Douglas</u>
1960	49,623	38,930	6,366	2,822
1970	51,264	39,361	5,938	2,677
%	+3.3	+1.1	-6.7	-5.1
1970	51,264	39,361	5,838	2,677
1980	70,715	53,746	15,326	8,249
%	+37.9	+36.5	+158.1	+208.1
estimate				
1980	70,715	53,746	15,326	8,249
1990	95,204	71,242	21,178	11,238
%	+34.6	+32.6	+38.2	+36.2

Employment

Total employment for the ADP region was 25,030 persons in 1977. This figure includes 2,741 employed people in Converse County and 22,289 employed people in Natrona County. The total employment figure for Converse County is undoubtedly much higher at the present time and may even have doubled, due to the recent energy impact on the communities of Glenrock and Douglas. Unfortunately, more recent figures are not available at this time.

The largest employers in both counties are the metal mining industries (SIC 10). The second largest employer is the oil and gas extraction industry (SIC 13), employing 350 persons in Converse County and 4,594 persons in Natrona County. The uranium, radium and vanadium ore industry (SIC 1094), oil and gas well drilling (SIC 1381), and special trade contractors (SIC 17) also employ substantial numbers of people in Natrona County. Other large industrial employers in Converse County

include: miscellaneous metal ore mining (SIC 109), heavy construction contractors (SIC 16), and special trade contractors (SIC 17). It is clear that the mineral-extractive industries have made a dramatic impact on the employment base of Natrona and Converse Counties (see Table 2).

Energy Consumption

The largest energy consumers in both Converse and Natrona Counties are the following industries: oil and gas extraction, petroleum refining, coal mining and uranium mining (Tables 3 and 4). While geothermal energy will have little impact on the mineral extractive industries, it could have a significant impact on refining processes or other fossil fuel processes where large amounts of heat are required. Commercial and industrial processes utilizing low-temperature heat sources could also employ the use of geothermal energy. Space heating of residential, commercial and industrial buildings is another applicable use of the resource.

Madison Formation

The Madison Limestone Formation underlying the ADP region and northeast Wyoming, extends into Montana, the Dakotas, Nebraska, and Canada. The formation was deposited during Mississippian time, about 300,000,000 years ago, when inland seas inundated most of Wyoming. In Wyoming, the Madison, or Pahasapa Limestone is more than 22,000 square miles in area, with thicknesses ranging from zero in the southeast to a

Table 2

EMPLOYEES BY INDUSTRY

SIC Code	Industry	Converse County	Natrona County	Total
	TOTAL EMPLOYMENT	2,741	22,289	25,030
	Agricultural Services, forestry, fisheries	10	60	70
	All Mining	725	3,608	4,333
10	Metal Mining	750	586	1,336
108	Metal Mining Services		230	230
109	Miscellaneous Metal Ores	375	356	731
1094	Uranium-radium-vanadium ores		1,284	1,284
13	Oil and gas extraction	175	2,438	2,613
131	Crude petroleum and natural gas		325	325
138	Oil and gas field services	175	2,156	2,331
1381	Drilling oil and gas wells		1,239	1,239
1382	Oil and gas exploration		197	197
1389	Oil and gas field services	149	718	867
15	General contractors and operative builders	99	618	717
151	General building contractors		464	464
16	Heavy construction contractors	175	548	723
17	Special trade contractors	175	1,147	1,322
171	Plumbing, heating, air conditioning		177	177
172	Painting, paper hanging, decorating		154	154
173	Electrical work		234	234
174	Masonry, stonework, and plastering		148	148
1741	Masonry and other stonework		70	70
1742	Plastering, drywall and insulation		60	60
175	Carpentering and flooring		61	61
176	Roofing and sheet metal work		93	93
177	Concrete work		58	58
179	Misc. special trade contractors		209	209
1791	Structural steel erection		51	51
1794	Excavating and foundation work		85	85
1799	Special trade contractors		53	53
	All manufacturing	70	1,756	1,826
20	Food and kindred products		58	58
27	Printing and publishing		179	179
271	Newspapers		60	60
275	Commercial printing		60	60
2751	Commercial printing, letterpress		8	8
29	Petroleum and coal products		754	754
291	Petroleum refining		662	662
32	Stone, clay, and glass products		114	114
327	Concrete, plaster and gypsum		112	112
3273	Ready-mixed concrete		37	37
34	Fabricated metal products		131	131
344	Fabricated structural metal products		186	186
35	Machinery, except electrical	10	330	340
353	Construction and related machinery	29	346	375
3533	Oil field machinery	8	38	46
48	Communication	4	531	535
49	Electric, gas and sanitary services	375	375	750
491	Electric services	375	175	550
492	Gas production and distribution		175	175

Table 2 Cont'd.

