ASSESSMENT OF THE GEOTHERMAL POTENTIAL WITHIN THE BPA MARKETING AREA

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ABSTRACT

This study estimates the potential of geothermal energy that can be used for direct heat applications and electrical power generation within the Bonneville Power Administration (BPA) marketing area. The BPA marketing area includes three principal states of Oregon, Washington, and Idaho and portions of California, Montana, Wyoming, Nevada, and Utah bordering on these three states. This area covers approximately 384,000 square miles and has an estimated population of 6,760,000. The total electrical geothermal potential within this marketing area is 4,077 MW_e from hydrothermal resources and 16,000 MW_e from igneous systems, whereas the total thermal (wellhead) potential is 16.15×10^{15} Btu/yr. It should be realized that only a fraction of this energy may be used due to economic, institutional, and environmental constraints. Much of this region is sparsely populated, and therefore geographically matching a resource with a user may be difficult. Moreover, the region's generally high environmental values and predominant federal land management authority may also significantly impede resource development.

Approximately 200 geothermal resource sites were initially identified within the BPA marketing area. This number was then reduced to about 100 sites thought to be the most promising for development by the year 2000. Favorable direct-use sites were those with a significant load within a 25-mile radius of the geothermal resource. These 100 sites, due to load area overlap, were grouped into 53 composite sites; 21-3/4 within BPA preference customer areas and 31-1/4 within nonpreference customer areas. The geothermal resource potential was then estimated for high-temperature (>302°F = 150°C), intermediate-temperature (194°-302°F = 90°-150°C), and low-temperature (<194°F = 90°C) resources. A conversion potential (beneficial heat) for the 53 composite sites

was estimated at 3,097 x 10^{12} Btu/yr (approximately 3 quads/yr) and 3,293 MW_e probable development and an additional 3,050 MW_e possible development. This estimate required the development of a model for estimating the low-temperature resources.

The geothermal energy load at each of these 53 sites was then estimated for both electrical energy and fossil fuel displacement (direct-use load). The major components in the direct-use load were space heating and water heating loads for residential, commercial and public buildings, and the industrial process heating load. The total direct-use load (based on 1980 populations) was estimated at 33.5 x 10^{12} Btu/yr, of which 15.8 x 10^{12} Btu/yr was potential electrical load displacement and the remainder fossil fuel load displacement. The direct-use load was distributed 80 percent to residential, 3 percent to commercial, 4 percent to public, and 13 percent to industrial use. Approximately 21 percent of the total load was within the BPA preference customer area. The estimated development schedule for direct use and electrical power generation is as follows:

Year	1980	1985	1990	1995	2000
Direct-use load (x 10^{12} Btu/yr)	0.4	1.8	4.5	8.8	14.4
Electric power (MW_e)	5	5	305	1,125	1,675

Five general projects are identified that should be considered by BPA to encourage geothermal development in their market area. These include: a) regional resource planning and development; b) wellhead generators; c) resource exploration, confirmation, and evaluation; d) district heating; and e) heat pumps. Each project is described in generic terms and several specific sites are then recommended for development.

SUMMARY

In addition to the Abstract, a quick review of the report can be made by reading the following pages:

CONVERSION FACTORS

METRIC/ENGLISH CONVERSIONS

$1\ m^3 = 35.3\ ft^3 = 264$ gals
1 meter = 3.281 ft
1 kilogram = 2.2 lb
1 liter $= 0.264$ gal $= 0.0353\ ft^3$
1 liter/sec = .001 m^3/sec = 15.8 gpm
1 joule = 0.000948 Btu
$1^{o}C = (^{o}F-32^{o}) \times 5/9$
$1\ m^2 = 10.76\ ft^2$

NOMINAL FUEL HEATING VALUES

1 cubic foot natural gas = 1000 Btu
1 pound bituminous coal = 12,500 Btu
1 gal #2 fuel oil = 1.42×10^5 Btu
1 Therm = 10^5 Btu
1 barrel crude oil = 5.6 million Btu

ENERGY UNIT CONVERSION CHART (100% Efficiency)

