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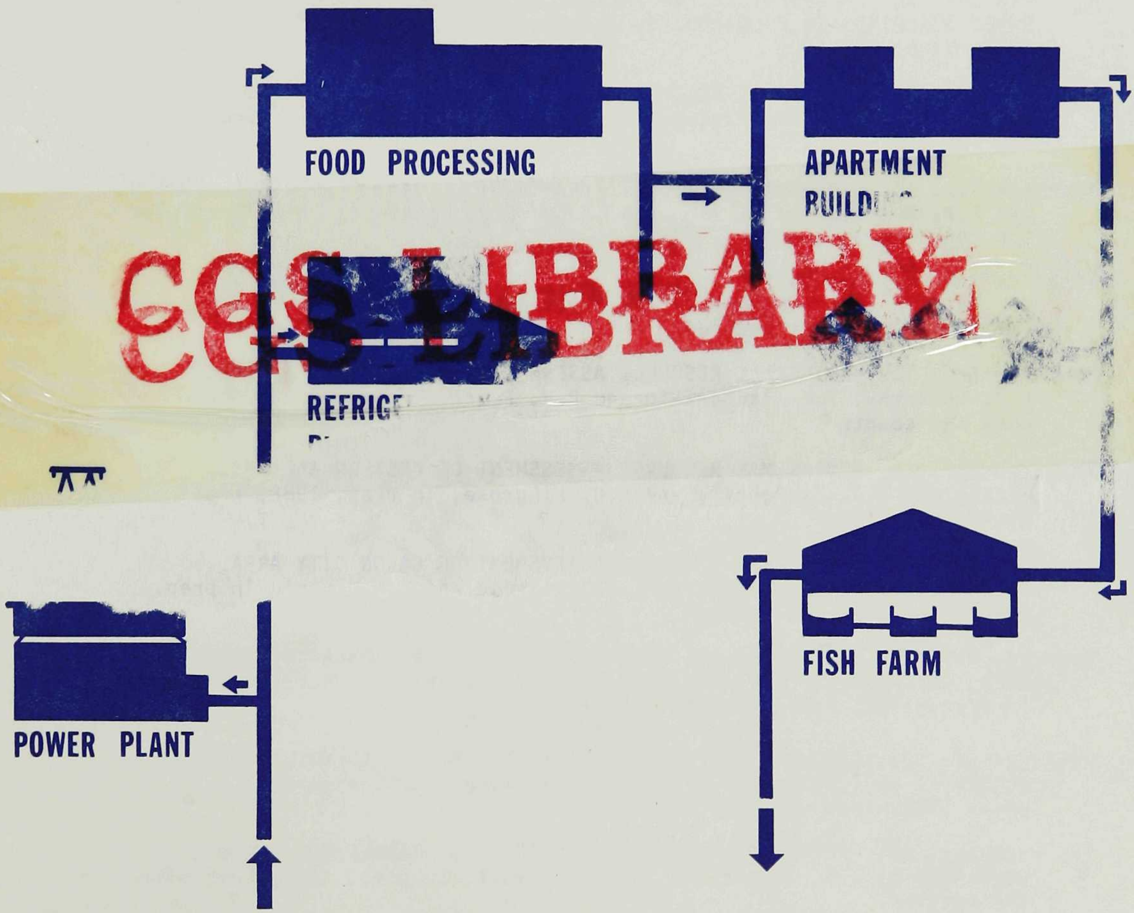
INDUSTRIAL MARKET OPPORTUNITIES FOR GEOTHERMAL ENERGY IN COLORADO

BY BARBARA A. COE



COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO 1982

GEOTHERMAL ENERGY PUBLICATIONS--

Following is a list of publications relating to the geothermal energy resources of Colorado published by the Colorado Geological Survey

Bull. 11, MINERAL WATERS OF COLORADO, by R.D. George and others, 1920, 474 p., out of print.

Bull. 35, SUMMARY OF GEOLOGY OF COLORADO RELATED TO GEOTHERMAL ENERGY POTENTIAL, PROCEEDINGS OF A SYMPOSIUM ON GEOTHERMAL ENERGY AND COLORADO, ed. by R.H. Pearl, 1974, $3.00

Bull. 39, AN APPRAISAL OF COLORADO'S GEOTHERMAL RESOURCES, by J.K. Barrett and R.H. Pearl, 1978, 224 p., $7.00

Bull. 44, BIBLIOGRAPHY OF GEOTHERMAL REPORTS IN COLORADO, by R.H. Pearl, T.G. Zacharakis, F.N. Repplier and K.P. McCarthy, 1981, 24 p., $2.00.

Resource Ser. 6, COLORADO'S HYDROTHERMAL RESOURCE BASE--AN ASSESSMENT, by R.H. Pearl, 1979, 144 p., $2.00.

Resource Ser. 14, AN APPRAISAL FOR THE USE OF GEOTHERMAL ENERGY IN STATE OWNED BUILDINGS IN COLORADO, by R.T. Meyer, B.A. Coe and J.D. Dick, 1981, 63 p., $5.00.

Resource Ser. 15, GEOTHERMAL RESOURCE ASSESSMENT OF OURAY, COLORADO, by T.G. Zacharakis, C.D. Ringrose and R.H. Pearl, 1981, 70 p., Free over the counter.

Resource Ser. 16. GEOTHERMAL RESOURCE ASSESSMENT OF IDAHO SPRINGS, COLORADO, by. F.N. Repplier, T.G. Zacharakis, and C.D. Ringrose, 1982, Free over the counter.

Resource Ser. 17, GEOTHERMAL RESOURCE ASSESSMENT OF THE ANIMAS VALLEY, COLORADO, by. K.P. McCarthy, T.G. Zacharakis, and R.H. Pearl, In prep. 1982, Free over the counter.

Resource Ser. 18, GEOTHERMAL RESOURCE ASSESSMENT OF HARTSEL, COLORADO, by K.P. McCarthy, T.G. Zacharakis and R.H. Pearl, In prep. 1982, Free over the counter.

Resource Ser. 19, GEOTHERMAL RESOURCE ASSESSMENT OF WESTERN SAN LUIS VALLEY, by T.G. Zacharakis and C.D. Ringrose, In prep. 1982, Free over the counter.

Resource Ser. 20, GEOTHERMAL RESOURCE ASSESSMENT OF CANON CITY AREA, COLORADO, BY T.G. Zacharakis, C.D. Ringrose and R.H. Pearl, In prep. 1982, Free over the counter.

Resource Ser. 22, GEOTHERMAL RESOURCE ASSESSMENT OF STEAMBOAT SPRINGS AREA, COLORADO, by K.P. McCarthy, T.G. Zacharakis and R.H. Pearl, In prep. 1982, Free over the counter.

Resource Ser. 23, GEOTHERMAL RESOURCE ASSESSMENT OF HOT SULPHUR SPRING, COLORADO, by T.G. Zacharakis, K.P.McCarthy and C.D. Ringrose, In prep. 1982, Free over the counter.

Resource Ser. 24, GEOTHERMAL RESOURCE ASSESSMENT OF RANGER HOT SPRINGS, COLORADO, by T.G. Zacharakis and R.H. Pearl, In prep. 1982, Free over the counter.

Special Pub. 2, GEOTHERMAL RESOURCES OF COLORADO, by R.H. Pearl, 1972, 54 p. $2.00.

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April 1982

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PREFACE

The need has arisen in Colorado for a comprehensive appraisal of the potential use of geothermal energy by industry. The broad spectrum of expertise required to fully evaluate this potential includes: 1) an understanding of industry processes, 2) marketing and planning skills, and 3) a working knowledge of the many facets of geothermal energy development.

In-house knowledge of some of the topics to be covered was limited at the Colorado Geological Survey. For this reason, Barbara Coe, an independent marketing consultant with a great deal of experience regarding institutional concerns and other aspects of geothermal development, was contracted to produce the following report. This document represents Ms. Coe's work entirely, with only minor geotechnical contributions from the Colorado Geological Survey.

ACKNOWLEDGEMENTS

Data, information and ideas from numerous sources were necessary in order to conduct this analysis. The assistance of all those, many of them Colorado State employees, who provided information is sincerely appreciated. In particular, Jack Olson and Evan Metcalf of the Colorado Division of Commerce and Development, competently and willingly provided information and steered us to additional sources of information. Their help was invaluable. Additionally, the assistance of Richard Pearl, Section Chief, Groundwater Section of the Colorado Geological Survey, and administrator of this Contract, and Kevin McCarthy, Chief of the Geothermal Project, was enormously helpful in providing direction, focus, and information for the study. Much appreciated, too, are the efforts of Donna Velyvis who patiently typed the entire draft report, as well as assisting with the research, of Becky Nelson and Lori Thomas, who typed the final copy, and of Cheryl Brchan, who with her usual expertise, developed the illustrations and prepared the layout for the report.

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SECTION I

INTRODUCTION

Geothermal energy can be used for heat for a wide variety of industrial activities and processes. It is a clean, easy to use, potentially renewable source of energy that can often be provided at a lower total cost than other energy resources. This report describes the results of an investigation of the potential for use of geothermal energy for a variety of industrial uses in Colorado.

A. Intent of Report

This investigation is a part of the effort by the Colorado Geological Survey, under a contract with the U.S. Department of Energy, to provide information to help stimulate private development of geothermal energy. The report is intended to help industrial energy users in Colorado learn more about the desirability of using geothermal energy for specific industrial uses. At the same time, it can help prospective geothermal energy producers, investors, and distributors identify the potential market for the product. Furthermore, it may be useful to local communities with geothermal resources in their efforts to stimulate economic development or retain existing industries.

This investigation focuses on the potential industrial market demand for geothermal energy. Previous studies have focused upon the potential supply of geothermal energy to existing energy markets, usually for residential and commercial consumption. Because the vast majority of the manufacturing in Colorado occurs along the Front Range, whereas the vast majority of the identified geothermal sites are found west of the Front Range, the industrial potential for use of geothermal energy in Colorado has been largely discounted. It is now suspected, however, that the industrial potential for use of geothermal energy might be greater than has been assumed.

Several events occurring in Colorado account for this suspicion: Much of the economic activity in western Colorado, such as mining, agriculture, and tourism, is ideally suited to the use of geothermal energy. Rapid population growth is being stimulated in western Colorado by energy and mineral development and recreation. This population growth, in turn, stimulates additional industrial growth. Furthermore, as energy costs continue to rise, industries are becoming more interested in locating new plants where lower cost energy is available.

Another reason for focusing on the potential industrial demand for geothermal energy of Colorado is the advantage to the producer and distributor of marketing to that sector. Although not the largest fuel consuming sector, industrial facilities tend to consume greater quantities of fuel per facility than do residential or industrial facilities. This means that the heat load per facility will be high relative to the capital, maintenance and administrative costs of energy production and delivery systems. Furthermore, the magnitude of the sales per user and the year-round use will help assure a sufficiently large market to warrant development of a geothermal resource with a less extensive marketing effort than is required to acquire a large number of individual customers.

B. Format of Report

Four major sections make up the report. This first section introduces the topic and describes the format and methodology. Then before any meaningful thought can be given to the potential demand for geothermal energy, some initial facts about the geothermal resources in the state must be understood. The second section, therefore, describes resource characteristics, estimated temperatures, and the difficulty of drilling for each of the areas in which geothermal energy has been identified. A prospective geothermal energy user or producer should bear in mind, however, that only a limited amount of information regarding the total resource is available. Much exploration is needed in order to identify all of the areas with usable geothermal energy and the magnitude of that energy.

The third section of the report first presents an overview of the potential demand for geothermal energy in Colorado among four major industrial sectors: agriculture, manufacturing, mining, and tourism. Following that, a closer look is given to the potential demand in each of those sectors. Section Four is the summary and conclusions section.

C. Methodology of Investigation

This investigation focused upon two major questions: 1. what existing industrial facilities which are co-located with geothermal energy are a potential market for the energy and; 2. what industrial facilities not currently co-located with geothermal energy might reasonably be expected to consider opening new facilities or relocating to areas that have geothermal energy? The latter question is confined to the manufacturing sector, since agriculture, mining and tourism facilities are generally not flexible regarding location. The first two are dependent upon resource availablility; the latter is dependent upon an increasing demand for lodging and food.

To answer these questions, the facilities whose temperature requirements are low enough to use geothermal energy were identified. In order to allow for the full range of possibilities, uses requiring temperatures up to 400°F were included. Resource temperatures are not known for certain in most cases, but are not expected to be over 400°F. Then, to understand which existing co-located facilities could use the energy, those data that were available concerning facilities in the areas now known to have geothermal energy were obtained. These included manufacturers, mines, and tourist facilities, namely, hotels/motels and restaurants. (Because most of the agricultural uses discussed are <u>new</u> uses of heat, rather than existing ones, no data were available concerning them.) Estimates of the energy requirements for the facilities were then obtained or calculated.

To understand the potential demand for geothermal energy among <u>new</u> industrial users is more difficult. Although the variety of possibilities is quite vast, where industries will decide to locate new facilities is impossible to know. No patterns govern their locations, which are selected by a decision process involving a complex search and analysis by individual firms. Various industries have, however, unique location criteria. Some are more centralized than others; some require raw materials, labor or a market near at hand. For others, certain types of transportation facilities or high-level research institutes are critical. Some of these requirements were identified through interviews with staff members of the Colorado Division of Commerce and Development, who work closely with firms making such location decisions. Some industries whose requirements could be met by geothermal sites in western Colorado were pinpointed; others whose requirements were clearly not met at such locations were eliminated from further consideration, based on this information. A second analysis took as its point of departure the assumption that the future would resemble the present. If industries are currently (in 1977, since those were the latest data available) located in a significant number (i.e., 10 counties) of areas other than major metropolitan areas, they were considered to be possible candidates. The total energy consumption and average plant consumption were then reviewed as a basis for selecting those that would be likely to be both most interested in the energy and of greatest interest to a geothermal energy seller. Additionally, studies of the location decision making criteria and processes for four industries that were conducted by the Earl Warren Legal Institute (Bressler and Hanemann, 1979, 1980) were extremely helpful in assessing the potential market demand in Colorado for geothermal energy of the lumber, onion and potato, greenhouse and chemical industries.

The most promising candidates for using the energy, based on the analysis, are identified in each sector. Some examples of existing geothermal users in each are indicated whenever possible, along with a brief description of the design and operation of the systems. Any critical issues about which a prospective producer or user should be aware are discussed as appropriate. The last section summarizes the investigation and findings and provides some suggestions for targeting markets.

SECTION II

GEOTHERMAL SITES IN COLORADO

A. Location of Geothermal Sites

Colorado has sufficient geothermal energy for it to be seriously considered as an energy resource. Fifty-eight geothermal sites have been positively identified and inventoried (Figure 1 and Table 1), and this is probably not the full extent of the energy. Frequently, the prime geothermal prospects are found in areas lacking hot springs or other natural surface expressions. As Tom Schessler of the U.S. Forest Service so aptly put it: "absence of evidence is not evidence of absence," where natural resources are concerned. Diligent exploration is required before the extent of the energy will be known. Little geothermal exploration has been performed in Colorado thus far because there is little evidence of resources that are in the high temperature, high volume and high pressure category required for power generation, the primary focus of geothermal exploration work to date.

Even so, the geothermal energy that is known in Colorado is significant. Furthermore, it is distributed widely throughout the mountains from north to south. Of the 63 counties in Colorado, 23 have some geothermal surface expressions, either hot springs or wells. This means that a large number of communities and facilities could use geothermal energy. Table 2 shows sites matched with communities that are within 5 miles of an incorporated community. As indicated, 17 sites are ideally located relative to population centers.

Of the 24 counties with observed geothermal energy, most are characterized by the Colorado Division of Commerce and Development as either economically distressed or growth-impacted. Where economic distress, or low incomes and/or high unemployment, is found, frequently it stems from too little industrial diversity. If an energy resource can be offered that is clean, abundant, easy to use and less expensive than alternatives, it may help encourage the development of new industry in such areas.

Of those counties in Colorado that are characterized as growth impacted, many are growing because of energy exploration and development; some are growing because new or existing ski areas or other recreation sites are attracting residents; and some are growing because their natural beauty, clean air and small populations attracts people who are seeking an improvement in their quality of life.