EMPLOYEES BY INDUSTRY

SIC Code	Industry	Converse County	Natrona County	Total
	Wholesale trade	66	2,375	2,441
50	Wholesale trade-durable goods		1,905	1,905
5013	Automotive parts and supplies		168	168
505	Metals and minerals, except petroleum		56	56
5051	Metals service centers and office			
506	Electrical goods	8	55	63
507	Hardware, plumbing and heating equipment	4	56	60
508	Machinery, equipment and supplies		1,334	1,334
5082	Construction and mining machinery	10	476	486
5084	Industrial machinery and equipment	11	600	611
5085	Industrial supplies	9	100	109
51	Wholesale trade - nondurable goods		375	375
514	Groceries and related products	6	71	77
516	Chemicals and allied products		82	82
517	Petroleum and petroleum products		201	201
	Retail trade	555	4,746	5,301
52	Building materials and garden supplies	54	268	322
521	Lumber and other building materials		111	111
527	Mobile home dealers		66	66
53	General merchandise stores		502	502
531	Department stores		460	460
54	Food stores	98	547	645
541	Grocery stores	91	483	574
55	Automotive dealers and service stations	110	993	1,103
58	Eating and drinking places	178	1,382	1,560
5812	Eating places	116	1,145	1,261
5813	Drinking places	62	176	238
59	Miscellaneous retail	60	513	573
	Finance, Insurance, Real Estate	175	1,414	1,589
60	Banking	62	514	576
602	Commercial and stock savings banks	62	514	576
61	Credit agencies other than banks		229	229
64	Insurance agents, brokers and service		89	89
63	Insurance carriers		83	83
65	Real Estate		346	346
	Services	321	4,256	4,577
70	Hotels and other lodging places	99	627	762
701	Hotels, motels and tourist courts	60	750	810
72	Personal Services		295	295
73	Business services		744	744
739	Miscellaneous business services		435	435
7394	Equipment rental and leasing		140	140
75	Auto repair, services and garages		403	403
7538	General automotive repair shops		139	139
79	Amusement and recreation services		142	142
80	Health services	77	537	614
81	Legal services		103	103
83	Social services		142	142
86	Membership organizations		364	364
89	Miscellaneous services		458	458
	Nonclassifiable establishments	1	60	61

Sources: County Business Patterns, U.S. Census, Wyoming Data Handbook,
Department of Administration and Fiscal Control, 1977.

TABLE 3
PROJECTED 1980 ENERGY CONSUMPTION BY INDUSTRY FOR CONVERSE AND NATRONA COUNTIES

Sic Code	INDUSTRY	ELECTRICAL (MWH)	NATURAL GAS (MWH)	COAL (TONS)	GASOLINE (BBLs)	DIESEL (BBLs)	OTHER FUELS EXCLUDING PROPANE (BBLs)	TOTAL BTU (BILLIONS)
01-07	All agricultural	6,594	32,970	---	57,567	22,242	---	538
11-1200	Coal mining	8,059	216,650	---	108,325	619,012	526,112	8,059
1300	Petroleum, natural gas	819,630	11,943,180	---	---	128,242	46,464	15,716
1094	Uranium	217,680	925,140	---	6,911	475,095	57,011	4,866
1452	Bentonite	6,000	243,000	---	321	11,571	---	332
15-16	Construction	4,881	73,215	---	58,107	232,429	---	1,795
2010	Meat products	432	4,080	1	---	---	151	7
2020	Dairy products	336	2,992	13	---	---	147	5
203-04	Other food products	29	353	4	---	---	16	1
2050	Bakery products	1,045	9,595	8	---	---	410	16
2080	Beverages	238	2,870	42	---	---	178	6
2300	Apparel	492	1,230	14	---	---	111	4
24-2500	Lumber, furniture	56	348	2	---	---	28	---
2600	Paper, paper products	352	2,772	55	---	---	376	7
2700	Printing and publishing	1,467	5,705	3	---	---	194	12
2800	Chemicals	1,404	16,872	217	---	---	400	28
3200	Stone, clay and glass	3,157	86,163	1,189	---	---	2,394	133
3300	Primary metals	1,200	9,000	77	---	---	302	16
3400	Other fab. metal products	3,349	26,792	91	---	---	905	45
3531	Const. min. and machines	2,775	22,940	348	---	---	335	41
3534	Hand machinery	2,331	19,684	49	---	---	777	33
3720	Aircraft, aircraft parts	288	1,062	8	---	---	70	3
2900	Petroleum refining	39,480	7,455,140	---	---	---	445,868	10,247
4600	Petroleum pipelines	1,370,000	---	---	---	---	---	4,671
5000	Wholesale trade	3,418	68,360	---	---	---	---	79
5800	Eating, drinking places	8,981	64,150	---	---	---	---	95
5257	Other retail	28,410	213,075	---	---	---	---	309
6061	Finance	5,943	50,940	---	---	---	---	71
6364	Insurance	693	11,550	---	---	---	---	14
6566	Real estate	3,300	42,900	---	---	---	---	54
7000	Hotels	9,269	178,250	---	---	---	---	209
7200	Personal services	1,500	75,000	---	---	---	---	80
7300	Business services	1,938	38,760	---	---	---	---	46
8000	Medical, health services	5,224	130,600	---	---	---	---	148
TOTAL		2,559,951 (MWH)	21,975,338 (MCF)	2,121 (TONS)	231,231 (BBLs)	1,488,591 (BBLs)	1,082,249 (BBLs)	47,686 (BTU BILLIONS)