British Thermal Units (Btu)	Cubic Feet Natural Gas (CF)	Kilowatt Hours Electricity (kwh)	Barrels of Oil (bbl)	Short Tons Bituminous Coal (T)	Tons of Refrigeratioi
1	0.001	0.000293	---	---	---
1000	1	0.293	0.00018	0.0004	.0833
3413	3.41	1	0.00061	0.00014	.284
1 Million	1000 (1 MCF)	293	0.18	0.04	83.3
3.41 Million	3413	1000 (1 MWh)	0.61	0.14	284
5.6 Million	5600	1640	1	0.22	466
25 Million	25,000	7325	4.46	1	2083
1 Quadrillion (Quad) (Q)	1 Trillion (1 TCF)	293 Billion	180 Million	40 Million	83.3 Billion

*Defined as the heat of fusion of one ton of water, equal to 288,000 Btus

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

Figures

TABLE OF CONTENTS (CONTINUED)

Tables

Maps

Charts

I. INTRODUCTION

A. OBJECTIVES OF THE STUDY

The purpose of this study is to estimate the potential of direct use and electrical generation of geothermal energy within the Bonneville Power Administration (BPA) marketing area. The potential for nonrenewable energy conservation and the prospects for geothermal use as an alternative energy resource over the next 20 years is evaluated within (1) the BPA preference customer's service areas and (2) the nonpreference customer's service areas.

More specifically, the study investigates: the energy potential of the geothermal resources in various site specific areas; the technical feasibility of developing and using these resources (including legal, institutional, and environmental constraints); estimates the potential for geothermal energy displacing all forms of existing energy use; suggests incentives BPA might offer to promote geothermal development; and identifies specific end-use pilot projects which BPA may undertake to demonstrate geothermal potentials.

B. REGIONAL ENERGY OVERVIEW

Broadly estimated, the total annual energy requirements (electric plus nonelectric) of the BPA market area are projected as follows:

1980	1.81×10^{15} Btu = 5.30×10^{8} Mwhr = 1.81 quads
1985	1.95×10^{15} Btu = 5.71×10^{8} Mwhr = 1.95 quads
1990	2.09×10^{15} Btu = 6.12×10^{8} Mwhr = 2.09 quads
1995	2.20×10^{15} Btu = 6.45×10^{8} Mwhr = 2.20 quads
2000	2.31×10^{15} Btu = 6.76×10^{8} Mwhr = 2.31 quads

The interchangeability of energy leads to considerable uncertainty in projections. Electrical energy served 35 percent of the total energy needs in the

BPA market area in 1962, but rose to 50 percent in 1975. It will rise further in its share as more homes are heated electrically. With all of the uncertainties in mind, the projected annual electrical consumption is as follows:

1980	9.25×10^{14} Btu = 2.71×10^{8} Mwhr
1985	9.95×10^{14} Btu = 3.16×10^{8} Mwhr
1990	1.23×10^{15} Btu = 3.60×10^{8} Mwhr
1995	1.28×10^{15} Btu = 3.67×10^{8} Mwhr
2000	1.39×10^{15} Btu = 4.07×10^{8} Mwhr

The U.S. Geological Survey (USGS) Circular 790 (Reference 1)* lists 16 hydrothermal resources and 17 igneous geothermal systems in the BPA service area whose reservoir temperatures are above 302°F (150°C) (including Yellowstone Caldera area). The USGS estimates that the magnitude of the hydrothermal resources over a 30-year period (excluding Yellowstone), depending upon method of exploitation, are:

Electrical power	3.66×10^{15} Btu = (4077 MW_e over 30 years)
Wellhead available work	9.06×10^{15} Btu
Wellhead thermal energy	46.72×10^{15} Btu

The most favorable or best case estimate of the available electrical energy, with allowance for progress in exploitation techniques and resolution of other resource constraints, is as follows:

1980	1.00×10^{6} Mwhr ≈ 0.7% of electrical needs
1985	1.06×10^{7} Mwhr ≈ 3.4% of electrical needs
1990	2.12×10^{7} Mwhr ≈ 5.9% of electrical needs
1995	3.16×10^{7} Mwhr ≈ 8.6% of electrical needs
2000	4.25×10^{7} Mwhr ≈ 10.4% of electrical needs

*All geothermal energy data and projections used in this report are taken from USGS Circular 790 unless otherwise noted.