In counties where growth is now occurring or in counties which are seeking economic growth, additional energy will be needed. Furthermore, where new facilities are being constructed, no retrofitting will be required, thus minimizing the cost of using geothermal energy.

Geothermal energy is a clean energy source that can easily be used for numerous thermal energy needs including not only space and water heating but also industrial processes. It can be developed by an energy consumer for his own use, thereby obtaining both lower cost energy currently and the security of his own energy source over the long range. The consumer in this case will pay only

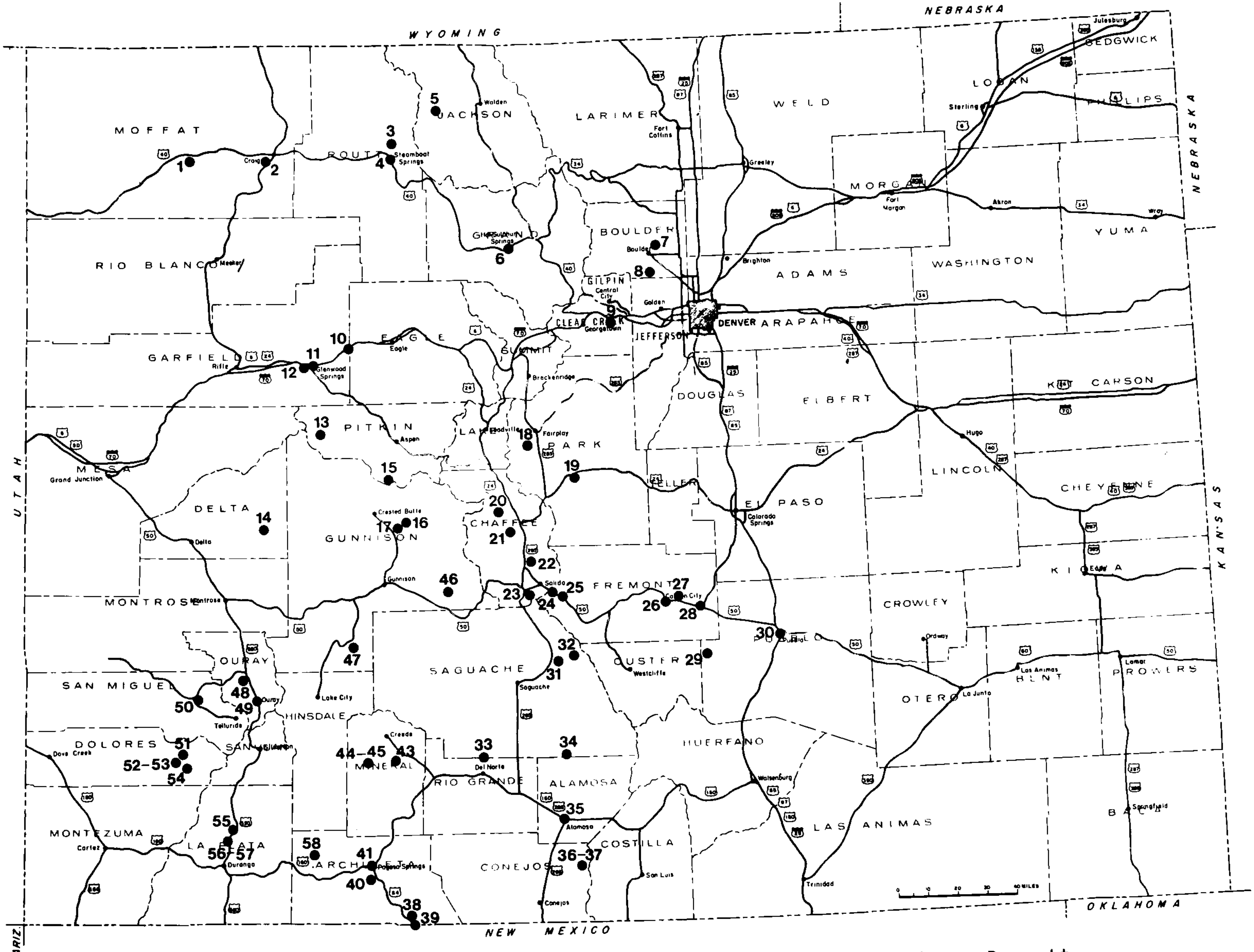


Figure 1. A Map of Thermal Sites in Colorado (see Table 1) (from Barrett and Pearl, 1978).

Table 1. List of Thermal Sites in Colorado

	Site Number	County
Antelope Hot Spring	44	Mineral
Birdsie Warm Spring	45	Mineral
Brands Ranch Artesian Well	5	Jackson
Brown's Canyon Warm Spring	22	Chaffee
Canon City Warm Spring	26	Fremont
Cebolla Hot Springs	47	Gunnison
Cement Creek Warm Spring	16	Gunnison
Clark Artesian Well	30	Pueblo
Colonel Chinn Hot Water Well	14	Delta
Conundrum Hot Springs	15	Pitkin
Cottonwood Hot Springs	20	Chaffee
Craig Warm Water Well	2	Moffat
Dexter Warm Spring	36	Conejos
Don K Ranch Artesian Well	29	Pueblo
Dotsero Warm Spring	10	Eagle
Dunton Hot Spring	51	Dolores
Dutch Crowley Artesian Well	39	Archuleta
Eldorado Springs	8	Boulder
Eoff Artesian Well	40	Archuleta
Florence Artesian Well	28	Fremont
Fremont Natatorium Hot Spring	27	Fremont
Geyser Warm Spring	52	Dolores
Glenwood Springs	11	Garfield
Hartsel Hot Springs	19	Park
Haystack Butte Warm Water Well	7	Boulder
Hot Sulphur Springs	6	Grand
Idaho Hot Springs	9	Clear Creek
Juniper Hot Springs	1	Moffat
Lemon Hot Spring	50	San Miguel
McIntyre	37	Conejos
Mineral Hot Spring	31	Saguache
Mt. Princeton Hot Springs	21	Chaffee
Orvis Hot Spring	48	Ouray
Ouray Hot Spring	49	Ouray
Pagosa Springs	41	Archuleta
Paradise Hot Spring	53	Dolores
Penny Hot Springs	13	Pitkin
Pinkerton Hot Springs	55	La Plata
Poncha Hot Springs	23	Chaffee
Rainbow Hot Spring	42	Mineral
Ranger Warm Spring	17	Gunnison
Rhodes Warm Spring	18	Park
Rico	54	Dolores
Routt Hot Springs	3	Routt
Sand Dunes Swimming Pool, Hot Water Well	34	Saguache
Shaws Warm Spring	33	Saguache
South Canyon Hot Spring	12	Garfield
Splashland Hot Water Well	35	Alamosa
Steamboat Springs	4	Routt
Stinking Springs	38	Archuleta
Swissvale Warm Spring	25	Fremont
Trimble Hot Spring	56	La Plata
Tripp Hot Spring	56	La Plata
Valley View Hot Springs	32	Saguache
Wagon Wheel Gap Hot Springs	43	Mineral
Waunita Hot Springs, Upper and Lower	46	Gunnison
Wellsville Warm Spring	24	Fremont

from Barrett and Pearl, 1978

Table 2. Geothermal Sites Within Five Miles of a Community

Geothermal Areas	Community
Glenwood Springs	Glenwood Springs
Splashland	Alamosa
Pagosa Hot Springs	Pagosa Springs
Steamboat Hot Springs	Steamboat Springs
Hot Sulphur Springs	Hot Sulphur Springs
Eldorado Springs	Eldorado Springs
Idaho Springs	Idaho Springs
Ouray	Ouray
Dunton	Dunton
Col. Chinn	Paonia
Wellsville/Swissvale	Salida
Canon City/Fremont	Canon City
Clark	Pueblo
Orvis	Ridgway
Rico	Rico
Poncha Springs	Poncha Springs, Salida
Craig	Craig

the maintenance and operating costs following payback of the initial capital investment. Or, it can be developed by an energy producer and sold to consumers or to a distributor for sale to consumers. Studies show that in both situations, geothermal energy is often a very cost-effective energy source. From the point of view of the consumer, it can save dollars. From the point of view of an investor in geothermal exploration and production, the rate of return on investment can also be quite attractive, as much as 30 percent according to one Colorado site evaluation (Coe, et al, in progress).

B. Characteristics of Geothermal Sites

The usefulness of a geothermal resource is primarily dependent upon several characteristics: temperature, water quality, discharge rate, pressure, drilling cost, and site location. Temperature, discharge rate, and pressure refer to the resource obtained from a well, not from springs--the two can be quite different. Drilling cost is largely a function of the drilling depth required and the difficulty of drilling in the particular formation.

Some research has been completed for all of the inventoried geothermal sites in Colorado. This includes geochemical techniques to estimate subsurface water temperatures. Because geochemical models frequently are not able to accurately predict temperatures, the temperature estimates should be used only as a guide, in conjunction with other data, not treated as known fact. Table 3 shows the measured surface and estimated subsurface temperatures, current discharge rate, and total dissolved solids (TDS) in the fluid at each site. In general, Colorado's resources are low to moderate temperature, with good water quality.

Table 3. Colorado Geothermal Site Characteristics Parameters

Site	Subsurface Temperature Estimate °C	Surface Temperature	Discharge (Gallons per minute)	Water Quality (Total Dissolved Solids)
Antelope	35	32	3	151
Birdsie	35	30	15	168
Brand's Ranch	42	42	80	262
Brown's Canyon	50	25	3	494
Canon City	42	40	200	1230
Cebolla	65	41	20	1460
Cement Creek	30	25	60	401
Clark	25	25	12	1210
Colonel Chinn	42	42	1	2130
Conundrum	40	38	50	1910
Cottonwood	105	58	60	370
Craig	40	39	24	896
Dexter	20	20	50	195
Don K. Ranch	28	28	25	1700
Dotsero	32	32	1500	10,400
Dunton	50	42	25	1340
Dutch Crowley	70	70	75	575
Eldorado Springs	26	26	200	101
Eoff Well	40	39	50	1500
Florence Well	34	34	130	1480
Fremont	35	36	18	1370
Geyser	60	28	100	1620
Glenwood	100	51	2678	21,500
Hartsel	55	52	50	2330
Haystack Buttes	50	28	4	1200
Hot Sulphur Springs	75	44	55	1220
Idaho Hot Springs	60	46	52	2110
Juniper Hot Springs	50	38	18	1150
Lemon W.S.	33	33	10	2810
McIntyre	20	14	5	165
Mineral Hot Springs	70	60	100	690
Mt. Princeton	150	83	60	351
Orvis	70	52	20	2490
Ouray	70	69	200	1660
Pagosa	80	58	300	3320
Paradise	46	46	30	6180
Penny	60	56	22	2960
Pinkerton	75	32	80	3990
Poncha	115	71	235	697
Rainbow	40	40	45	161
Ranger	30	27	150	474
Rhodes	25	24	200	194
Rico	44	44	60	2790
Routt	125	64	65	539

from Coe, 1978

TABLE 3 (CONT.)

Site	Subsurface Temperature Estimate °C	Surface Temperature	Discharge (Gallons per minute)	Water Quality (Total Dissolved Solids)
Sand Dunes	44	44	50	334
Shaws	30	30	40	424
Splashland	40	40	50	311
S. Canyon	100	48	18	800
Steamboat	125	39	200	6170
Stinking	40	27	24	899
Swissvale	35	28	145	500
Tripp/Trimble	45	44	1	3340
Valley View	40	37	135	252
Wagon Wheel Gap	100	57	60	1620
Waunita	175	80	50	613
Lower Waunita	110	75	40	549
Wellsville	35	33	200	484

To know with certainty what the resource characteristics are requires drilling and testing a well, usually following several preliminary exploration tasks such as geophysical surveys and gradient hole drilling.

At several locations in Colorado, wells have been drilled and tested and at several additional locations in Colorado, preliminary exploration has been done. For these sites, which are listed in Table 4, more information is available than for the others. Based upon both known and hypothesized data, various characteristics of the sites can be rated. Table 5 rates each site in the state based upon known or estimated temperature, discharge, water quality, and drilling difficulty. The reliability of the data is also indicated, depending upon the magnitude and quality of the data available.

Table 4. Sites Where Drilling and/or Preliminary Exploration Work Has Been Completed.

3	Routt Hot Springs	26	Canon City
4	Steamboat Springs	35	Alamosa
6	Hot Sulphur Springs	41	Pagosa Springs
9	Idaho Springs	46	Waunita Hot Springs
11	Glenwood Springs	49	Ouray
17	Ranger Warm Springs	55	Pinkerton
19	Hartsel	56	Tripp/Trimble
21	Mt. Princeton		

Table 5. Rating of Colorado Geothermal Site Characteristics. Lower numbers generally indicate more favorable characteristics for most applications.

Site	Subsurface Temperature Estimate	Surface Temperature	Surface Discharge	Water Quality	Drilling Difficulty	Data Reliability
Antelope	3	3	3	1	2	3
Birdsie	3	3	3	1	2	3
Brand's Ranch	3	2	2	1	2	2
Brown's Canyon	2	3	3	1	3	3
Canon City	2	2	3	1	3	3
Cebolla	2	2	3	1	3	2
Cement Creek	3	3	2	1	2	2
Clark	3	3	3	1	3	3
Colonel Chinn	3	2	3	2	3	3
Conundrum	3	2	2	2	3	2
Cottonwood	1	1	2	1	3	2
Craig	3	2	3	1	2	2
Dexter	3	3	2	1	3	3
Don K. Ranch	3	3	3	2	2	3
Dotsero	3	3	1	3	1	2
Dunton	2	2	3	1	2	3
Dutch Crowley	2	1	2	1	2	2
Eldorado	3	3	1	1	2	1
Eoff Well	3	2	2	2	3	2
Florence Well	3	3	2	1	3	2
Fremont	3	2	3	1	3	2
Geyser	2	3	2	2	2	3
Glenwood	1	2	1	3	1	2
Hartsel	2	2	2	2	1	1
Haystack Butte	2	3	3	1	3	3
Hot Sulphur Springs	2	2	2	1	2	2
Idaho Hot Springs	2	2	2	2	2	2
Juniper Hot Springs	2	2	3	1	1	2
Lemon Hot Springs	3	3	3	2	2	2
McIntyre	3	3	3	1	3	3
Mineral	2	1	2	1	2	2
Mount Princeton	1	1	2	1	2	1
Orvis	2	2	3	2	2	2
Ouray	2	1	1	2	1	2
Pagosa	2	1	1	3	1	1
Paradise	3	2	3	3	2	3
Penny	2	1	3	2	2	2
Pinkerton	2	3	2	3	1	1
Poncha	1	1	1	1	3	1
Rainbow	3	2	3	1	3	3
Ranger	3	3	2	1	2	2
Rhodes	3	3	2	1	2	2
Rico	3	2	2	2	1	2
Routt	1	1	2	1	3	1
Sand Dunes	3	2	2	1	3	3
Shaws	3	3	3	1	3	2
Splashland	3	2	2	1	3	3
S. Canyon	1	2	3	1	1	3
Steamboat	1	2	2	3	2	2
Stinking	3	3	3	1	2	3
Swissvale	3	3	2	1	2	2
Tripp/Trimble	3	2	3	3	1	1
Valley View	3	2	2	1	2	2
Wagon Wheel Gap	1	1	2	2	3	3
Waunita	1	1	2	1	2	1
Lower Waunita	1	1	3	1	2	1
Wellsville	3	3	1	1	2	2

from Kevin McCarthy, unpublished

TABLE 5 (CONT.)

EXPLANATION FOR TABLE 5

Subsurface temperature estimate from Pearl (1979).

>90°C	1
50-89°C	2
0-49°C	3

Surface temperature from Pearl (1979).

>55°C	1
35-54°C	2
0-34°C	3

Surface discharge from Pearl (1979) and CGS estimates

>200 gpm	1
50-199 gpm	2
0-49 gpm	3

Water Quality - Total Dissolved Solids from Pearl (1979)

0-1499 Mg/l	1
1500-2999 Mg/l	2
>3000 Mg/l	3

Drilling difficulty - a subjective estimate based on rock type, approximate depth to sufficient resource, and previous drilling experience at each site.

relatively easy	1
moderate	2
difficult	3

Reliability of data used in rating.