Source: Wyoming State Depad Office, 1979.

projected maximum of about 900 feet in Sheridan County. Most of Converse and Natrona counties possess formation thicknesses between 200 and 400 feet.

Most of the formation is beneath the Powder River Basin, one of the largest structural basins in the Rocky Mountain Province. The Madison also occurs in parts of Wyoming outside of the basin. In northeast Wyoming the Madison slopes basinward from mountainous areas and reaches depths in excess of 16,000 feet below land surface. In Converse County, depths range from 2,000 feet in the southeast to a projected 16,000 feet in the northwest. Depths in Natrona County vary from 2,000 feet along a line running in a southeast-northwest axis to a maximum depth of 10,000 feet in the extreme northeast. Most of the county has depths between 2,000 and 8,000 feet to the Madison.

Generally, the upper Madison is more cavernous than the lower due to greater weathering of the limestone which has a tendency to fracture and a susceptibility to go into solution in the presence of water. This tendency to fracture is one of the reasons aquifers are often found in a limestone formation. However, limestone can differ radically from type to type with respect to water yield. The rock type can be among the most productive aquifers, or conversely, one of the least productive, depending on local conditions.

Permeability and Porosity

Two factors directly related to limestone's ability to

hold or transmit water are porosity and permeability. Porosity indicates the amount and size of voids or openings in a material. Permeability is the ability of a medium to move a liquid through it. Unweathered limestone is a dense rock, and if it weren't for its brittle nature, would not make a good source water. However, thickbedded, hard, sedimentary rocks like limestone are conducive to being broken by closely spaced joints, which can be water-bearing openings.

A major problem of limestone is its unpredictability in regard to permeability. Fracturing and solution permeability are not ubiquitous and the heterogeneous nature of the rock sequences often creates large fluctuations in the water-yield capacity. It is also difficult to determine the amount of water stored within pores in the rock. Few quantitative measurements have been made to determine the amount of void space in the Madison limestone. One phenomenon of the Madison which would tend to increase the porosity and permeability is the transformation of calcite to dolomite in the ground. When this chemical process occurs, there is a decrease in volume and a corresponding increase in void space.

Flow of Madison Wells

The availability of groundwater in the Madison varies from area to area and as a consequence necessitates test drilling to accurately determine yield. Wells in Natrona and Weston counties have been recorded producing from hundreds to thousands of gallons per minute flowing, while other wells have yielded less

than 100 gallons per minute. A well near Midwest was recently measured at about 5,000 gpm.

Over forty wells have been drilled in the Madison in northeastern Wyoming, withdrawing more than 25,000 acre-feet per year (as of 1973). The majority of these wells were drilled to provide industrial water supplies, mainly for the secondary recovery of oil. In 1973, 540 acre-feet were withdrawn in Converse County and 15,542 in Natrona County.

The only noticeable effect of withdrawals of Madison groundwater has been interference between wells. The water withdrawn through wells may have decreased the amount of groundwater in storage and caused local declines in the piezometric surface, as has happened in the Midwest area. (Piezometric surface, in this context, refers to the surface to which the water from a given aquifer will rise under its full head.) However, well drawdown seems to have leveled off in these depressional areas, suggesting that increased inflow through the aquifer has equalized the water table.

Groundwater Quality

The quality of groundwater in the Madison is generally fair to good, with significant hardness. Water quality can be expected to be better in proximity to recharge areas and to deteriorate basinward. In areas where chemical analysis is available from the Madison and the overlying Tensleep formation, water from the former contains less dissolved solids than the latter at nearly all locations. Dissolved solid concentrations

are important in anticipating disposal techniques and in obtaining a value of viscosity for flow calculations. (A value of viscosity is a quantitative expression of the friction between the molecules of water when in motion.)

Dissolved solids are generally greater than 1,000 ppm over much of the study area, although wells can show extreme differences within a few miles of each other. Four wells tested in Natrona County showed between 2,600 and 3,200 mg/l of dissolved solids. (Ppm and mg/l can be considered equivalent up to concentrations of about 7,000 mg/l. For higher concentrations a correction for density of the solution is required, although the required correction is small.) Weston County and northeastern Converse County showed a much lower range of 250 to 500 mg/l (Table 5).