The potential for direct use of geothermal energy below 302°F (150°C), to displace electrical use, is also of interest as these lower temperature resources are not economically suited for electric power generation. The USGS Circular 790 lists 56 geothermal resources in the BPA market area, whose reservoir temperatures are between 194°F (90°C) and 302°F (150°C). The total energy of these resources is estimated as:

Wellhead thermal energy	1.36×10^{17} Btu
Wellhead beneficial heat	3.24×10^{16} Btu

If this total energy (electric and nonelectric) could be exploited over a 20-year period, it could provide a portion of our total energy in accord with the following projections:

1980	2.50×10^{12} Btu ≈ 0.2% of total energy needs
1985	8.10×10^{14} Btu ≈ 42% of total energy needs
1990	1.62×10^{15} Btu ≈ 78% of total energy needs
1995	2.44×10^{15} Btu ≈ 111% of total energy needs
2000	3.25×10^{15} Btu ≈ 140% of total energy needs

Thus, these geothermal reservoirs have the <u>theoretical</u> potential of meeting and exceeding all of the BPA market area needs by the year 2000, disallowing the fact that most moderate temperature reservoirs are not proximate to large populations or direct-use loads. While no estimates are available from USGS, it is generally understood that potential geothermal energy from reservoirs below 194°F (90°C) is significantly greater than the others combined. Further, it should be kept in mind that USGS Circular 790 represents estimates current to its date of publication in 1978. The main body of geothermal resource knowledge is growing rapidly and the prospects are good for discovery of far greater resources. USGS estimates that nationally the undiscovered resources are five times the discovered and, in the Cascades are 20 times (due to masking by cold surface ground water).

The geothermal development estimates presented in this introduction are based upon an ideal or most favorable development schedule. A more realistic schedule, based upon typical institutional, environmental, and economic constraints, is presented in Section III of this report. The ideal schedule is presented here to show the relative potential of geothermal energy in the Pacific Northwest. With increasing fossil fuel prices and fluctuating supplies, improvements in resource extraction and utilization technologies, and a concerted effort by government and industry, geothermal energy in this region can become a significant alternative energy resource. Thus, the conservative development schedule presented in Section IV of this report may very likely be exceeded and approach the ideal described above.