1 - High 2 - Medium 3 - Low

SECTION III

INDUSTRIAL MARKET FOR GEOTHERMAL ENERGY IN COLORADO

A wide variety of existing and possible uses for geothermal energy has been identified in previous studies. In addition to space heating, applications in agriculture, manufacturing and even in mining are quite feasible. Some specific examples, along with the temperatures normally required are shown on Figure 2.

Geothermal energy is sometimes thought to be exotic because in the United States its use has not been common. Actually, the use of geothermal energy is a simpler process than that of many other energy forms because it is already in usable form, (hot water or steam) requiring no combustion process.

Early historical records indicate the Romans, Chinese, Japanese, Turks, Icelanders, Central Europeans and Maori of New Zealand used geothermal energy for bathing, cooking and space heating. (Lienau, et al, 1979). These and other uses are common today in many areas. For example, the Soviet Union uses the energy form in their agricultural industry. New Zealand uses it for cooling, for earth drying and for paper and wood processing. Other current uses are drying of wool, fish, onions, and lumber and extraction of chemicals (Lienau, et al, 1979).

To use geothermal energy, hot water, or steam (or heat using a downhole heat exchange unit) is simply removed from a well and transmitted to a facility. There the heat will be used directly as hot water or steam or transferred to another medium - air, water or some other fluid. The heat is then transmitted through a system to perform such processing as space warming, preheating, washing, cooking, evaporating, sterilizing, distilling, drying and even refrigeration. System designs take into account the chemistry of the fluid which sometimes affects the hardware.

Analyses have shown numerous industrial uses for geothermal energy to be economically feasible or profitable. Evaluations are, however, site-specific because costs depend upon the characteristics of the resource resource and its location and upon the requirements of the proposed application. A fairly simple evaluation can be conducted based on existing information about resource sites and facility characteristics. Chapter 5 of the Direct Utilization of Geothermal Energy; A Technical Handbook (GRC S.P.7), provides a clear, detailed step-by-step method for performing such an analysis (Anderson and Lund, 1979).

In Colorado, the significant major industrial sectors that require thermal energy in the range that could be supplied directly by geothermal energy (that is, not converted to electricity) include agriculture, manufacturing, mining and tourism. As Figure 3 shows, the first three sectors in 1979 were responsible for $586,055,000, $3,341,825,000 and $832,404,000, or 2, 13, and 3 percent respectively of the total personal income derived in the state. Tourism is estimated to have brought in $890,000,000 in 1979 (Colorado Department of Labor and Employment, June, 1980).

The other major industrial sectors: construction; transportation, communication and public utilities, finance, insurance and real estate, retail

°F	°C		
392	200		
374	190		
356	180	Evaporation of highly conc. solutions Refrigeration by ammonia absorption digestion in paper pulp, Kraft	
338	170	Heavy water via hydrog. sulphide proc. Drying of diatomaceous earth	Temp. range of conventional power production
320	160	Drying of fish meal Drying of timber	
302	150	Alumina via Bayers proc.	
284	140	Drying farm products at high rates Canning of food	
266	130	Evaporation in sugar refining Extraction of salts by evaporation and crystalization	
248	120	Fresh water by distillation Most multiple effect evaporations, concentr. of saline sol. Refrigeration by medium temperatues	
230	110	Drying and curing of light aggreg. cement slabs	
212	100	Drying of organic materials, seaweeds, grass, vegetables, etc. Washing and drying of wool	
194	90	Drying of stock fish Intense de-icing operations	
176	80	Space heating Greenhouses by space heating	
158	70	Refrigeration by low temperature	
140	60	Animal husbandry Greenhouses by combined space and hotbed heating	
122	50	Mushroom growing	
		Balneological baths	
104	40	Soil warming	
85	30	Swimming pools, biodegradation, fermentations Warm water for year-around mining in cold climates De-icing	
70	20	Hatching of fish; fish farming	

Figure 2. Approximate Temperatures Required for Various Geothermal Uses (from Lienau, 1979).

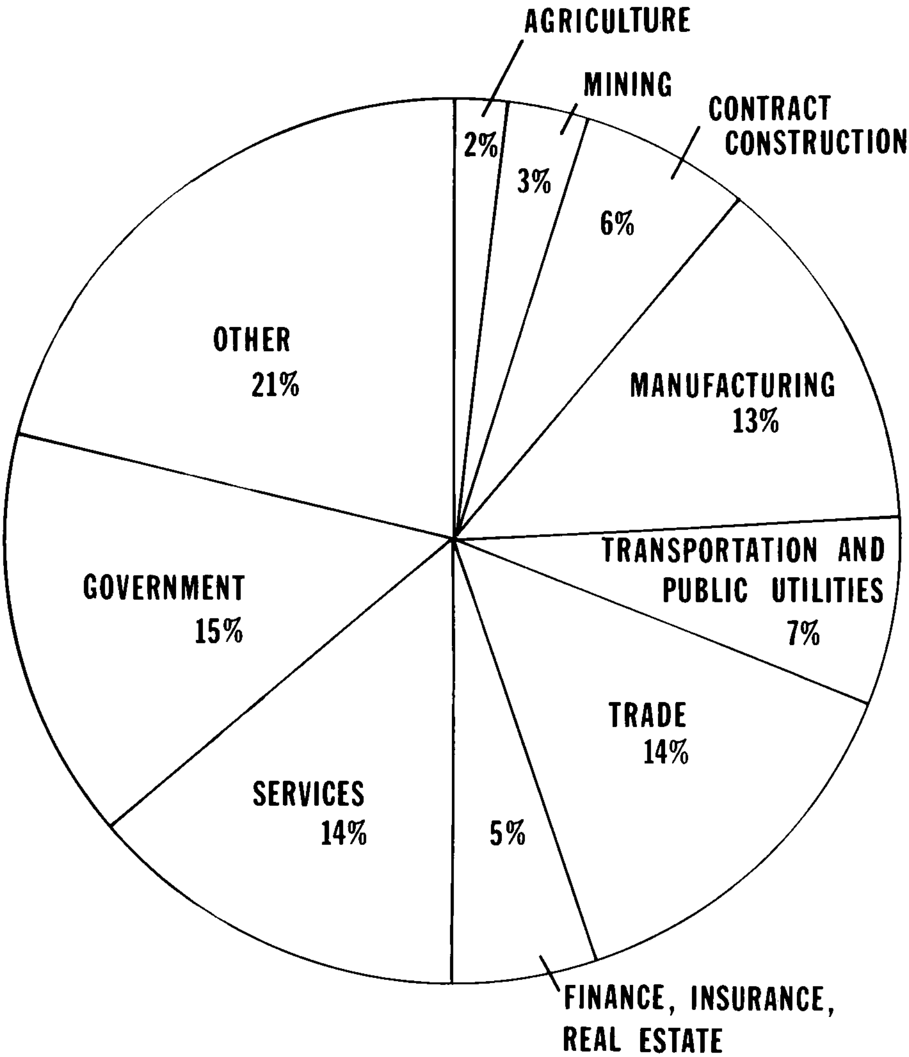


Figure 3. Percent of Personal Income Derived From Each Industrial Sector in Colorado (from Colorado Dept. of Labor and Employment, June 1980).

and wholesale trade, services and government, use thermal energy primarily only for space heat, so they are not addressed in this study. The one exception is public utilities, a sector which uses energy for conversion to electricity, another topic not addressed in this report. The potential market demand for geothermal energy within each of these sectors is discussed in the following sections.

A. The Potential in the Agricultural Industry

Within the agricultural sector, potential geothermal market demand is in production of crops, especially for heating and cooling greenhouses, and also in soil warming to extend growing seasons. Agricultural production of livestock is another potential use, for warming feedlots and livestock water and feed, for warming barns, lambing and calving pens and pig farrowing pens, for nurseries and for poultry houses. Geothermal fluid is also ideally suited to clean-up of dairy barns and equipment and animal shelters. Aquaculture is another possible agricultural use of geothermal energy, including warming water for fish hatcheries and raceways. Production of alcohol from farm produce is another possible use for geothermal heat, one that has gained considerable attention over the past several years. (Processing of many agricultural products is a prime potential use of geothermal energy, too, but to conform to the Standard Industrial Classification System, all processing will be discussed in the section entitled "Manufacturing.")

No estimates of the energy requirements for agricultural uses will be attempted. Because these uses would nearly all be new activities, any estimate of aggregate energy requirements could be only conjectural. Examples of agricultural uses of geothermal energy are given in the following section. Where information regarding energy requirements is available for those examples, it is presented along with the other details.

Crop Production. Crops can be grown using geothermal energy in a variety of ways. Greenhouses can be easily heated with geothermal energy. Geothermal heating systems are not unlike conventional types of space heating systems, using either water or air as a heating medium. Figure 4 illustrates some types of heating systems suitable for these and other space heating applications.

Geothermal greenhouse heating is not uncommon, even in the United States. For example, Honeylake Hydroponic Farms near Susanville, California, produces cucumbers and tomatoes using geothermal heat (Figures 5 and 6). At Klamath Falls, Oregon, two million tree seedlings are grown in 30,000 square feet of greenhouse area for the U.S. Forest Service and Bureau of Land Management. A combination of geothermal and solar heat keeps the temperature at 68° to 85°F. The operation is expected to produce 50,000 to 80,000 evergreen seedlings per day, for reforestation projects, using a crew of 4 or 5 people. (Lienau, 1979).

The facility used fluid from a 12" diameter geothermal well that can supply 1,100 gpm of 189°F water to a storage tank. The water is fed to the greenhouses by gravity flow and is controlled by manually operated valves. Finned pipe heaters under the plant benches heat the building. The temperature drop of the fluid is 26°F (Lienau, 1979).

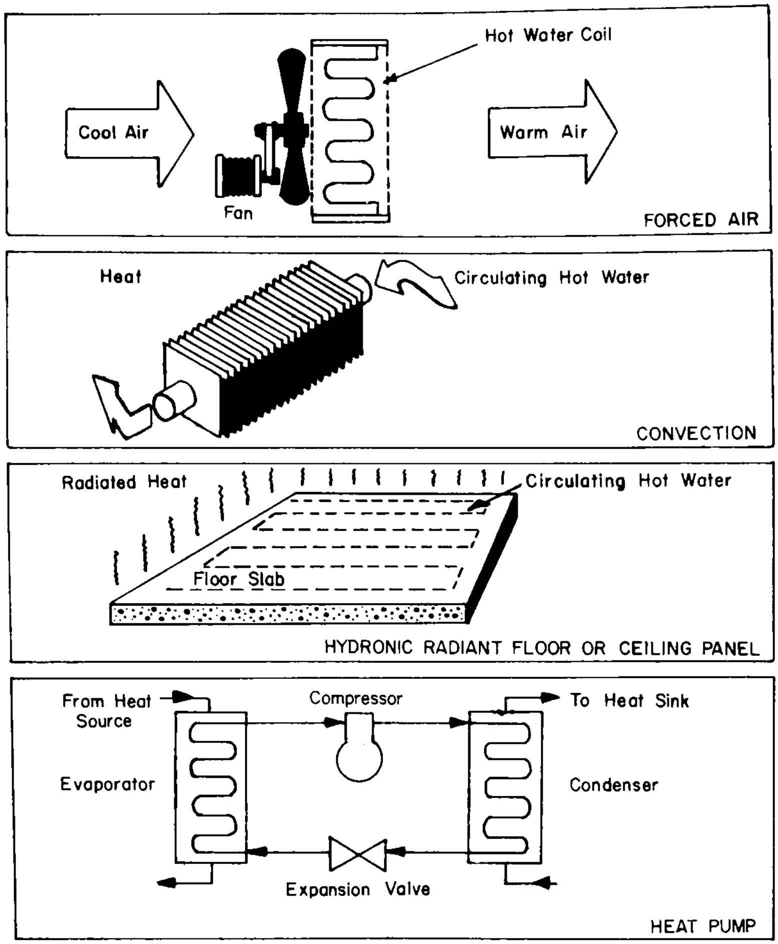


Figure 4. Types of Heating Systems Suitable for Geothermal Applications (from Lienau, 1979).

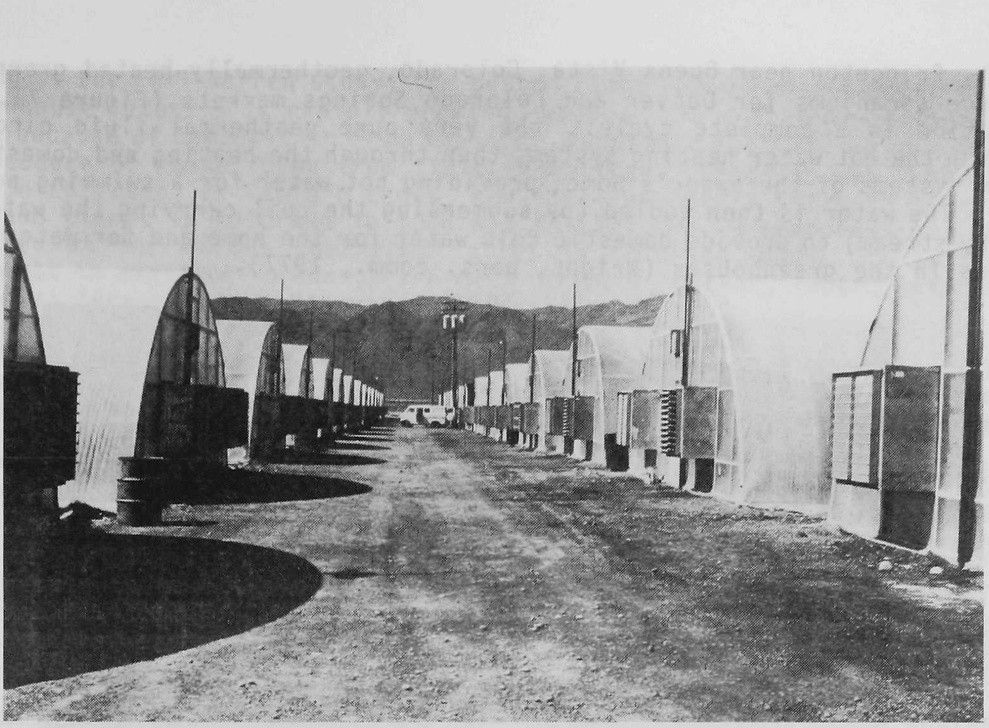


Figure 5. Greenhouses at Honeylake Hydroponic Farms, California.

Figure 6. Interior of Honeylake Hydroponic Greenhouse.

At Mt. Princeton near Buena Vista, Colorado, geothermally-heated greenhouses produce geraniums for Denver and Colorado Springs markets (Figure 7). This operation is a complete cycle: the very pure geothermal fluid circulates through the hot water heating system, then through the heating and domestic hot water systems of the owner's home, providing hot water for a swimming pool, as well. The water is then cooled (by submersing the coil carrying the water in a nearby stream) to provide domestic cold water for the home and for watering the plants in the greenhouses (Wright, pers. comm., 1977).

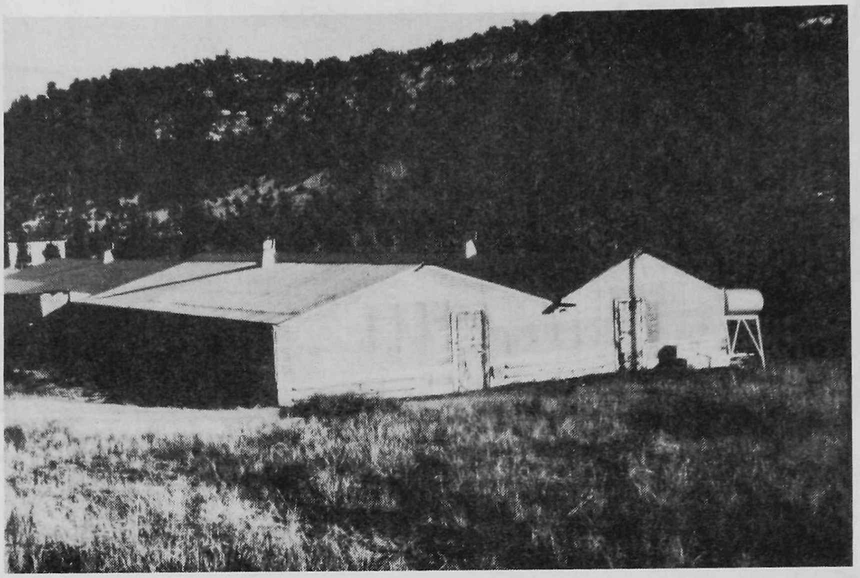


Figure 7. Wright Greenhouse at Mt. Princeton.