Water Temperature

Water temperature of the Madison within the region commonly varies from 50° to 250°F (10°-121°C) with increasing depth. Two wells in Natrona County had temperatures as high as 190° and 208°F (87°-98°C) between 5,000 and 7,000 feet (Wyoming State Engineers Office, 1974). Much of northern Converse County has groundwater temperatures estimated to be between 230° and 280°F (110-137°C), however, this groundwater is found between 11,500 and 15,000 feet below the surface (Figure 4). Many of the waters thus far tested in the Madison formation have temperatures exceeding those due to normal gradient, and it appears feasible to recover and utilize this geothermal source. The practical economics of developing geothermal energy for community heating or other applications involves some risks due to the heterogeneity of the rock,

TABLE 5
TYPICAL WATER ANALYSIS FOR THE MADISON/PAHASAPA FORMATION

Madison (Average of 15 Wells)			Natrona County Wells			
Constituent	mg/l	Range mg/l	T33, R77 Sec 15	T39, R78 Sec 26	T40, R79 Sec 26	T40, R79 Sec 35
Calcium (Ca)	310	227-498	338	307	366	328
Magnesium (MG)	56	26-72	55	40	28	60
Sodium (Na)	462	340-738	452	738	492	469
Potassium (K)	32	21-73	58	73	36	---
Carbonate (CO ₃)	0	---	---	---	---	---
Biocarbonate (HCO ₃)	122	96-159	124	133	112	98
Chloride (Cl)	634	443-1050	322	1050	619	640
Sulfate (SO ₄)	1023	800-1430	1560	900	1120	1060
Nitrate (NO ₃)	0.1	0-0.2	1.1	0.2	0.2	---
Fluoride (F)	4.0	3.2-5.0	5.0	5.0	3.2	---
Silica (SiO ₂)	43	25-74	40	62	47	---
Iron	0.6	0.2-4.8	4.8	.2	.58	---
Manganese (Mn)	-----	-----	-----	-----	-----	---
Boron (B)	0.4	0.12-0.65	.71	.65	.51	---
Total Dissolved Solids (TDS)	2687		3040	3290	2860	2770
Sum of Tons	2625	2040-3240	2900	3240	2770	2600
Hardness as CaCO ₃						
Total	1004	810-1490	1070	932	1030	---
Noncarbonate	904		968	832	938	---
ph	7.1	6.4-7.8	7.4	7.5	7.5	7.3
Temperature (°C)	67°	38°-98°	-----	88°	98°	---
Carbon Dioxide (CO ₂)	16 (Calc.)		-----	-----	-----	---

NOTE: The above analysis represents the arithmetic mean of the chemical and physical characteristics of water produced from 12 wells scattered through 9 townships in north-eastern Natrona County and southeastern Johnson County. All wells produce water used for secondary oil recovery operations in the Teapot, Salt Creek, Meadow Creek, Susses, and Dugout Oil Fields.

Source: Wyoming State Engineer's Office, 1974.

Figure 4
Groundwater Temperature (°C) in the Madison Limestone and
Equivalent Rocks, (USGS Open File Report 78-905)

influencing quantity and quality of the groundwater. Applied uses will require site specific analysis to gain additional aquifer information.

Resource Utilization

The Converse-Natrona region is characterized by a vast source of potential geothermal waters in the Madison Limestone, which underlies much of the region. Use of these waters is restricted however, due to factors of temperature and depth. Temperature of underground waters in this area is not hot enough for electrical development and is consequently restricted to low temperature utilization such as commercial space heating, aquaculture, greenhouse or residential heating. Cost of development will be influenced by depth to the Madison Formation, which in some locations is as much as 16,000 feet below the ground surface. In other locations, such as the Midwest-Edgerton and Douglas-Glenrock areas, the resource is close enough to the surface to make its utilization economically feasible. Drilling costs in the Midwest area were recently estimated to be \$432,000 for a well with casing to reach the top of the Madison Formation at 4,800 feet.

Midwest Area

The Midwest area probably has the greatest potential for immediate and successful development due to proven resource information, and interest on the part of local concerns to make use of the geothermal source. Wells in the immediate vicinity

have recorded temperatures of 120° to 170°F (49-78°C) at 1,000 to 4,500 feet, with maximum calculated gradients between 40° and 100°F (4°-38°C) per 1,000 feet. Water injection wells that penetrate the Madison formation produce 160° to 175°F (71°-80°C) waters that flow to the surface at rates exceeding 7,000 gpm (Decker, 1980).