II. GEOTHERMAL RESOURCE OVERVIEW

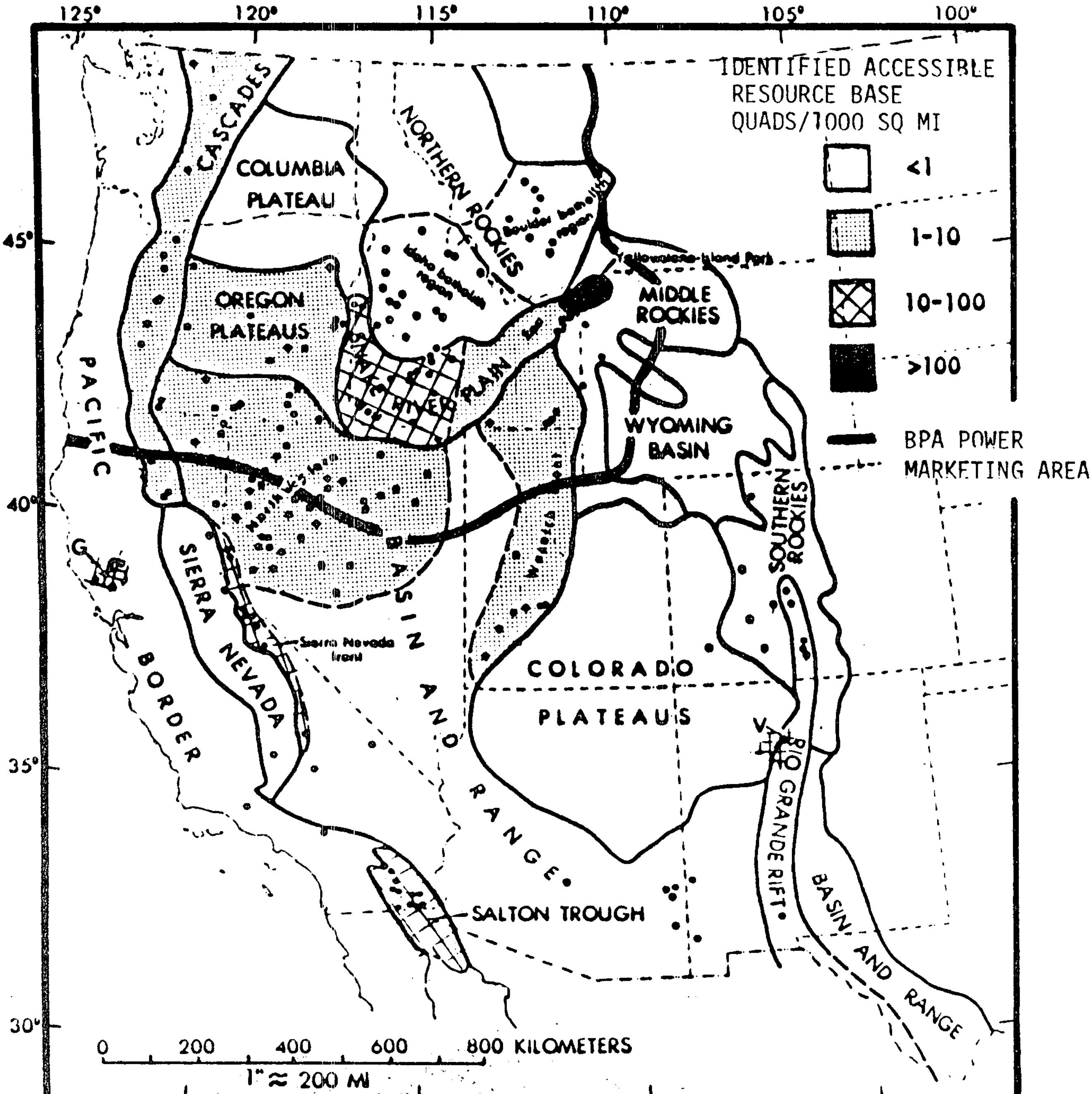
A. REGIONAL SUMMARY

The BPA market area covers all of three northwestern states and portions of five more. The approximate area and population of this region is as follows:

State	Area (mi^2)	Population
Oregon	97,000	2,500,000
Washington	68,000	3,500,000
Idaho	84,000	820,000
Northeastern California	10,000	25,000
Western Montana	60,000	350,000
Western Wyoming	15,000	10,000
Northern Nevada	45,000	25,000
Northwestern Utah	5,000	10,000
	384,000	6,760,000

The approximate boundary of the BPA market area is shown on the map in Figure 1 , which includes preference municipal and cooperative utilities, and non-preference investor-owned utilities. Superimposed on this map are the major geologic provinces of the region. Table 1 gives a summary of the accessible hydrothermal geothermal resources measured in 10^{18} Joule ($\simeq 10^{15}$ Btu = 1 quad) for the identified and undiscovered energy (Reference: USGS Circular 790). Based on the land area for each geologic province, an approximate ratio of identified energy to land area was calculated and indicated on the market area map.* As can be seen, the most intense energy potential per unit of land area is the Yellowstone caldera

*It should be realized that this energy is not uniformly distributed over each of these provinces; however, the relative comparison is useful for a rough overview.



Dots indicate locations of identified hydrothermal convection systems with reservoir temperatures ≥194°F (90°C), G = Geysers, V = Valles Caldera

Figure 1. Geologic Provinces of the Western United States.
(Reference USGS Circular 790)

TABLE 1.

Summary of the identified and undiscovered accessible resource base for geologic provinces of the Western United States. (Identified components includes energy in National Parks.)