In the San Luis Valley, a geothermal well was planned for use in mushroom growing. The heat would be used for compost preparation, spawning and production. Figure 8 shows a schematic of a geothermally-heated mushroom growing facility. As noted by Coury and Associates, although the mushroom industry has experienced rapid growth, currently most of the mushrooms consumed in the Denver region of Colorado are imported from Utah or California (1980).

Greenhouse owners see geothermal energy as an attractive energy source, according to a survey by the Earl Warren Legal Institute. Since energy costs and availability are of concern in this high energy-consuming industry, they would welcome the opportunity to purchase geothermal energy from a distributor if they can obtain it at a lower cost than that of their current fuel. Although most greenhouse owners are not willing or able to relocate simply to obtain the energy, those that are currently near a geothermal resource or are expanding and could consider a new location for the expansion could find the use of geothermal energy very appealing. Numerous greenhouse operators in Colorado have already expressed interest.

According to the Earl Warren study, the potted plant and green plant sector of the greenhouse industry is rapidly growing, whereas the cut flower sector has declined because of competition from imports. Vegetable cultivation is a small sector because of competition from field-grown crops (Bressler and Hanemann, 1980). In Colorado, as Table 6 shows, the total wholesale value of sales of flowers and plants in Colorado in 1980 was $31,827,000. Greenhouses could be constructed at any of the geothermal sites in Colorado where the location requirements in addition to energy are met: climate, market, labor, water and raw material (Bressler and Hanemann, 1979).

Soil warming experiments have been conducted at Raft River, Idaho, to learn how to increase crop growth with geothermal energy. At Pagosa Springs, Colorado, which has a very short growing season, it was reported that tomatoes once were grown by using geothermal fluid to raise the soil temperature. Although not as well-developed as greenhouse use, this application may be a significant one in the future.

Table 6. Sales and Value of Flowers in Colorado, 1980

Kind	Number of Producers	Unit	Sales: Number Sold	Sales: % of sales at whls	Sales: whls. price	Value: Value of sales at wholesl.
	number	unit	thous.	%	$'s	thous. $
Carnations:						
Standard	79	Blooms	79,850	99	.146	11,658
Miniature	35	Bunches	1,107	100	2.01	2,225
Roses:						
Hybrid Tea	14	Blooms	22,598	100	.234	5,288
Sweetheart	15	Blooms	8,566	100	.212	1,816
Snapdragons	9	Stems	107	51	.319	34
Potted Plants:						
Chrysanthemums	13	Pots	287	95	3.16	907
Poinsettieas	30	Pots	418	81	3.22	1,346
Geraniums	53	Pots	865	80	.990	856
Lilies	17	Pots	139	96	2.67	371
Hydrangeas	11	Pots	29	96	3.47	108
Bedding Plants:						
Flowering	68	Flats	575	83	4.81	2,766
Vegetable	62	Flats	125	71	4.04	505
Foliage Plants	29	-----	---	85	-----	3,947
						$31,827

from 1981 Colorado Agriculture Statistics, Colorado Department of Agriculture

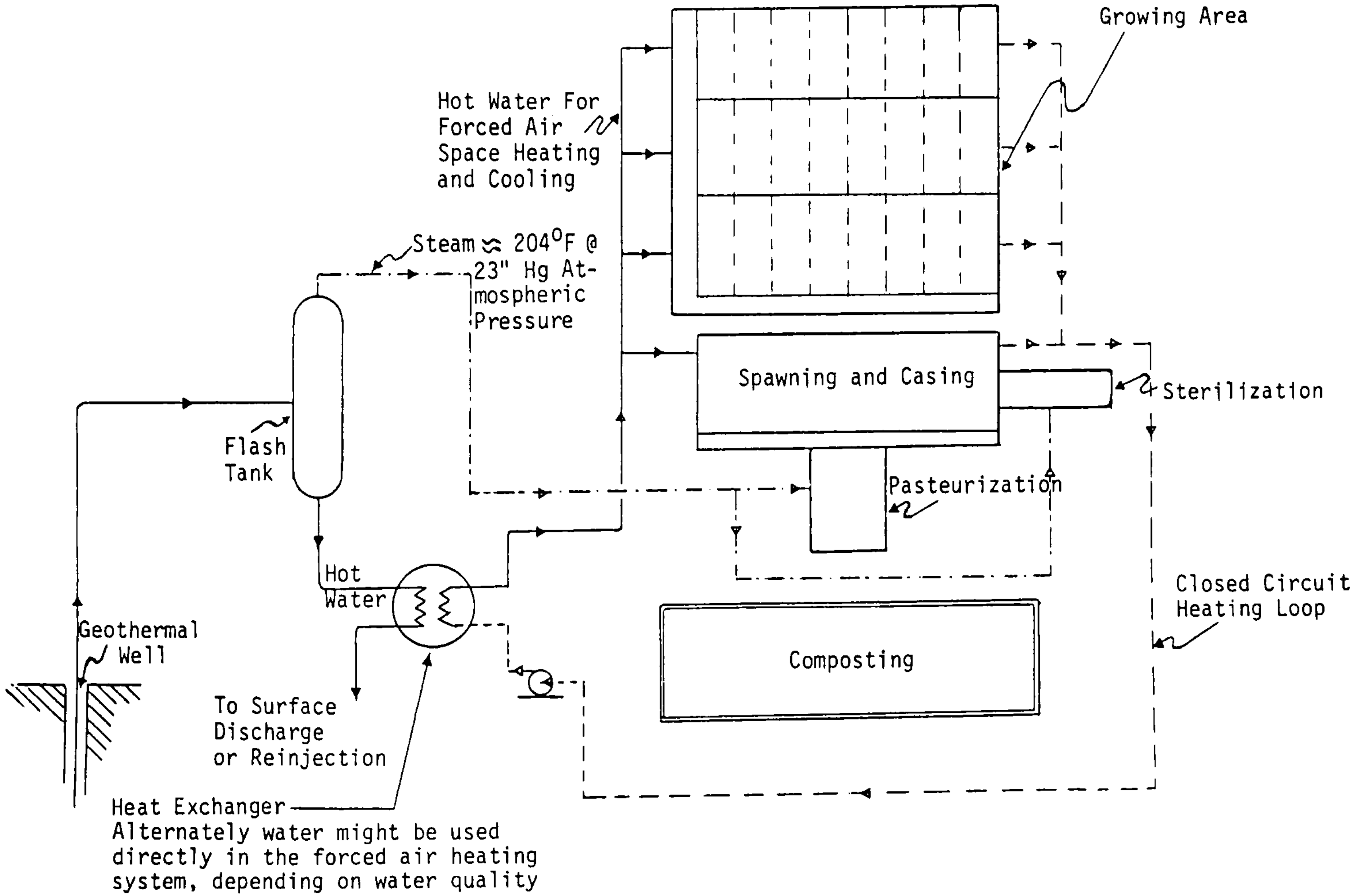


Figure 8. Schematic of Geothermally-Heated Mushroom Growing Facility (from Coury and Associates, Inc.).

Livestock Production. Livestock production can be assisted by geothermal energy. As noted in the Geothermal Resources Council's Special Report No. 7, advantages of raising livestock in controlled environments include: lower mortality (especially during the first few weeks of life) more weight gain per unit of feed, faster growth, lower fat levels in meat, better quality by-products such as hides, larger litters, and easier waste management (Anderson and Lund, 1979). Coils in floor slabs can heat open cattle feed lots. A variety of types of space heating systems can heat calving and lambing pens and pig farrowing houses, nurseries and poultry hatcheries and brooders. The space heating system schematics shown previously are applicable to these situations.

Some livestock producers are new using geothermal energy to improve production. In the San Luis Valley, for example, Weisbart's livestock operation has pig farrowing pens and nurseries heated with geothermal energy cascaded from one pen to another to provide progressively lower temperatures as required by animal size. The operation is an integrated one, with geothermal heat used to produce methane for electricity generation from animal waste and waste water used for watering the animals and slushing the pens (Coe, 1980).

Livestock producers now located in counties known to have geothermal energy are the most obvious potential markets for this application of geothermal energy. These are shown on Table 7.

New operations could be established also. Studies have investigated the economic feasibility of geothermal energy use in the livestock industry. One such study, for Mountain Home, Idaho, is the Mountain Home Geothermal Project, an investigation of geothermal energy applications in a integrated livestock meat and feed production facility. The operation would include:

a. A sprouted grain grower for production of enzymes an vitamins as a constitutent of animal feed;
b. Multi-animal livestock feed mill facililty;
c. Modular, totally confined swine raising facility;
d. Hog slaughter and marketing facility;
e. Animal by-product processing facility;
f. Potato dehydration and processing plant;
g. Total waste management facility including methane generation (Energetics Marketing and Management Assoc., Ltd., 1979).

Figure 9 is a schematic diagram of the hot water mains for such an integrated system.

Table 7. Livestock Production in Counties with Geothermal Energy, 1980, 1981.

County	Head of Cattle 1981	Head of Sheep 1981	Head of Hogs and Pigs 1980
Alamosa	13,500	12,000	800
Archuleta	14,000	1,100	100
Boulder	32,000	3,200	3,600
Chaffee	9,000	500	100
Clear Creek	100	600	---
Conejos	38,000	30,000	9,000
Delta	44,000	26,000	5,700
Dolores	5,900	------	---
Eagle	19,000	5,500	100
Fremont	16,000	400	2,500
Garfield	35,000	21,000	400
Grand	22,500	2,000	---
Gunnison	39,500	100	---
Jackson	38,000	200	---
La Plata	32,500	10,000	1,500
Moffat	34,000	121,000	200
Ouray	15,000	900	---
Park	11,000	1,500	---
Pitkin	5,000	100	---
Pueblo	52,000	3,500	3,400
Routt	30,000	23,000	100
Saguache	34,000	11,000	3,000
San Miguel	7,500	15,000	---
	547,500	288,300	30,600
	17 percent of Statewide production	56 percent of Statewide production	10 percent of Statewide production

from Colorado Department of Agriculture, 1981

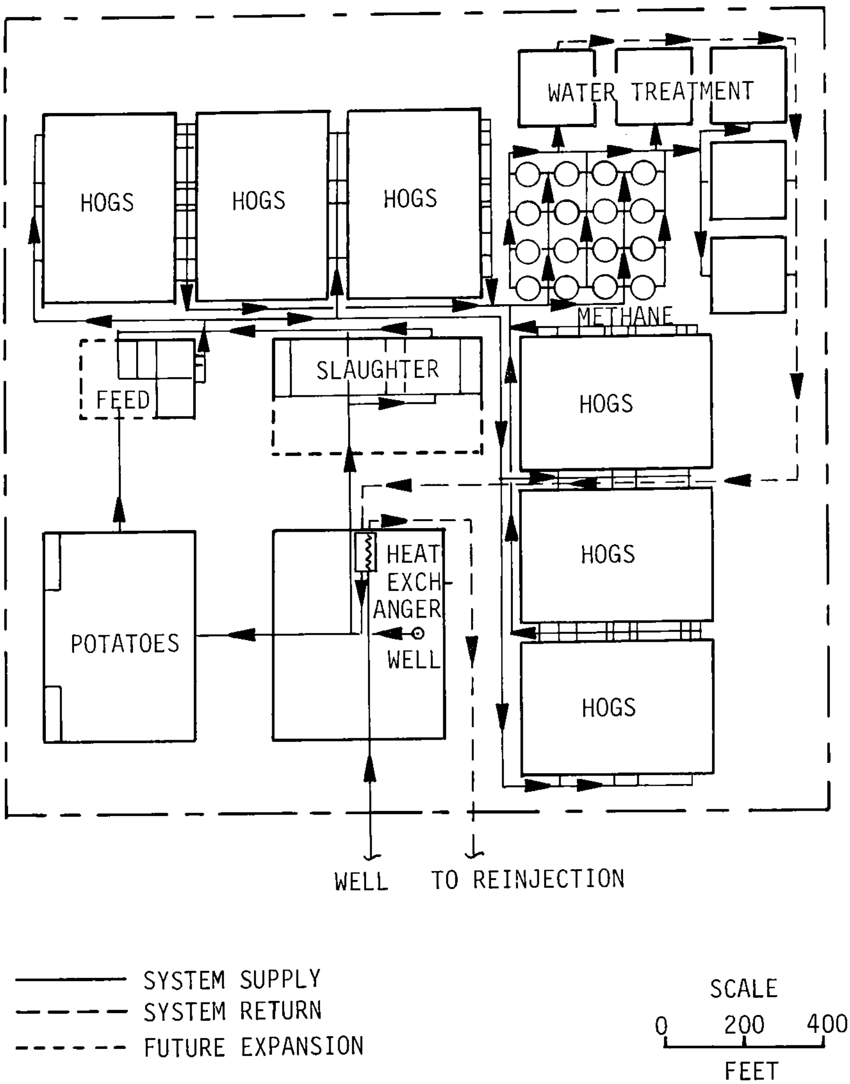


Figure 9. Schematic Diagram of Hot Water Mains for Integrated Livestock and Feed Production Facility (from Energetics and Marketing and Management Association, Ltd., 1979).

According to the report, because swine are greatly influenced by climatic conditions, swine raising is becoming highly technical. The facility would control temperatures by both heating and cooling, to improve swine conception rate, size of pigs, survival rate, health and growth (Energetics Marketing and Management Assoc., Ltd, 1979).

Producing animal feed at the same location precludes tranportation costs and uncertainty over availability and price of feed. Swine slaughter facilities at the site can assure that hogs are slaughtered at the most advantageous time. By consolidating the entire cycle and conducting more of the production steps himself, the producer can add to his profit.

Aquaculture. Aquaculture is another potential use for geothermal energy that has been widely discussed and explored. Species that can be cultivated using geothermal fluid or heat include carp, buffalo fish, paddle fish, catfish, pike, perch, bass, tilapia, frogs, mullet, milkfish, eels, salmon, smelt, sturgeon, shad, shrimp, crayfish, crabs, oysters, clams, scallops, mussels, and abalone (Anderson and Lund, 1979).

The results of an informal survey of fish markets in the Denver area indicated that a freshwater shellfish, "Malaysian prawns," is much in demand but difficult to obtain, since it is generally shipped from Southeast Asia. This species is one that is raised commercially in Israel and experimentally at Klamath Falls, Oregon, using geothermal fluid (Michael Anison, pers. comm., and Lund, 1979). For that matter, even the growth of Colorado stream trout can be enhanced by raising water temperatures somewhat. The Rainbow Springs Trout Ranch, near Durango, Colorado, uses spring water that is slightly warmer than normal in their feeding ponds. Owners report enhanced growth from the slightly elevated temperatures (Putnam, pers. comm.). The operators of the Colorado Fish Hatchery near Salida, Colorado, indicated interest in using the heat to enhance trout growth (Coe, et al, 1982). As the demand for fish as a source of protein continues to grow, the opportunities for using geothermal fluid to enhance growth will expand as well.

At Klamath Falls, at the Oregon Institute of Technology, a pond 30' by 8' by 4' deep contains giant freshwater prawns and mosquito fish. (Figure 10). The prawns are hatched in salt water, transferred to a small holding pond then tranferred to the larger pond. Water temperature is 80°F for optimum growth rates which range from 6" to 8" and about 5 to 6 prawns per pound in about six months (Figure 11). Commercial fish food and zooplankton are used for food for the prawns (Lund, 1979).