Due mainly to restrictions caused by relatively low temperatures and the economics of the region, one of the most effective uses of the geothermal waters would be in the space heating of buildings, which could include residential, commercial and industrial applications. Large amounts of hot water issuing from the Madison formation are presently being used in the secondary oil recovery operations at the Salt Creek Oil Field. Three wells with a combined flow of 7800 gpm, at temperatures of 178°F (81°C) are being used in the oil field operations. The hot Madison wells are approximately 4500 feet deep. The geothermal water is cooled to 100°F (38°C) before it is discharged at the surface.

Other direct uses are being planned for development in the area of Midwest and Edgerton. A private developer is planning a small greenhouse complex cascading to an aquacultural facility 3 miles from Midwest. In addition, another developer is planning to build a small industrial park in conjunction with the town of Midwest. District heating systems for the towns of Midwest and Edgerton have also been proposed with a great deal of public interest. Major impedences to development may be the relative cost of hydrocarbon versus geothermal resources, possible

high concentrations of solids, and questions of ownership rights in regards to the geothermal water.

Economic Analysis of Proposed District Heating System

Preliminary economic analysis has been conducted for the proposed geothermal district heating system for Midwest by the Physical Science Laboratory of the New Mexico Energy Institute (PSL-NMEI) and by EG&G of Idaho. Summaries of their initial economic studies appear in the Appendix of this report. The reader will note that the price per MMBTU for the geothermal fuel covers a large range of values in the examples included in the Appendix. There are also many discrepancies between drilling, investment and distribution costs over the three studies included. This is presumably due to the number of assumptions and "best-guess" estimates that were made by PSL-NMEI and EG&G whenever actual data were lacking.

A Site Specific Development Analysis (SSDA) for the Midwest region will be completed in the near future. This SSDA will also include the neighboring town of Edgerton, as well as some industrial park applications for the resource. Specific data will be provided by the GCO to various organizations specializing in geothermal economic analysis. It is hoped that cost studies will then be generated that more accurately describe the physical and economic realities of the Midwest region.

Casper Region

Casper, unlike the Midwest area, does not seem to be

situated over a thermal anomaly and has not been as extensively tested. However, two sites are under study as possible geothermal resource development areas. The Emmigrant Gap Ridge area has yielded bottom hole temperatures of 90°-117°F (32-47°C) at depths ranging from 1,350 to 1,550 feet. A temperature of 202°F (95°C) was recorded in a 2,922 foot deep well in the vicinity of the Casper airport (Decker, 1980). The 200°F temperature is of interest and an effort is being made to confirm this lone measurement, to find supporting data, and interpret the local geologic structure. More data is needed in the Casper region before an accurate economic assessment of potential geothermal development can be made. However, it does appear that geothermal development in this region is likely to occur wherever feasible when consideration is given to the large population base and the variety of industries which might utilize process or space heat applications.

Douglas-Glenrock Corridor

The Douglas-Glenrock corridor is underlain by Madison limestone at depths ranging from 2,000 to 8,000 feet with possible temperatures of 100° to 200°F (38-94°C). Seven miles south of Douglas on the Platte River is the Douglas Warm Springs. This privately-owned spring has a surface temperature of 86°F (30°C) with a flow of 800 gpm. The springs apparently originate in the upper Opeche shale, a member of the Goose Egg Formation. Shallow fracturing precludes a deep-seated water source for the

springs, suggesting that further investigation is necessary to define the gradient and the heat sources active in the area (Breckenridge, 1978).

Douglas and Glenrock have experienced large population increases over the last decade with projections for continued large growth in the future. It has been estimated that Douglas alone will require 1,500 new housing units to accommodate the expected increase in population (Converse County Planning Office, 1980). Much of the increased energy demand will be for space heating, which could be offset by geothermal energy. With the resource potential of the area, many of these new units as well as existing homes and businesses, could probably be tied into an economical district system of geothermal heating.

A more reliable definition of the resource area is needed however, and will require additional research with shallow drill holes. It is probable that the entire eastern part of the Powder River Basin is characterized by a complex pattern of normal to high heat flow and perhaps shallow low-temperature hydrothermal reservoirs in isolated areas. More site specific information is required before the geothermal resource can be fully utilized.

SITE DATA SUMMARY

MIDWEST/SALT CREEK RESERVOIR

Location: Natrona County, 40 miles north of Casper in the area surrounding Midwest.

Elevation: 4,800 feet at Midwest, estimated depth to top of reservoir is 2000 feet.

Quadrangle: Midwest

Ownership: 400 acres of private land, the rest of the reservoir surface area is state land, largely leased by Amoco Oil Company. Total subsurface reservoir area is estimated at 10-12² miles.

Temperature: Bottom hole temperatures between 1000 and 4,500 feet (.3-1.4 km) are in the range of 120°-170°F (49°-77°C). Water injection wells that penetrate the Madison Formation produce 178°F (81°C) water.