Province	Accessible resource base (x 10^{18} J ≈ x 10^{15} Btu) Identified	Undiscovered
Pacific Border		
The Geysers-Clear Lake area--------------------	150	150
Other--	3	15
Cascades Mountains-----------------------------	57	1,140
Sierra Nevada Mountains------------------------	5	5
Columbia Plateau-------------------------------	0*	0*
Oregon Plateaus--------------------------------	80	400
Snake River Plain		
Western		
Central and southwest--------------------	470	940
Camas Prairie and northern margin---------	21	100
Eastern--	21	1,520
Yellowstone-Island Park------------------------	1,240	170
Basin and Range		
Northwestern-----------------------------------	280	1,400
Sierra Nevada front----------------------------	120	40
Wasatch Front and northeastern margin----------	67	170
Other--	12	60
Salton Trough----------------------------------	240	480
Rio Grande rift		
Valles caldera area----------------------------	87	87
Other--	6	60
Colorado Plateaus------------------------------	1	50
Rocky Mountains		
Idaho batholith--------------------------------	14	70
Boulder batholith------------------------------	11	55
Middle Rocky Mountains and Wyoming Basin-------	2	10
Southern Rocky Mountains-----------------------	5	25
Alaska		
Alaska Peninsula and Aleutian Islands----------	10	580
Central Alaska---------------------------------	11	220
Southeast Alaska-------------------------------	10	100
Other--	0	100
Hawaii---	9	45
TOTAL--	2,900	8,000

Reference: USGS Circular 790

*Some have been identified since 1978 by the state of Washington.

and surrounding area where over 1,240 quads of energy have been identified. The second highest potential area for geothermal is the western and central Snake River Plain. The next level of potential includes the Cascades, the Oregon Plateau, the Northern Basin and Range, the Eastern Snake River Plain, and the Wasatch Front. The remaining areas, even though low in energy potential, have many low-temperature resources (warm springs and shallow, warm ground water) that can satisfy many local energy needs. As an example, the Columbia Plateau includes an extensive low-temperature resource in the Yakima Valley that can be used with heat pumps.

A summary of the identified energy potential of hydrothermal convective systems by state is as follows (based upon USGS Circular 790 and various state reports):*

State	Electric Generation Potential MW_e	Thermal Potential (wellhead) MW_t	Thermal Potential (wellhead) $\times 10^{15}$ Btu/yr
Oregon	2,031	104,371	3.12
Washington	27	12,811	0.38
Idaho	366	304,893	9.12
Northeastern California	1,490	52,715	1.58
Western Montana	0	9,356	0.28
Western Wyoming	0**	4,037	0.12
Northern Nevada	163	50,417	1.50
Northwestern Utah	0	1,500	0.05
	4,077	540,100	16.15

It should be realized that only a fraction of this energy may be used due to economic, institutional, and environmental constraints. Much of this region is sparsely populated, and therefore geographically matching a resource with a user

*The energy remaining in identified igneous systems is summarized on page 11 of this report.

**Yellowstone caldera area excluded due to National Park status.

may be difficult. Moreover, the region's generally high environmental values and predominant federal land management authority may also significantly impede resource development. The projected actual or practical energy development potential will be addressed later in this report (Table 13).

In addition to the identified accessible resource base (up to 3 km [2 miles] deep and referenced to 15°C [59°F]) listed in Table 1, a substantial amount of geothermal energy remains undiscovered. These resources will be identified and confirmed by future geophysical and exploratory drilling work. The undiscovered portion is estimated to be from 2 to 20 times the identified portion, depending upon the data available. As an example, the undiscovered portion of the Cascades is estimated to be 20 times the identified due to masking by high precipitation and cold shallow ground water. A summary of the undiscovered portion is listed in Table 1 for each major geologic province.

USGS Circular 790 provides a list of areas favorable for discovery and development of low temperature (194°F = <90°C) geothermal water. Information on wells, springs, temperature, and dissolved solids is provided; however, no calculations of the energy potential of these low-temperature resources was made by USGS. The mapping which accompanies Circular 790 provides an approximation of the areal extent of the low-temperature resources based upon known wells and springs in the area. The areal extent, along with information from Circular 790 and various state reports, was used to make a preliminary estimate of the energy potential of each of these low-temperature resources.