Several other uses of geothermal energy for agriculture are found in the San Luis Valley in Colorado. Burley Jenkins raises catfish for Oklahoma and New Mexico markets in geothermal fluid at Sand Dunes Hot Water Well, and Gary Weisbart raises tilapia and eels south of Alamosa (Coe, 1980).

B. The Potential in the Manufacturing Industry

A second industrial sector that could use geothermal energy is manufacturing, which could use geothermal energy for process heat. As indicated by the Solar Energy Research Institute, 47 percent of the 1972 national industrial energy consumption was in the manufacturing sector. The six largest manufacturing consuming sectors were chemicals and allied products; primary metals; petroleum

Figure 10. Geothermal Prawn Pond at Klamath Falls, Oregon.

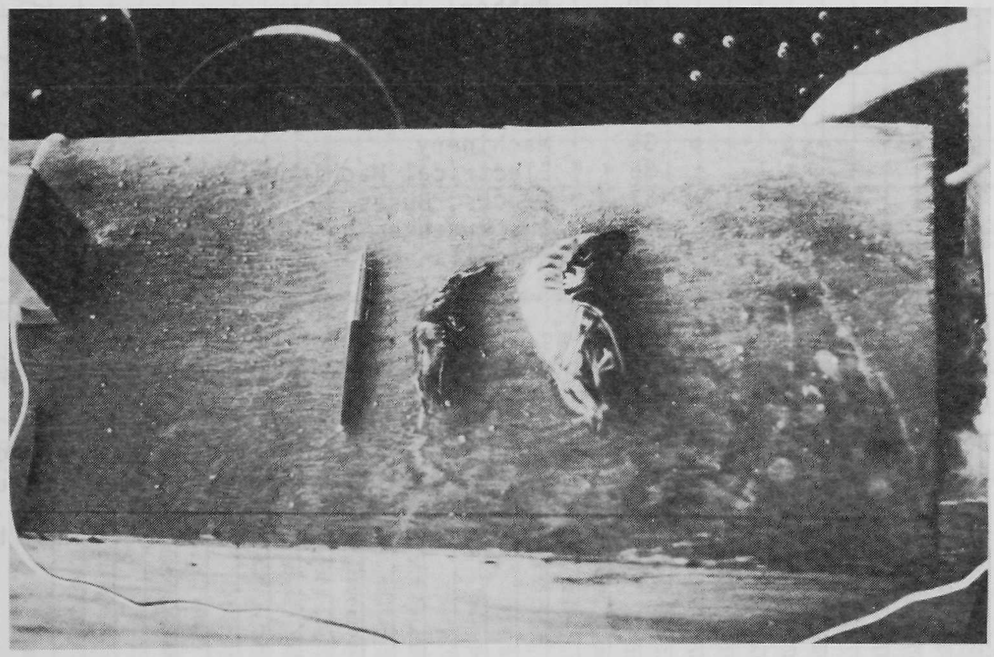


Figure 11. Malaysian Prawn.

and coal products; paper and allied products; stone, clay, and glass products; and food and kindred products (Solar Energy Research Institute, 1980).

Although many manufacturing processes require temperatures higher than those expected from geothermal energy in Colorado, a surprisingly large number require temperatures under 400°F. An initial screening indicated that some SIC's (Standard Industrial Classifications) in every major (2-digit) category (Table 8) use temperatures within the range that can be satisfied by geothermal energy.

A complete list of more specific (4-digit) classifications is provided in Table 9. All of those manufacturing processes listed may be considered as potential markets for geothermal energy.

TABLE 8

SOME STANDARD INDUSTRIAL CLASSIFICATIONS (S.I.C.) AND CODE NUMBERS

20	Food and Kindred Products
21	Tobacco
22	Textiles
23	Apparel
24	Lumber and Wood Products
25	Household Furniture
26	Paper Products
27	Printing
28	Chemicals
29	Lubricating Oils
30	Rubber
31	Leather
32	Clay/Concrete
33	Primary Metals
34	Fabricated Metals
35	Machinery
36	Electrical Machinery
37	Trucks, Buses
38	Instruments
39	Miscellaneous

Some processes now requiring higher process heat temperatures might be candidates as well, because processes can be changed to use lower temperatures if it is profitable to do so.

Because industrial processing requires a relatively steady, year-round energy supply, it is an attractive market for prospective geothermal producers. The steady demand also allows a producer to offer geothermal energy at a lower price. Where the energy use is seasonal, a geothermal project must be paid out over a longer period of time.

Table 9. Estimated Thermal Energy Requirements of Manufacturing Plants in Counties with Geothermal Energy (from the New Mexico Energy Institute, 1982).

MANUFACTURER / COUNTY	Alamosa	Archuleta	Boulder	Chaffee	Cl. Creek	Conejos	Delta	Dolores	Eagle	Fremont	Garfield	Grand	Gunnison	Jackson	LaPlata	Moffat	Ouray	Park	Pitkin	Pueblo	Routt	Saguache	SanMiguel	Total
2011 Meat Packing			2.366	.131		.262	.131			.131					.131					4.996				8.148
2013 Sausages/Meats	.067		.603																	.536				1.206
2016 Poultry			8.602																	.325				8.927
2021 Creamery Butter							.379																	.397
2024 Ice Cream							.074						.148							.518				.740
2026 Fluid Milk			1.386	.396						.198	.099								.099	1.485	.099			3.762
2033 Canned Fruits							7.823																	7.832
2034 Dehyd. Fruits								.372																.372
2047 Dog, Pet Food															.574									.574
2065 Confectionery															.026									.026
2086 Soft Drinks	.037			.110							.037				.765					.402				1.351
2087 Flavoring Ext.										.123														.123
2097 Mfg. Ice										.060	.060									.420				.540
2099 Food Prep.	.145		1.595							.145					.145					3.480				5.510
2253 Knit Mills			.029																.235					.264
2321 Men's Shirts			.001																	.052				.053
2329 Men's Clothing			.109				.006																	.115
2339 Women's Outwear	.202		.512																					.714
2386 Leather			.005																					.005
2391 Curtains			.054																	.006				.060
2392 House Furnish.			.040																					.040
2392 Textile Bags			.362																		.016			.378
2394 Canvas			.540																					.540
2411 Logging Camps				.069			.069					.138				.069								.345
2421 Sawmills		6.100		.073		.073	1.030	2.573		.221		.809	.146	3.161	3.088	.515		.146		.146	.294	.073	.146	18.594
2431 Millwork			.388												.064					.032				.484
2434 Cabinets			.024					.024		.024					.024					.024	.024			.144
2439 Wood Members										.019	.019									.019				.057
2448 Wood Pallets												.026												.026
2449 Wood Containers			.005																					.005
2451 Mobile Homes			.490																					.490
2452 Wood Buildings			1.328				.026				.179		.179									.076		1.788
2499 Wood Products			.252	.084									.084		.084					.084				.588
2511 Wood Furniture											.032									.032				.064

Table 9 (Cont.)

MANUFACTURER \ COUNTY	Alamosa	Archuleta	Boulder	Chaffee	Cl. Creek	Conejos	Delta	Dolores	Eagle	Fremont	Garfield	Grand	Gunnison	Jackson	LaPlata	Moffat	Ouray	Park	Pitkin	Pueblo	Routt	Saguache	SanMiguel	Total
2519 Householdd. Furn.			.027																					.027
2521 Wood Office Furn.			.006																					.006
2531 Public Bldg. Furn.			.003																					.003
2541 Wood Partitions			.028	.014															.014					.056
2591 Drapery Hardware																				.067				.067
2599 Furn. & Fixtures																					.085			.085
2645 Die-Cut Paper																								
2646 Pressed Pulp			11.585																					11.585
2661 Building Paper			1.533																					1.533
2711 Newspapers	.008	.008	.216	.008	.008		.008	.008	.024	.008	.056	.016	.032	.008		.048	.008			.296	.056		.008	.824
2721 Periodicals			.021						.005		.016	.005			.005				.039					.091
2731 Book Publishing			.113																	.010				.123
2741 Misc. Publishing			.027																					.027
2751 Commerc. Ltr. press	.022		.290				.157								.179					.201		.022		.871
2752 Commerc. Litho	.024		2.879	.073		.024	.024			.195	.096		.024						.072	.462	.048	.024	.024	3.969
2761 Business Forms															.026									.026
2782 Bankbooks			.013																					.013
2789 Bookbinding			.096																	.006				.102
2791 Typesetting			.006						.002						.002									.010
2795 Lithographic			.024																					.024
2813 Industrial Gases																				18.596				18.596
2819 Industrial Chem.			1.469							22.042														23.511
2821 Plastics Material			1.095																					1.095
2833 Medicinals			7.875																					7.875
2834 Pharmaceutical			5.322																					5.322
2844 Toilet Prep.							.024																	.024
2851 Paints			.074							.223										.074				.371
2869 Organic Chemicals			153.930																					153.930
2879 Agric. Chemicals							.677																	.677
2899 Chemical Prep.			.525																					.525
3111 Leather Tanning							1.575																	1.575
3131 Boot & Shoe Stock											.029													.029
3142 House Slippers			.006																					.006
3171 Women's Handbags			.016																					.016

Table 9 (Cont.)

MANUFACTURER \ COUNTY	Alamosa	Archuleta	Boulder	Chaffee	Cl. Creek	Conejos	Delta	Dolores	Eagle	Fremont	Garfield	Grand	Gunnison	Jackson	LaPlata	Moffat	Ouray	Park	Pitkin	Pueblo	Routt	Saguache	SanMiguel	Total
3172 Leather Goods (Pers.)			.016																					.016
3111 Leather Goods (Nec.)															.050					.400				.450
3259 Clay Prod.			37.222							1.063										15.952				54.237
3271 Concrete Block										.248					.248					.744				1.240
3272 Concrete Prod.			1.605				.321		.749	.428	.107									1.819				5.029
3273 Ready-Mixed Conc.		.123	2.715	.123			.123		.740		.864	.123	.123		.864	.246				.864				6.908
3275 Gypsum Prod.			2.164																					2.164
3281 Cut Stone			.096							.096										.168				.360
3291 Abrasive Prod.																								
3292 Asbestos																								
3293 Gaskets							.039																	.039
3296 Mineral Wool																				32.900				32.900
3317 Steel Pipe																				40.800				40.800
3321 Gray Iron			1.116																					1.166
3324 Steel Investment																								
3325 Steel Foundries			1.267																					1.267
3339 Nonferrous Metals			.595																					.595
3361 Alum. Foundries			1.515																	.649				2.164
3362 Brass, Bronze			4.880																					4.880
3421 Cutlery			.945																					.945
3423 Hand Tools			.120							2.117			.060											2.297
3429 Hardware			.350																	.050				.400
3432 Plumbing Fittings											.057													.057
3433 Heating Equipment			.094												.047					.141				.282
3441 Fabric. Metal			.480																	.280				.760
3442 Metal Doors																				.340				.034
3443 Fabric. Plate Work			.166																					.166
3444 Sheet Metal Work			.146																	.925				1.071
3446 Archit. Metal Work			.042							.042					.021					.062				.167
3448 Prefab. Metal Bldgs.													.037		.037									.074
3449 Misc. Metal Work			.430																	.062				.492
3451 Screw Mach. Prod.			.020																					.020
3452 Bolts, Nuts			2.870																					2.870
3462 Iron Forgings																				17.640				17.640

Table 9 (Cont.)

MANUFACTURER / COUNTY	Alamosa	Archuleta	Boulder	Chaffee	Cl. Creek	Conejos	Delta	Dolores	Eagle	Fremont	Garfield	Grand	Gunnison	Jackson	LaPlata	Moffat	Ouray	Park	Pitkin	Pueblo	Routt	Saguache	SanMiguel	Total
3469 Metal Stampings			.096				.048			.144														.288
3471 Plating, Polishing																								
3479 Metal Coating			2.632																	.564				3.196
3484 Small Arms													.013											.013
3489 Ordnance & Access.																								
3494 Valves, Pipe Fit.			.862																		.172			1.034
3498 Fabric. Pipe																				.294				.294
3499 Fabric. Metal			4.106				.148			.049										.049				4.352
3519 Combus. Engines																				.252				.252
3613 Switchgear			.192																					.192
3622 Indus. Controls			.073																					.073
3634 Elec. Housewares																			.095					.095
3643 Current Wiring			.660																					.660
3647 Vehicular Lighting																				.106				.106
3651 Radio Receiv. Sets			.051																					.051
3662 Communic. Equip.			.067							.024														.091
3672 Cathode Ray Tubes																								
3673 Electron Tubes			.060																					.060
3674 Semiconductors			.910																					.910
3677 Coils/Transformers			.016																					.016
3679 Elec. Components			1.995						.225	.015														2.235
3693 X-ray Apparatus			.289																					.289
3699 Elec. Equipment			.020																					.020
3811 Engin. Instruments			.120																					.120
3823 Proc. Control Instru.			.099																					.099
3824 Fluid Meters			.212																					.212
3825 Instru.-Electricity										.019														.019
3829 Measuring Devices			.692								.014													.706
3832 Optical Instruments			.150												.525									.675
3841 Surgical Instru.			.837																		.019			.856
3842 Surg. Appliances			.032																	.032				.064
3851 Ophthalmic Goods			.019								.057									.057				.133
3861 Phot. Equipment			.034																					.034

Table 9 (Cont.)

MANUFACTURER / COUNTY	Alamosa	Archuleta	Boulder	Chaffee	Cl. Creek	Conejos	Delta	Dolores	Eagle	Fremont	Garfield	Grand	Gunnison	Jackson	LaPlata	Moffat	Ouray	Park	Pitkin	Pueblo	Routt	Saguache	SanMiguel	Total
3911 Jewelry			.016		.008	.144									.024					.008				.200
3931 Musical Instru.			.020							.020														.040
3944 Games, Toys			.814												.022									.836
3949 Sporting Goods			7.854												.039				.039					7.932
3951 Pens, Pencils					.008																			.008
3952 Lead Pencils			.013																					.013
3953 Marking Devices										.008	.008													.016
3961 Costume Jewelry			.036			.252									.036				.036					.360
3964 Needles, Pins			.031																					.031
3993 Signs, Displays			.016							.003					.003				.003	.015				.040
3995 Burial Caskets										.129														.129
3999 Mfg. Industries			.462							.770			.066							.066				1.364
TOTALS	.505	6.231	288.210	1.081	.024	.755	12.682	2.977	1.745	28.564	1.730	1.117	.912	3.169	7.029	.878	.008	.146	.632	147.202	.889	.119	.178	506.76

Source: New Mexico Energy Institute

Use of geothermal energy in numerous manufacturing processes has been demonstrated or investigated. Some of the demonstrated commercial uses include:

1. Tasman Pulp and Paper Company in New Zealand;
2. Drying of diatomaceous slurry in Iceland to produce filteraids to be used in beer processing;
3. Milk pasteurization at the Medo Bel Creamery in Klamath Falls, Oregon;
4. Dehydration of onions at the Geothermal Food Processors plant at Brady Hot Springs, Nevada;
5. Alcohol production at Wabuska Hot Springs, Nevada.

Uses that have been investigated, either through experimental projects or through feasibility studies are shown on Table 10.

Table 10. Applications of Geothermal Energy That Have Been Investigated.

Alcohol Production
Barley Malting
Corn Milling
Chile Drying
Fruit and Vegetable Freezing
Fruit and Vegetable Preserving
Onion Dehydration
Tomato Paste Manufacturing
Sugar Beet Processing
Sugar Cane Processing
Meat and Poultry Packing
Glue Making
Zinc Processing
Lumber Kiln Drying
Tungsten Processing
Protein Recovery
Papaya Processing
Wine Making
Pulp and Paper
Tanning
Pharmaceuticals
Spinning and Weaving
Milk Pasteurizing

Note: See Appendix A for complete listing of papers describing these applications.

Some examples of the process heat systems for commercial applications of geothermal energy are as follows:

Alfalfa Drying. In New Zealand, the Broadlands Lucerne Company uses geothermal energy to process alfalfa.

In the drier, about 7 tons per hour of dry saturated steam raises the air temperature to 124°C. The drier is designed to produce one ton per hour of dried alfalfa (Lienau, 1978).