Flow: 7,800 gpm from three wells

Geologic description: Deep sedimentary basin underlying the entire Powder River Basin and extending as far south as this area. The principal water bearing formation is the Madison Limestone. The Madison is overlain by the Tensleep Formation, a water-bearing sandstone. The surface of the Madison defines a broad 16,000 foot deep structural basin. The cavernous formation itself ranges from a few feet to nearly a thousand feet in thickness.

Present development status: The water issuing from the Madison is currently being used for flooding of oil fields. Many uses for this resource have been suggested, from district heating of Midwest and nearby Edgerton to raising prawns through geothermal aquaculture.

Sources: Decker, 1980; James, 1978; Breckenridge, 1978; and J. Officer, oral comm., 1980.

SITE DATA SUMMARY

DOUGLAS WARM SPRING

Location: Sec. 8cd, T.31N., R.71W., 7 miles South of Douglas in Converse County

Elevation: 4,760 feet

Quadrangle: Chalk Buttes

Ownership: Private - Bill Weiss, Douglas

Access: Seven miles south of Douglas on Esterbrook Road

Temperature: 30°C (7/29/76)

Flow: 800 gpm

Geologic description: The spring issues from the alluvium of the Platte River covering the Permian Goose Egg Formation. Immediately above the spring the Goose Egg crops out as a thin-bedded, medium-grained limestone interbedded with fissile mudstone. Below the outcrop, the slope is covered with a friable, purple-grey, limey siltstone. Structurally, the spring occurs at the crest of the northwest trending LaBonte anticline. A conspicuous fault in the limestone at the spring is represented by a zone of fault breccia, two feet wide, due to fracturing at the anticline crest.

Present development: The spring has been used for bathing and irrigation since the early 1900's. The present bathing and swimming facilities known as "Jackalope Plunge" were constructed in 1961. Overflow runs into the Platte River and supports a dense fish population.

Source: Breckenridge, R.M. and B.S. Hinckley, Thermal Springs of Wyoming, 1978.

SITE DATA SUMMARY

Location: Town of Glenrock, Converse County

Glenrock is interested in applying either excess steam from the Dave Johnson Power Plant and/or geothermal waters to power and/or heat industrial facilities located within the town's industrial park.

An application for feasibility study money submitted to the FHA was rejected, forcing the town to look elsewhere for funding.

Source: Converse County Planning and the Glenrock Town Manager, 1980.

APPENDIX A

INSTALLATION OF SUPPLY, DISTRIBUTION AND DISPOSAL SYSTEMS TO PROVIDE GEOTHERMAL SPACE HEATING IN MIDWEST AND EDGERTON, WYOMING (A PRELIMINARY COST ESTIMATE)

ASSUMPTIONS FOR PRELIMINARY COST ESTIMATES

<u>ITEM</u>	<u>MIDWEST</u>	<u>EDGERTON</u>
Population	750	600
Single Family Residences (1000 ft ²)	340	270
Businesses (2000 ft ²)	10	5
Residential Design Heat Load	65,000 BTU	65,000 BTU
Business Design Heat Load	160,000 BTU	160,000 BTU
Total Design Heat Load	2.37×10^7 BTU	1.835×10^7 BTU
Annual Heat Load	5.25×10^{10} BTU	4.125×10^{10} BTU
Peak Geothermal Flow	1,860 gpm	1,460 gpm
Present Annual Fuel Cost		
Each Residence	\$700	\$700
Each Business	\$1200	\$1200
Estimated Annual Fuel Savings (Natural Gas @ \$3.40/MMBTU)	\$250,000	\$195,000

OTHER ASSUMPTIONS AND COMMENTS:

Principal assumptions used are shown in the table above. Additional assumptions will be described here. A 25% utilization factor is employed to determine annual heat loads which are consistent with reported annual costs for natural gas space heating estimates (\$700/home; \$1200/business) at a current rate of \$3.40/MMBTU. Thermal efficiency of natural gas heating is estimated at 80%. Typical cost for heating system conversion and service connection is estimated to be \$2000/unit. Distribution grid costs are assessed at \$1000/unit, assuming no sidewalks or paved streets are disturbed or reconstructed.

Supply system costs are based on capacity to deliver 1860 gpm to Midwest and 1460 gpm to Edgerton. Peak flows are based on temperature drops (ΔT) of 25°F (-4°C) for home heating systems and 35°F (2°C) for business systems. The supply system is sized to carry 3360 gpm from the source to Midwest (1 mile) and 1460 gpm from Midwest to Edgerton (3/4 mile). Supply system costs assessed to Edgerton reflect an assignment of the cost for increased capacity over the 1 mile from the source to Midwest. Costs for black steel and asbestos cement supply piping systems are included in the analysis; costs also include insulation, waterproofing, bury and backfill. No costs are assessed for royalty, easement or right-of-way, permits, or engineering design.

The method for disposal is undefined at this time. Disposal wells and pumps are priced at \$200,000 for each townsite. Other possibilities for disposal include surface disposal or release to subsequent energy users.

Capital and annual cost schedules for Midwest and Edgerton are developed separately with annual costs for system amortization at 10% and 16% over 20 years. Annual operation and maintenance is based on costs for electrical power at 3.5¢/Kwh and maintenance at 2% of capital costs. Private development is not considered in this preliminary analysis, so profit and tax effects are not appropriate in this analysis. Preliminary cost estimates are shown in the following table.

PRELIMINARY COST ESTIMATES

<u>Capital Costs (\$)</u>	<u>Midwest</u>		<u>Edgerton</u>	
	<u>Steel Supply</u>	<u>ASM-CEM</u>	<u>Steel Supply</u>	<u>ASM-CEM</u>
Cost Element				
Supply	246,000	110,000	234,000	105,000
Distribution (\$1,000/unit)	<u>350,000</u>	<u>350,000</u>	<u>275,000</u>	<u>275,000</u>
Sub Total	596,000	460,000	509,000	380,000
Disposal	<u>200,000</u>	<u>200,000</u>	<u>200,000</u>	<u>200,000</u>
Sub Total	796,000	660,000	709,000	580,000
Retrofit (\$2,000/unit)	<u>700,000</u>	<u>700,000</u>	<u>550,000</u>	<u>550,000</u>
Project Total	\$1,496,000	\$1,360,000	\$1,259,000	\$1,130,000
<u>Annual Costs (\$)</u>				
O&M, Supply, Distribution	19,000	16,000	16,000	14,000
O&M, Disposal	7,000	7,000	7,000	7,000
<u>Amortization of Capital Costs</u>				

Supply, Distribution:

1. 10%, 20 yrs (.1175)	70,000	54,050	59,808	44,650
2. 16%, 20 yrs. (.1687)	100,000	77,602	85,868	64,106

Disposal:

1. 10%, 20 yrs (.1175)	23,600
2. 16%, 20 yrs (.1687)	33,800

Retrofit:

1. 10%, 20 yrs (.1175)	82,250	82,250	64,625	64,625
2. 16%, 20 yrs (.1687)	118,090	118,090	92,785	92,785

Using data from the table above, and assuming the "worst-case" costs (disposal by injection well, steel supply pipe, 16% interest on borrowed money), the total capital and annual costs are about:

	<u>Midwest</u>	<u>Edgerton</u>	<u>Total</u>
Capital	\$1,500,000	\$1,260,000	\$2,760,000
Annual	278,000	235,000	513,000

Assuming the "best-case" costs (0 disposal cost, asbestos-cement supply pipe, 10% interest), capital and annual costs are approximately:

	<u>Midwest</u>	<u>Edgerton</u>	<u>Total</u>
Capital	\$1,160,000	930,000	\$2,090,000
Annual	175,000	130,000	305,000

Comparison of these annual costs with the estimated annual fuel cost savings (\$445,000) show the "worst-case" estimate to exceed annual fuel savings by about 12%; the "best-case" estimate is less than the savings by about 30%. In view of rapidly escalating fossil fuel costs, this preliminary analysis indicates a high probability that a more detailed assessment will also show geothermal space heating can be an economically attractive alternative to the present use of natural gas.

The foregoing development of costs is based on minimal information and should be viewed as a preliminary estimate only. A more detailed development may alter the results significantly, however, based on available information the estimated costs are believed to be reasonable by the author of the above tables.

Source: I. A. Engen, Marketing Assistance, EG&G of Idaho, Inc., March, 1980.

APPENDIX B

MIDWEST DISTRICT HEATING SYSTEM (CASE 1)

INVESTMENT COSTS

<u>CATEGORY</u>	<u>NET PRESENT VALUE (1980-2010)</u> <u>DISCOUNTED AT COST OF CAPITAL</u>
Research Investment	\$ 71,413
Design	115,589
Management Fee	0
Wells	5,112
Transmission	149,709
Distribution:	
Residential Retrofit	383,726
Residential Hookup	133,328
Commercial Conversion	27,023
Industrial Conversion	0
Heat Exchangers	50,825
Central System	621,382
Total	\$1,558,109

Price per MMBTU: \$4.08

Year on line: 1982

COST AND BENEFIT SUMMARY (1980-2010), DISCOUNTED

Federal Factors:	<u>Fed. Tax</u> \$125,929	<u>Tax Credit</u> \$308,390	<u>Royalty</u> \$179,611
State Factors:	<u>State Tax</u> \$0	<u>Sales Tax</u> \$29,125	<u>Property Tax</u> \$135,086
Net Savings Through Year:	<u>1990</u> \$357,000	<u>2000</u> \$1,041,000	<u>2010</u> \$1,641,000