According to Paul I. Lienau, the margin of profit for alfalfa pellet production is only about $5 per ton, so any saving on energy costs is significant. He illustrates a rotary drum alfalfa dryer using 220°F geothermal water as shown on Figure 12 (Lienau, 1978).

<u>Ethanol Production</u>. At Wabuska Hot Springs near Yerington, Nevada, geothermal heat is used to produce 400,000 gallons per year of ethanol from corn shipped from the midwest. A 350 foot well pumps 440 gpm of water at 220°F. The waste is expected to be marketed as cattle feed. (GRC Bulletin, January, 1981).

<u>Lumber Drying</u>. For kiln drying of lumber, air would be heated by passing it over finned heat exchange tubes carrying hot water that are placed inside the kiln. Water temperature should be about 20° to 40°F above ambient operating temperatures in the kiln, or about 200° to 240°F, preferably. Where geothermal temperatures are lower the energy could be supplemented in the final stages of the drying cycle. Figure 13 compares conventional and geothermal kiln drying systems. Although wood waste is often used for kiln fuel, where it has other income-producing uses (such as for plywood extender or bark chips for gardens) or can be burned for environmental reasons, geothermal energy may be an economic alternative.

<u>Milk Pasteurization</u>. The Medo Bel Creamery, in Klamath Falls, Oregon obtains 180°F geothermal fluid from a 765 foot well which it uses for milk pasteurization, ice cream production and space heating. The savings over the cost of conventional fuel is estimated to be $1000 per month. The milk is heated by 172°F water for 15 seconds using a plate heat exchanger which is capable of processing 800 gallons of milk per hour (Figure 14). (Lund, 1979)

Ice cream mix is pasteurized with geothermal heat. Hot water and process steam are mixed to 250°F in a 250 gallon storage tank. The heat is then used to pasteurize the ice cream mix at 145°F for 30 minutes (Lund, 1979). About 800 ppm of dissolved solids, about half sulfate, one quarter sodium and a tenth silica are contained in the water. The pH of the water is 8.8. Little corrosion is evident in the well. The jet pump was replaced only once in the 30 year operation of the system (Lund, 1979).

<u>Onion Dehydration</u>. Geothermal Food Processors at Brady Hot Springs, Nevada, uses geothermal fluid for dehydration of onions and other vegetables.

A typical dehydration process uses a continuous belt conveyor or batch process with hot air of about 100° - 200°F. Figure 15 shows a conveyor dryer with blowers and exhaust fans that move the air through water coils containing the geothermal fluid or water heated by geothermal energy and through the beds of onions (Anderson and Lund, 1979).

<u>Potato Processing</u>. Potato processors commonly can use geothermal fluid 300°F or lower. Figure 16 shows a complete french-fried potato processing operation. The potatoes are scrubbed, preheated and then peeled. They next are washed and cut. Then the potatoes are dewatered then fired in oil heated to 375°F. Low temperature geothermal fluid could be supplemented for the last stage if necessary.

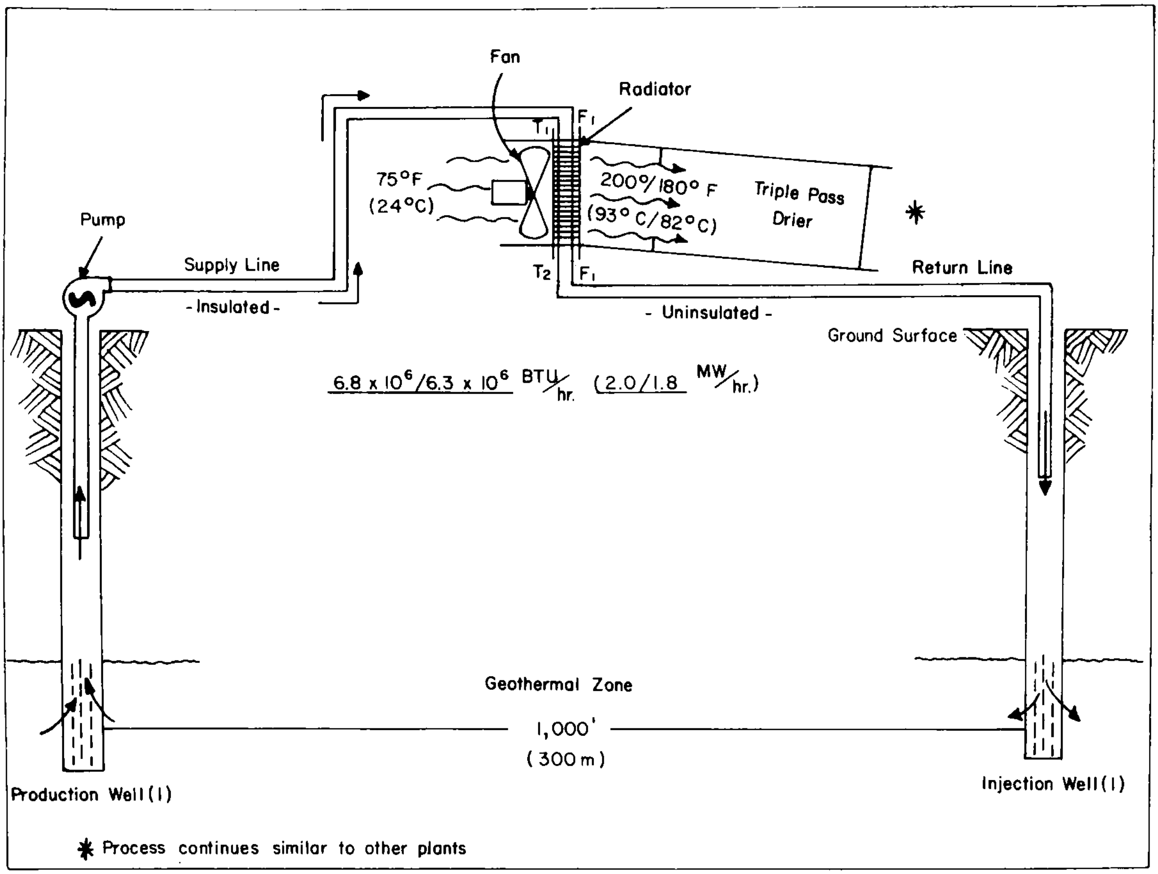
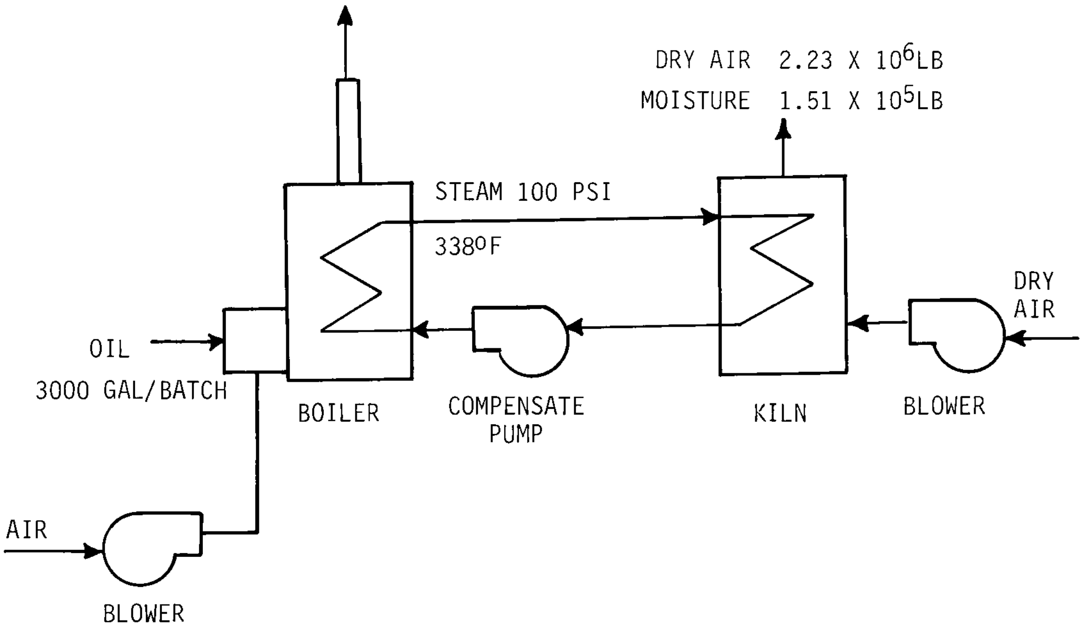


Figure 12. Rotary Drum Alfalfa Dryer (from Lienau, 1979).

I. CONVENTIONAL BOILER SYSTEM



II. GEOTHERMALLY HEATED SYSTEM

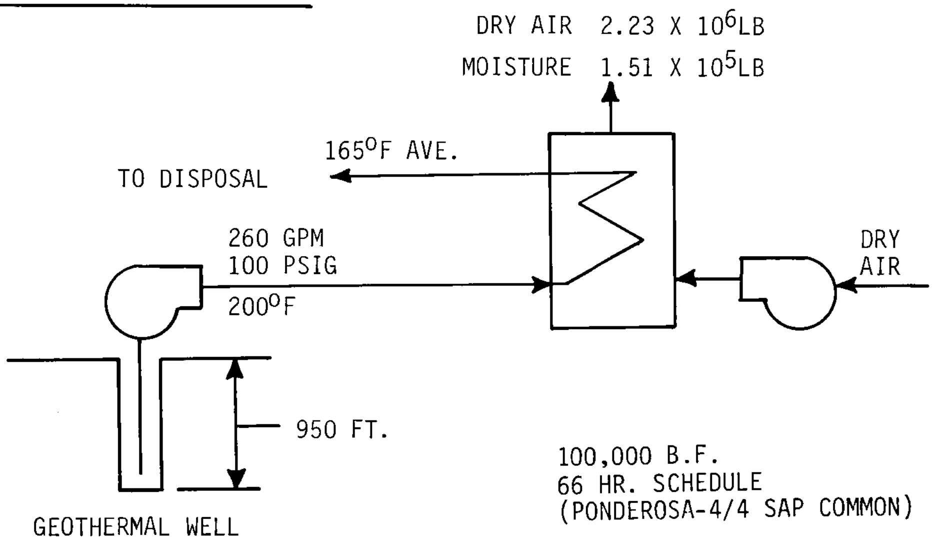


Figure 13. Conventional and Geothermal Lumber Kiln Driers (from V.T.N.-C.S.L., 1977).

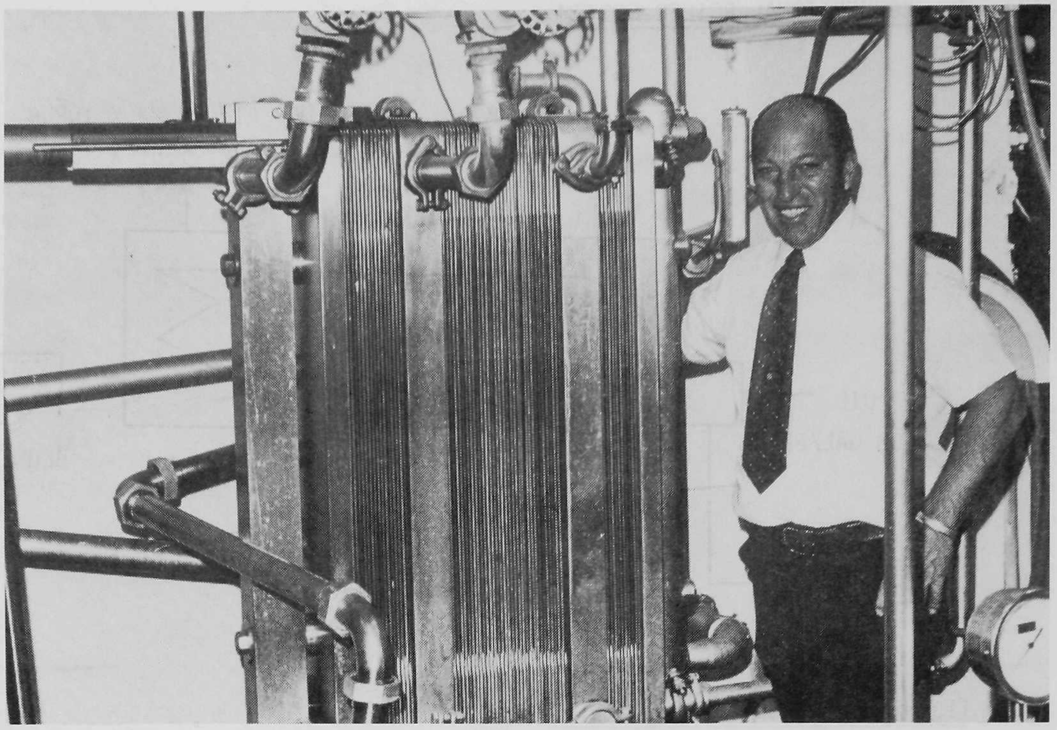


Figure 14. Heat Exchanger for Milk Pasteurization at Medo-Bell Dairy, Klamath Falls, Oregon.

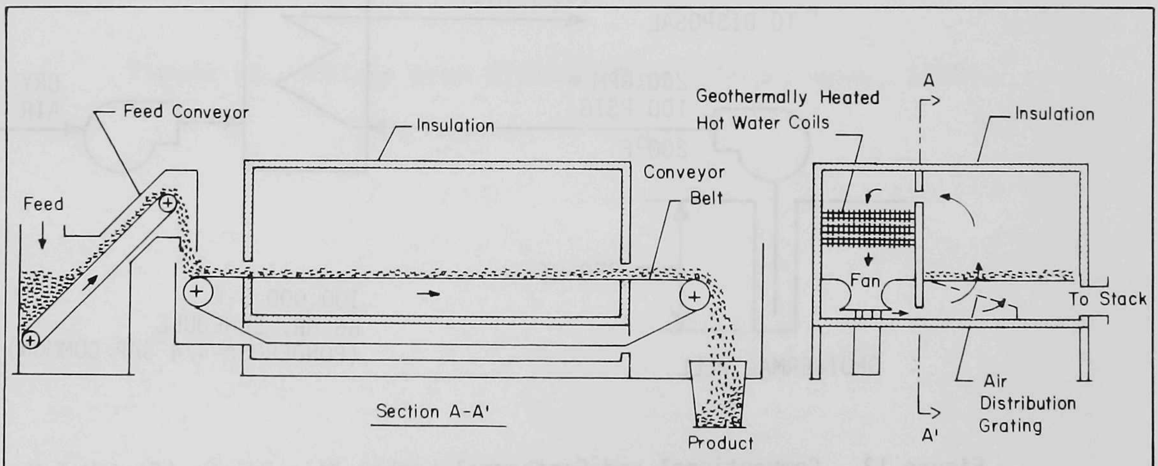


Figure 15. Schematic of Conveyor Dryer for Vegetable Drying (from Lienau, 1979).