EVALUATION OF INVESTMENT (NET PRESENT VALUE)

Investors Return on Investment:	\$586,319
Equity Investment:	\$366,238
Equity Portion:	0.3
Economic Judgement:	\$220,081
Ratio of Rate of Return to Investment:	1.6
Investors Break-Even Year:	1990
Total Project Break-Even Year:	2000
Price of Geothermal:	\$4.08/MMBTU
Price of Natural Gas:	\$3.80/MMBTU
Year on Line:	1982

Required Flow Rate

Available Flow	5000 gpm
Required Flow Rate:	359 gpm
Spare Flow Rate:	4641 gpm

Source: NMEI printout from BTHERM Computer Model, May 1980.

Assumptions Made In Appendix B:

1. Research investment includes first production and injection well, in addition to engineering and geophysical studies.
2. Design is 10% of initial pre-production investment.
3. Management fees are included only for municipal development.
4. Transmission is pipeline cost from field to central distribution system.
5. Well costs include any wells required over initial well included in research investment, and all pumps, royalties, or other associated well costs.
6. Developers share of money was assumed at 80%.
7. Degree days was assumed at 7000. The actual figure for Midwest is 7007.
8. Depth was assumed at 4800 feet. An adequate resource in Midwest could possibly be achieved at depths significantly shallower than 4000 feet. The 4800 foot depth is a "worst-case" figure.
9. Distance was assumed at 1 mile.
10. Exploration time was assumed to be 1 year.
11. Flow rate is 5000 gpm.
12. Royalty rate (percent of gross income) was assumed to be 10%.
13. Population is 750 for the town of Midwest.
14. Temperature of the geothermal fluid was assumed to be 158°F. Actual temperatures achieved may be as high as 180°F in this region.

APPENDIX C

MIDWEST DISTRICT HEATING (CASE 2)

INVESTMENT COSTS

<u>CATEGORY</u>	<u>NET PRESENT VALUE (1980-2010)</u> <u>DISCOUNTED AT COST OF CAPITAL</u>
Research Investment	\$ 79,200
Design	131,268
Management Fee	0
Wells	14,500
Transmission	143,866
Distribution:	
Residential Retrofit	368,750
Residential Hookup	128,125
Commercial Conversion	25,969
Industrial Conversion	0
Heat Exchangers	48,842
Central System	597,131
Total	<u>\$1,537,651</u>

Price per MMBTU: \$4.22

Year on Line: 1982

Source: NMEI printout from B THERM computer model, May 1980.

Assumptions Made In Appendix C:

1. Research investment includes first production and injection well, in addition to engineering and geophysical studies.
2. Design is 10% of initial pre-production investment.
3. Management fees are included only for municipal development.
4. Transmission is pipeline cost from field to central distribution system.
5. Well costs include any wells required over initial well included in research investment, and all pumps, royalties, or other associated well costs.
6. Developers share of money was assumed at 80%.
7. Degree days was assumed at 7000.
8. Depth was assumed at 4800 feet.
9. Distance was assumed to be 1 mile.
10. Exploration time was assumed to be 1 year.
11. Flow rate is 5000 gpm.
12. Royalty rate (percent of gross income) was assumed to be 10%.
13. Population of Midwest is 750.
14. Temperature of geothermal fluid is assumed at 158°F.
15. Growth rate for investments and operating costs, estimated industrial growth per year, and population growth were all set to zero on this run.

APPENDIX D

APPROXIMATE TEMPERATURES FOR GEOTHERMAL USES IN WYOMING

TEMPERATURE

F	C	
212	100	DRYING OF ORGANIC MATERIALS i.e. GRASS, VEGETABLES WASHING AND DRYING OF WOOL
194	90	DRYING OF STOCK FISH INTENSIVE DE-ICING OPERATIONS
176	80	DISTRICT SPACE HEATING GREENHOUSE SPACE HEATING
158	70	REFRIGERATION BY LOW TEMPERATURE
140	60	ANIMAL HUSBANDRY GREENHOUSE BY COMBINED SPACE AND HOTBED HEATING
122	50	RESIDENTIAL SPACE HEATING MUSHROOM GROWING
104	40	SOIL WARMING
86	30	SWIMMING POOLS, BIODEGRADATION, FERMENTATION
68	20	HATCHING OF FISH, FISH FARMING

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5. Officer, Jack. Mayor of Midwest, Wyoming.
6. Zaborac, John. Converse Area Planning Office.

An informative paper is only as useful as the facts that it contains. If you have any suggestions or information that you think our office should be aware of, please contact us at the following address:

Geothermal Commercialization Office
P. O. Box 4096, University Station
Laramie, Wyoming 82071

(307) 766-4820 or
Toll-free in Wyoming 1 (800) 442-8334