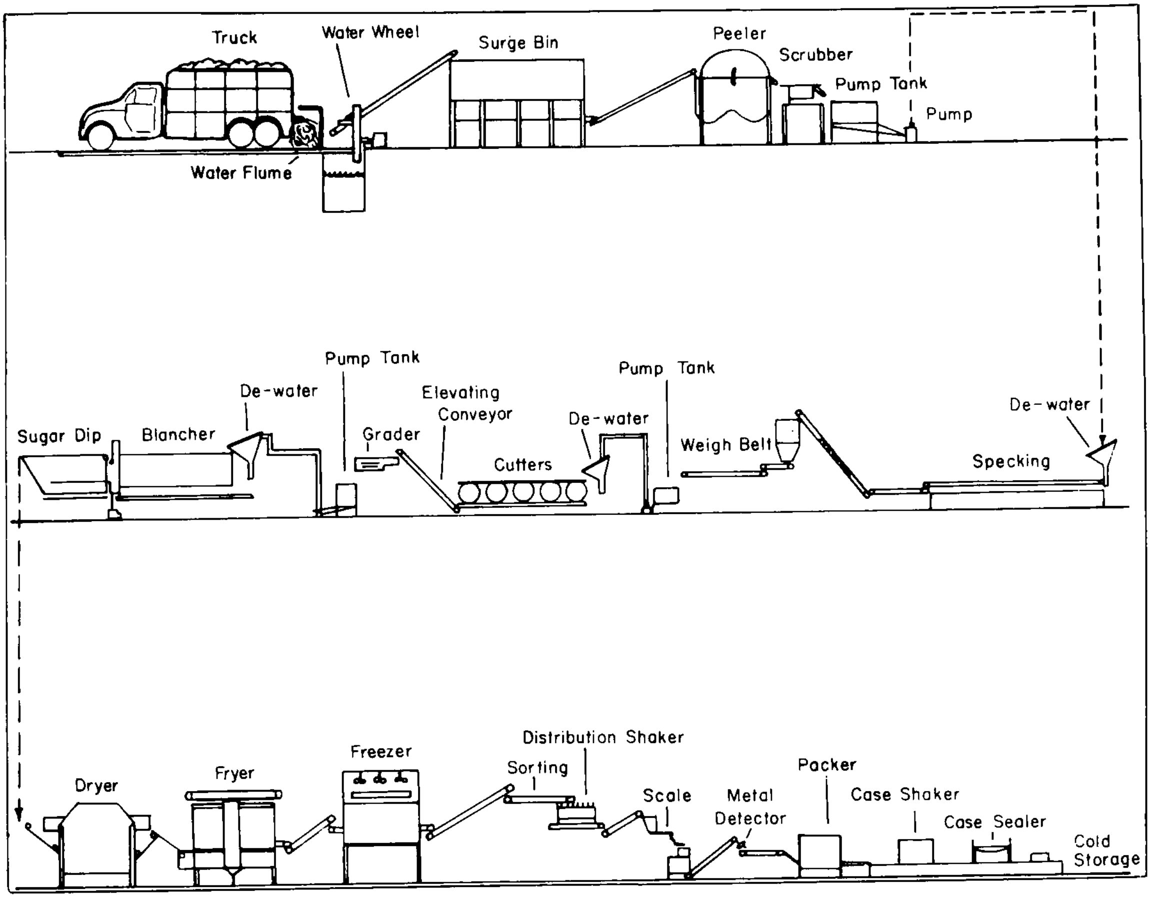


Figure 16. Potato Processing Schematic (from Lienau, 1979).

As indicated, numerous manufacturing processes could use geothermal energy. Since energy prices have been rapidly rising, energy has become a larger production cost factor for many firms. Therefore, those plants currently located near identified geothermal sites are among the likely candidates for using geothermal energy. Table 9 lists those plants in the counties where geothermal energy has been identified and their estimated energy requirements (1977 data). All of these are considered to be potential candidates for use of geothermal energy.

Possible New Plants. There may also be a significant market for geothermal energy among manufacturing plants not now located near geothermal sites. Replacement plants and expansions may for a variety of reasons be located at new sites. As a matter of policy, the State of Colorado is encouraging additional value-added for products originating in the State before they leave the State. That is, agricultural or timber products, for example, could be processed more extensively in Colorado prior to export. (Metcalf, pers. comm.) Whether new manufacturing plants are established near geothermal sites depends upon the site location criteria of the particular process and firm. Several factors determine the suitability of a particular location for a particular manufacturer. These include: materials, labor, market, transport, energy, public policy. Management considerations, which also impact location decisions, vary from firm to firm.

Some industries require highly-populated urban area locations. For efficient, effective operation, they may need a large or highly-trained labor force, large local market, major research and educational institutions and/or a wide range of transportation modes including jet air and rail. Others prefer larger cities for the life style they afford. Industries with these criteria for location are not the most likely potential users of geothermal energy since most geothermal sites (except for Boulder and Pueblo) are at locations a significant distance from the Colorado Front Range and have small populations (see Section II).

Some new manufacturing plants will be established in more sparsely-populated areas, however, including those with geothermal energy. As population grows in western Colorado, new market-oriented industries will be needed. Some industries will decentralize, opening small plants in new locations. Certain industrial categories are more likely to be attracted to such areas than others. To attempt to identify those categories, the major manufacturing groups that are most dispersed outside metropolitan areas were identified, as shown on Table 11.

Of these eleven categories, those that most commonly require process heat temperatures within the range of geothermal energy are food, apparel, lumber, furniture, printing, fabricated metal and miscellaneous. Fabricated processes, however, as well as apparel, furniture and printing, require only small amounts of low temperature heat for a very few processing steps. Additionally, most chemical manufacturing requires low temperatures as do several specific stone, clay and concrete categories. These include structural clay, concrete products and ready-mix and gypsum, stone and asbestos products. Machinery and transportation equipment almost always require high temperatures and can, therefore, be excluded as potential candidates for geothermal energy use. Of these eight categories that are potential markets, food, chemicals and stone, clay and concrete have the highest total energy requirements and those three plus lumber have the highest percentages of non-metro energy requirements.

Table 11. Estimated Thermal Energy Requirements of Selected Industries in Non-Metro Colorado Counties in BTU's x 10^{10} (1977).

	Food	Apparel	Lumber	Furniture	Printing
Total Energy Required, Statewide	883.559	14.677	58.300	14.672	37.137
Total Energy Required, Outside Denver Metro and El Paso County	536.359	3.124	34.362	.942	10.153
Percent Energy Required, Outside Denver Metro and El Paso County	61	22	59	6	27

	Chemicals	Stone, Clay, Concrete	Fabricated Metal Prod.	Machinery	Transportation Equipment
Total Energy Required, Statewide	737.763	1,231.234	173.852	131.999	69.801
Total Energy Required, Outside Denver Metro and El Paso County	428.135	707.143	54.311	53.007	26.310
Percent Energy Required, Outside Denver Metro and El Paso County	58	57	31	40	38

Adapted from New Mexico Energy Institute Data

The analysis indicates, therefore, that of the manufacturing processes most likely to locate near geothermal sites, those that would have the greatest demand for geothermal energy are:

1. Food and kindred products
2. Lumber and lumber products
3. Chemicals
4. Clay, concrete, gypsum and asbestos

These industries consume a total, in Colorado, of 29,109 billion Btu's of thermal energy annually, according to New Mexico Energy Institute estimates (Table 12).

Although the total energy requirement in non-metro areas for these four sectors could not be completely satisfied by geothermal energy, the magnitude of the potential market demand is evident. Some food processing plants already use geothermal energy and members of the lumber industry have indicated interest in geothermal energy.

Some of these industries are already eying geothermal energy. According to Bressler & Hanemann (1980), most of the onion and potato plant managers they interviewed were seeking either alternative fuels or ways to conserve energy to cut their production costs. Nearly all of them indicated willingness to purchase geothermal energy from a distributor. To obtain information, they

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Table 12. Energy consumption of select industries in Colorado.

Industry	Types of Processes	Energy Requirements Statewide (10^{10} Btu's)
Food	Drying, peeling, canning, washing, freezing, chilling, warming, scalding, blanching, clean-up, cooking, sterilizing, pasteurizing, evaporating	883.6
Lumber	Drying, curing	58.3
Chemicals	Heating, drying, digesting, washing	737.8
Clay, Concrete, Stone	Curing, heating water, drying	1,231.2
		2,910.9

Energy requirements data from New Mexico Energy Institute, 1979.

generally use consultants or others outside the industry. Little information is shared among industry competitors (Bressler and Hanemann, 1980).

Also according to a study by Bressler and Hanemann, the lumber industry has expressed interest in geothermal energy. Most of the industry representatives interviewed indicated they would consider development of geothermal energy or buy it from a distributor. They indicated that information about energy is often obtained from other members of the industry, either individually or through trade organizations (Bressler and Hanemann, 1980). Unfortunately, the industry is at a low point because of the severe decline in building. In the future, however, geothermal energy may help reduce industry costs.

The chemical industry, on the other hand, may be less likely to consider geothermal energy in the near future. Although members of the chemical industry who were interviewed indicated that energy was a major problem for them, they stressed that raw material availability is their main site location criteria. Also, many have high temperature as well as low temperature requirements. Where geothermal energy is proximate to the raw materials necessary for chemical production, most chemical companies would be willing to consider purchasing geothermal energy, according to the survey. Most of the information they use for making such a decision is obtained through company-supported research rather than through trade journals and associations or other firms in the industry (Bressler and Hanemann, 1979).

In summary, a potential market demand is found in the manufacturing sector, both among those manufacturing types now co-located with geothermal energy and among those that will expand or relocate in the future. For demand among co-located manufacturing to materialize depends largely upon the extent to which geothermal energy is made available and can reduce production costs. For plants to locate where they can use geothermal energy depends both upon those criteria and the satisfaction of other site location criteria. Where there is a match, both the geothermal producer and the manufacturer stand to benefit.

C. The Potential Market for Geothermal Energy in the Mining Industry

Several mining processes that use temperatures within the specified range were investigated as potential users of geothermal energy. These included processing of iron ore, copper concentrate, bituminous coal, potash, phosphate rock and sulphur. The latter three are not produced commercially in Colorado. Copper concentrate is produced along with other metals but not smelted in Colorado (Schwochow, pers. comm.). Although iron ore requires high temperatures for some processes, it could probably use geothermal energy for lower temperature processes. However, when processes require high temperatures, waste heat can usually satisfy lower temperature needs.

One of the mining processes did seem to be a possible use of geothermal energy in the foreseeable future: bituminous coal drying. Coal is dried for one of two reasons: either to dewater the coal in order to minimize shipping costs or to remove water used for washing the coal. In the first case, the coal would need to be dried near the mine mouth or possibly at a transportation mode transfer point. In the second case, the coal could be washed and dried either at the mine mouth or transfer point or at the receiving end, where the coal is to be burned. Currently, only two facilities in Colorado are known to be drying coal. They are the Dorchester Coal Company near Canon City and Mid-Continent Coke and Coal Company near Redstone.

At the Dorchester facility, washed coal is passed across an 80 foot table that is heated to 255°F with propane. One gallon of propane is required per ton of coal, with about 300,000 gallons of fuel, or about 30 billion Btu's required for a heating season (DeLucio, pers. comm.).

In the future, additional coal could be dried in Colorado, either to reduce shipping costs* or to reduce pollutants. Indeed, the feasibility of coal dewatering has been investigated in some areas already (Pearson, pers. comm.). Where geothermal energy is available proximate to coal production or to coal conversion, coal drying could be economically feasible. To determine the feasibility would require a site specific analysis.

To identify the potential for drying coal with geothermal energy, coal field and mine locations were identified. As shown on Figure 17, many coal and geothermal sites are co-located. As Table 13 indicates, of 24 counties with identified geothermal energy, 16 have coal fields and 10 have permitted coal mines (Kelso, Ladwig and Sitowitz, 1981).

Table 13. Coal Fields and Coal Mines Co-Located with Geothermal Energy

Counties with Coal Fields and Geothermal Sites	Permitted Coal Mines
Archuleta	X
Boulder	
Delta	X
Dolores	
Fremont	X
Garfield	X
Grand	
Gunnison	X
Jackson	X
La Plata	X
Moffat	X
Ouray	
Park	
Pitkin	X
Routt	X
San Miguel	

from Kelso, Ladwig and Sitowitz, 1981

*If rail freight rate regulation is eliminated, railroads could, if they wish, charge higher rates for dried coal, thereby defeating the purpose of drying. However, since the coal would consume less space if it were dewatered, the railroads would gain hauling capacity for coal whether it was dewatered or not.

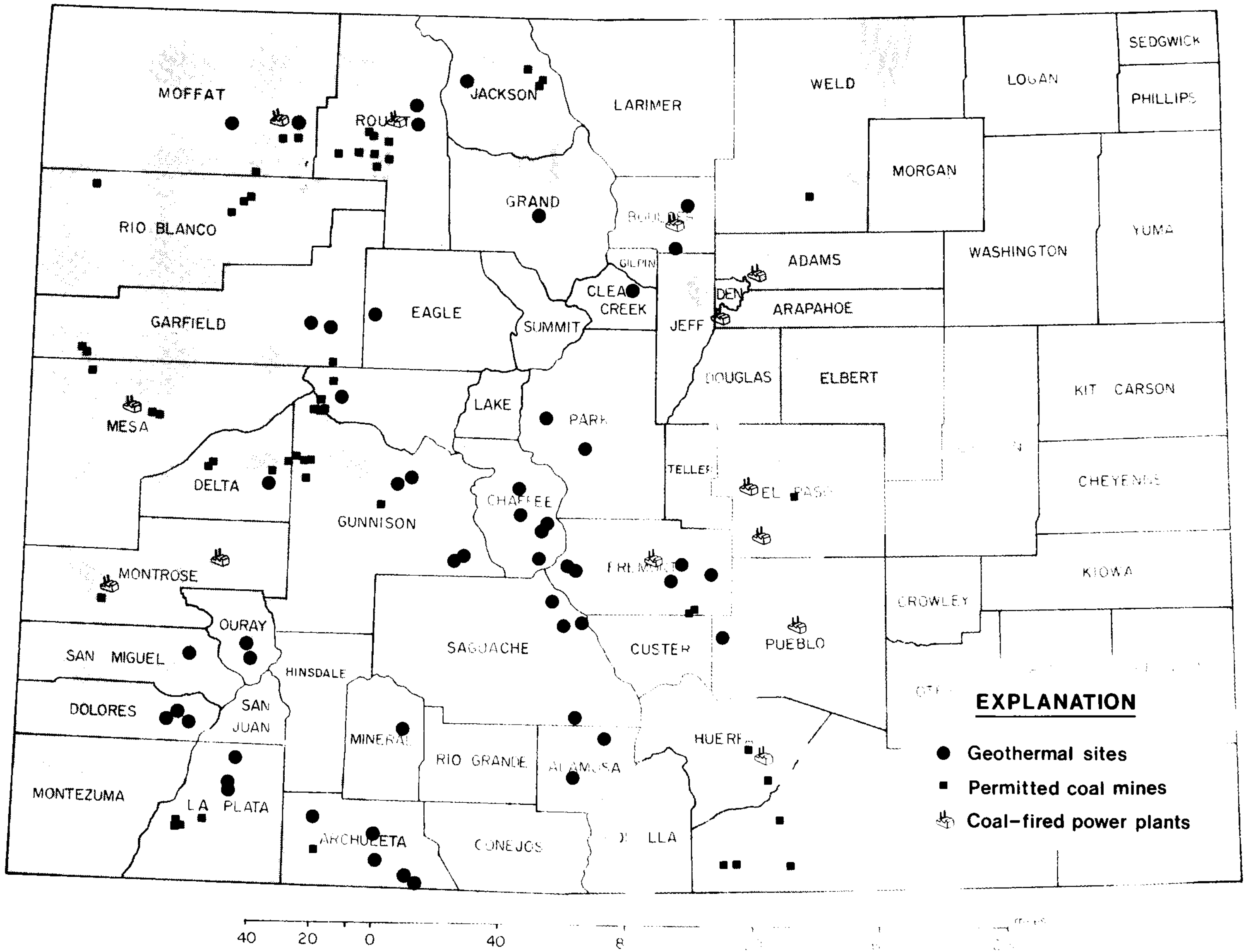

Figure 17. Coal Supply and Demand Sites, and Geothermal Sites in Colorado. Screened area indicates coal regions.

Additionally, locations of coal-fired power generating plants were compared with geothermal sites. As indicated on Figure 17, plants are located in counties which are known to have geothermal energy. Whether drying of coal with geothermal energy occurs depends upon the availability of geothermal energy near mines, coal transfer points or users, the need for drying, the economic benefits of drying, and the economic advantages of using geothermal energy for heat. The location of geothermal energy in Colorado does seem to coincide reasonably well with prospective drying sites. The other questions can only be answered through subsequent, detailed analyses. Where coal drying is being considered at locations near geothermal sites, however, coal producers may be well-advised to consider geothermal energy as a heat source.

D. The Potential Market for Geothermal Energy in the Tourism and Travel Industry

Travel and tourism is a big business in Colorado. According to the Colorado Office of Tourism, expenditures by tourists totaled \$1.6 billion in 1980, \$1.8 billion in 1981, and are forecast to be \$2.2 billion in 1982. Total travel expenditures in 1980 were more than double the tourism figure, \$3.3 billion. As Table 14 shows, the total travel expenditures in all of those counties in which geothermal energy has been identified were \$839 million in 1980.

Numerous hotels, motels and restaurants are necessary to accommodate travelers in Colorado. Hotels, motels and restaurants use large amounts of hot water for cleaning, cooking and laundry. The energy required in Colorado for heating that hot water and for heating space, as well as for some cooking, was estimated to be 2970 billion Btu's for hotels and motels, and 3060 billion Btu's for restaurants per year in 1978 (Colorado Energy Research Institute, 1979).

Geothermal energy can easily heat water and space for hotels, motels and restaurants. Other commercial buildings can equally easily be heated with geothermal energy but the lodging and dining facilities, in particular, can benefit and are targeted as an exceptional market opportunity because of the large, year-round energy requirements. The market potential for other commercial facilities is more appropriately examined as part of a heating district.

Because water and space have long been heated with geothermal energy, numerous examples can be cited. Examples specific to the category of lodging and dining facilities include the famous Baden, Baden Resort in Germany. Japan has many such facilities. In the Ohtake area of Japan, for example, geothermal fluid is delivered to 8 hotels for room heating, bathing and dishwashing. Each hotel uses about 11 gpm of fluid 113° to 140°F, a total for the 8 hotels of 91 gpm (Geoheat Utilization Center, June, 1980). In the United States, the El Capitan Casino at Hawthorne, Nevada, uses geothermal heat. Water at a temperature of 210°F from a 650 foot well producing 700 gpm is delivered through fiberglass pipe a mile to the Casino.

Table 14. Travel in the Colorado Counties with Identified Geothermal Energy

	Total Travel Expenditures (Thousands)	Travel-Generated Payroll (Thousands)	Travel-Generated Employment (Jobs)
Alamosa	$ 12,097	$ 2,592	425
Archuleta	14,937	3,195	529
Boulder	70,819	16,683	2,500
Clear Creek	10,448	2,170	351
Conejos	3,603	740	119
Delta	8,028	1,641	261
Dolores	564	96	13
Eagle	185,623	39,729	6,552
Fremont	21,669	4,557	745
Garfield	60,875	12,908	2,113
Grand	53,882	11,322	1,780
Gunnison	30,990	6,417	1,034
Jackson	1,554	317	51
La Plata	74,639	15,711	2,566
Mineral	3,633	720	115
Moffat	15,138	3,187	522
Ouray	7,012	1,458	237
Pitkin	139,630	30,028	4,935
Pueblo	20,902	4,533	703
Routt	73,817	15,614	2,565
Saguache	5,152	1,071	173
San Miguel	6,283	1,301	213

from Business Research Division, 1982

Closer to home, the Mt. Princeton Hot Springs Resort (Figure 18) near Buena Vista, Colorado, uses geothermal fluid for space heat for cabins as well as for the swimming pool. The Adobe Inn at Pagosa Springs, a hotel, restaurant, and complex of shops, uses geothermal energy to heat the building and water for a laundry. The Spring Inn Motel and other buildings in Pagosa Springs also use geothermal energy. (A new geothermal district heating system has recently been constructed in Pagosa Springs.) At the Weisbaden Lodge in Ouray, Colorado, geothermal fluid is used for space and water heating and for mineral baths and a swimming pool (Pearl, 1979). Heating systems are similar to those shown on Figure 4. In Glenwood Springs, Colorado, a geothermal well drilled in September, 1981, to provide heat for an office building may also be used for a major hotel (Dick, pers. comm.).

Interest in natural hot water for both recreation and health has had a resurgence along with the increased interest in recreation and health in general. Entrepreneurs may find the timing right to establish new facilities with both spas and natural hot water energy. At least one such facility is

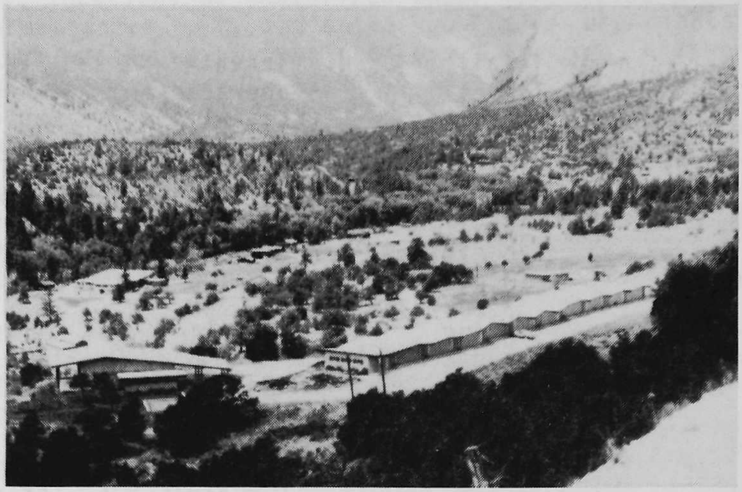

Figure 18. Mt. Princeton Hot Springs Resort.

already underway: Canadian investors are planning to build a 400 unit motel with a swimming pool and sauna on 33 acres they have purchased at Pagosa Springs (Colorado Geological Survey, 1982). The Ramada Inn at Glenwood Springs, Colorado, was designed so that it could use geothermal energy in the future. Hotel, motel, and restaurant owners in Salida, Colorado, have expressed interest in using fluid from Poncha Hot Springs for space and hot water heat (Coe et al, in process). The potential for using geothermal energy at the Baca Inn in the San Luis Valley was investigated. Proponents of economic development in Ouray, Colorado, have discussed the possibility of a geothermally-heated convention center.

Numerous hotels, motels and restaurants in Colorado are located near geothermal areas and could, therefore, easily use the energy. In fact, many of Colorado's most popular vacation towns originated as hot spring resort areas. As Table 15 shows, 25 geothermal areas in Colorado have or have had natural hot water baths or pools. Undeveloped spring areas in remote areas are also popular, for a refreshing dip after cross-country skiing or for "skinny" dipping any time of year.

To attempt to estimate the potential market demand for geothermal energy for lodging and dining facilities in Colorado, the total thermal energy requirements for the facilities were estimated. In those counties, as shown on Table 16, in which geothermal energy has been identified, there are estimated to be nearly 15,000 hotel and motel rooms (University of Colorado and City Chambers of Commerce) and 2807 restaurants (Ferd Dircks, pers. comm.). Based on average energy usage per room, these hotel and motel rooms would require about 700 billion Btu's of thermal energy. Restaurant energy requirements are more difficult to estimate because of the lack of data. However, based on the percentage of the total number of restaurants in the state that are in the counties with geothermal energy, the energy requirement would be about 796 billion Btu's (adapted from Colorado Energy Res. Inst., 1979).

Table 15. Geothermal Swimming Pools and Baths in Colorado.

Type of Use	Name of Area
Swimming Pools	Juniper Hot Springs
	Steamboat Hot Spring
	Hot Sulphur Springs
	Eldorado Warm Springs
	Idaho Hot Springs
	Glenwood Hot Springs
	Cement Creek Hot Springs
	Cottonwood Creek Hot Springs
	Mt. Princeton Hot Springs
	Poncha Hot Springs
	Shaws Warm Spring
	Splashland Hot Water Well
	Pagosa Hot Springs
	Wagon Wheel Gap Hot Springs
	Upper Waunita Hot Springs
	Ouray Hot Springs
	Valley View Hot Springs
Baths	Juniper Hot Springs
	Hot Sulphur Springs
	Idaho Hot Springs
	Glenwood Hot Springs
	Valley View Hot Springs
	Cebolla Hot Springs
	Orvis Hot Springs
	Ouray Hot Springs
	Dunton Hot Springs
	Paradise Hot Springs
	Mt. Princeton Hot Springs

Much of this energy demand could readily be met with geothermal energy, and, as travel continues to expand in Colorado, many additional hotel and motel rooms and restaurants will be built, creating an even larger demand for energy including geothermal energy. Certainly, no abatement of this travel expansion is in sight.

Table 16. Number of Hotel and Motel Rooms and Restaurants in Counties with Identified Geothermal Energy, 1981.

County	Number of Restaurants	Estimated thermal energy Required* (Billion Btu's)	Number of Hotel/Motel Rooms	Estimated thermal energy Required* (Billion Btu's)
Alamosa	61		400	
Archuleta	26		200	
Boulder	662		1,000	
Chaffee	78		1,055	
Clear Creek	79		180	
Conejos	31		39	
Delta	10		153	
Dolores	6		49	
Eagle	160		10	
Fremont	125		677	
Garfield	123		717	
Grand	110		8	
Gunnison	77		2,093	
Jackson	14		42	
La Plata	159		1,523	
Moffat	57		325	
Ouray	25		188	
Park	36		N.A.	
Pitkin	146		2,744	
Pueblo	643		1,386	
Routt	116		1,406	
Saguache	33		15	
San Miguel	30		386	
	2,807	796	14,596	700

N.A. - Not Available

*Restaurant energy was estimated to be 26 percent of total state natural gas requirements estimated by CERI. Hotel/motel energy was derived from the normalized natural gas requirement of 47 x 10^6 Btu's estimated by Colorado Energy Res. Inst. (1979) for Montrose.

Sources: Business Research Division, 1975, Chambers of Commerce, and Colorado Department of Health.

SECTION IV

SUMMARY OF THE INDUSTRIAL MARKET FOR GEOTHERMAL ENERGY IN COLORADO

The industrial potential of geothermal energy in Colorado has been little discussed, in the past, probably because Colorado's major industrial area along the Front Range apparently has no geothermal sites with temperatures above normal close by. The emphasis in prior discussions of potential demand for geothermal energy has been primarily upon space heating of commercial and residential buildings. Industrial use is, however, an attractive prospect for both consumers and producers/distributors of geothermal energy. The heat load of the industrial consumer is usually relatively high and is often stable year-round. Rising energy bills eat into profits, stimulating the search for ways to reduce those bills. The energy producer/distributor can more economically supply energy to one or a few major geothermal energy consumers than to numerous small users, because of the cost of distribution and heating systems. Furthermore, he stands to receive a greater return in a shorter time because industrial consumption is relatively steady, compared to more seasonal commercial and residential consumption.

This research shows that four major industrial sectors offer a potential market for geothermal energy in Colorado. These are agriculture, manufacturing, mining and travel. Among the 58 geothermal sites that have been inventoried, most have some potential for industrial use in these four sectors.

A. Geothermal Sites

Although 58 geothermal resource areas in 24 counties have been positively identified so far, many more may be found in the future. Of these sites, some are more conducive to industrial development than are others. Temperature, discharge, water quality, and drilling difficulty all influence the desireability of the prospect. Most of these characteristics cannot be known with certainty until after wells are drilled. However, some sites are prime candidates for various kinds of industrial development because of the characteristics that are known about them. Table 17 shows those sites that have the highest measured temperatures and are nearest to existing communities. This does not imply that others are unsuitable, merely that additional information is needed in order to judge their suitability for use by one or more of the industrial sectors discussed below.

B. Agriculture

In the agriculture industry, potential uses of geothermal energy include both crop and livestock production. Geothermal heat for greenhouse production of crops, such as potted and green plants, is becoming increasingly attractive to greenhouse owners experiencing high heating costs. At least one potted plant greenhouse operation in Colorado now uses geothermal heat. Although the cut flower sector is declining and the vegetable sector small, these, too, can use geothermal energy where the situation allows.

Livestock production and aquaculture could use geothermal energy more extensively than is currently done in Colorado. At least two swine production

Table 17. Most Desirable Geothermal Sites for Development Based on Existing Information.

Site No.	Site
3,4	Steamboat Springs-Routt
6	Hot Sulphur Springs
11,12	Glenwood Springs-South Canyon
19	Hartsel Hot Springs
20	Cottonwood Hot Springs
21	Mt. Princeton Hot Springs
23	Poncha Springs
41	Pagosa Springs
48	Orvis Hot Springs
49	Ouray

operations and three aquaculture operations in Colorado have found the use of geothermal energy to be extremely beneficial. Feed lots, barns and pens can be heated to increase survival and growth rates of calves, swine and lambs. Poultry houses can be heated to enhance the production of eggs and chicks. Hatcheries, raceways and ponds can also use geothermal fluid to increase the growth of such aquatic species as catfish, eels, prawns and even trout. As shown in Section III, all 24 counties in Colorado with geothermal energy also have agriculture production.

C. Manufacturing

Numerous types of manufacturers in Colorado can use geothermal energy. Some manufacturers in every major category have maximum temperature requirements that could be satisfied by geothermal energy. These include food in kindred products, tobacco, textiles, apparel, lumber and wood products, printing, chemicals, leather, clay and concrete and even metals manufacture.

Manufacturing plants co-located in counties with geothermal energy include food processing plants, lumber mills, clothing manufacturers, chemical plants, concrete producers, and printers. Altogether, the manufacturing plants in those counties (in 1977) were estimated to require over 5,000 billion Btu's of thermal energy (New Mexico Energy Institute, 1982).

Additional manufacturing plants seem likely to locate in the future where geothermal energy is available. Based on their current distribution in non-metro counties, energy requirements, and to some extent their site location criteria, the major manufacturing categories that would seem to have the greatest demand for geothermal energy in Colorado are the food, lumber, chemicals, and clay, concrete and stone industries. Some of the processes possible using geothermal energy are drying, peeling, canning, washing, freezing, chilling, warming, scalding, blanching, clean-up, cooking, sterilizing, pasteurizing, and evaporating for food processing; drying and curing for lumber products; heating, drying, digesting, and washing for chemical manufacturing; and curing, heating water, and drying of clay, concrete, and stone products. As shown in Section III, manufacturing in these sectors is estimated to consume about 29,110 billion Btu's of thermal energy, according to the New Mexico Energy Institute.

D. Mining

Fewer opportunities for satisfying energy needs were found in the mining industry. With one exception, those mining processes that can readily be met with geothermal energy are not conducted on a commercial scale in Colorado. Drying of coal was the one mining process that seemed likely to find the use of geothermal heat desirable in the not-too-distant future. Heating bills for drying coal either after dewatering - to reduce shipping charges, or after washing - generally for environmental reasons, are a significant cost item. The two coal dryers that were identified in the State, as well as numerous coal fields, are located near geothermal sites.

E. Travel and Tourism

Because of the intensity of the travel and tourism industry in Colorado, (much of it focused upon areas with hot springs) hotels, motels and restaurants are a significant potential market for geothermal energy. Unlike most other commercial establishments, these facilities use large quantities of hot water year around for cleaning, laundry and bathing. Heating the hot water, along with heating large areas of space consumes significant amounts of energy. As indicated by the Colorado Energy Research Institute (1979), in Montrose, Colorado, for example, a restaurant requires more than twice the thermal energy required by a supermarket per square foot. In those counties where geothermal energy is located, the hotel/motel industry is estimated to require about 700 million Btu's of thermal energy, or 23 percent of the statewide total energy requirements for that group. Restaurants in those counties were estimated to require, in 1977, about 796 billion Btu's or 26 percent of the statewide total.

For these uses, geothermal energy in the temperature range of 120°-180°F is quite acceptable. Installations are standard types of heating and hot water systems that have been used for decades, taking into account, when necessary, the chemical composition in the fluid. Since the travel and tourist industry in Colorado continues to grow, an increasing energy demand in this sector can be anticipated.

F. Conclusion

Clearly, there is an industrial market demand for energy in Colorado that could be satisfied by geothermal energy. Particularly in the four sectors identified: agriculture, manufacturing, mining and travel, energy demands are within the temperature range, within the geographic area and within the technological range of geothermal energy. In the agriculture sector, greenhouses, livestock production and aquaculture could benefit from geothermal energy use. In the manufacturing sector, processing of food and kindred products and lumber products and to some extent chemicals and clay, concrete and stone products are obvious markets. In the mining industry, the potential for geothermal use is less evident; a demand may be found in the coal drying process. In the travel sector, heating of hot water and space for hotels, motels and restaurants is clearly a strong potential market, given the co-location of tourism and geothermal energy. Using geothermal energy for these industrial applications can in many cases reduce costs for these industries. At the same time, the demand for energy for industrial use can be the impetus needed by geothermal producers to profitably develop geothermal sites in Colorado.

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APPENDIX A

Sources of Information
for
Geothermal Energy Applications

APPENDIX A

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