Fortunately, detailed information is available for the Klamath Falls low-temperature resource; thus data from this example can be transferred to other areas to give the preliminary estimate of their potential. The energy potential of the Klamath Falls resource is calculated as follows:

1. Estimated wellhead thermal energy: 8.18×10^{18}J;
2. Estimated areal extent: 200 miles^2; and

3. The estimated wellhead thermal energy per unit area is:

$$\frac{8.18 \times 10^{18} J}{200 \text{ mi}^2} = \frac{7.8 \text{ Q*}}{200 \text{ mi}^2} \simeq 0.0388 \text{ Q/mi}^2 = 0.00129 \text{ Q/yr/mi}^2 = 1.29 \times 10^{12} \text{ Btu/yr/mi}^2.$$

Since this resource is estimated to have a mean reservoir temperature of 232°F (111°C), resources below 194°F (90°C) will have to have adjustments made for temperature. Thus, a resource less than 194°F (90°C) will be estimated at 0.020 to 0.030 Q/mi^2 (0.67 to 1.00 x 10^{12} Btu/yr/mi^2),** depending upon temperature and the estimated reservoir permeability.

In USGS Circular 790, if the resource is listed in both the above 194°F (90°C) category and below 194°F (90°C) category, the energy has already been included in the former estimate; thus no calculations need be made for the below 194°F (90°C) resource.

As a matter of interest, the Klamath Falls area uses only a peak of 1.3 x 10^8 Btu/hr (38.4 MW_t), and a total of 2.3 x 10^{11} Btu/year (7.8 MW_t). This could increase to around 300 MW_t peak use if the entire community were using geothermal for space heating. The wellhead potential is 8.18 x 10^{18}J over 30 years, or 2.95 x 10^{10} Btu/hr (8,640 MW_t). Thus, less than one-half of one percent of the local energy potential is being used at present, and less than four percent is estimated to be used in the future.

In addition to the hydrothermal systems identified by USGS and included in the previous table, a number of young igneous-related systems exist, due to the conductive cooling of magma, and are also listed in this table. These systems are assumed to be within 10 km of the surface, and are often referred to as hot dry rock systems, due to the lack of fluid to transfer the heat by convection. At present, work is being done by Los Alamos Scientific Laboratory in New Mexico to

*Q = quad = 10^{15} Btu, J = joule = 9.480 x 10^{-4} Btu.
**USGS Circular 790 uses 30 years as the reservoir life.

utilize these hot dry rock systems. Although this method is still in the experimental stages, and therefore not commercially usable, it does bear noting for possible future consideration. The igneous systems within the BPA market area and the total energy remaining in the system by state are as follows:

	x 10^{18}J	MW_e*
1. Northern California--Medicine Lake	724	181
2. Oregon--Crater Lake, Newberry, South Sister, Glass Buttes, Wait Peak Caldera, Frederick Butte area, Melvin-Three Creeks Buttes, Cappy-Burn Butte, and Bear Wallow Butte	1,445	361
3. Washington--Glacier Peak and Mount St. Helens** . . .	70	18
4. Idaho--Island Park System, Blackfoot Domes, Big Southern Butte, and Rexburg Caldera	25,730	6,432
5. Western Wyoming--Yellowstone Caldera System.	36,100	9,025
6. Northern Utah--None identified	0	
7. Western Montana--None identified	0	
8. Northern Nevada--None identified	0	
Total for BPA Market Area	≃ 64,000	≃ 16,000
or	≃ 64,000 quads	

Many of these igneous systems are located within national parks or environmentally sensitive areas and, therefore, even though the technology of extracting the heat may be solved, the resource may be restricted or eliminated from commercial use. However, future energy demands and public opinion may modify such institutional and environmental constraints.

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*Based on USGS Circular 790 (p. 34-35, 41), it is assumed only 1 percent of the igneous system energy is hydrothermal giving an estimate of 0.25 MW_e per 10^{18}J (10^{15} Btu).

**Mt. Baker not included, however, the state of Washington estimates there is potential that should be considered.

The single greatest institutional constraint to geothermal development in BPA's market area is the predominant land control of the U.S. Forest Service and BLM. Together these two agencies manage over 50 percent of the region's land area and, in turn, their geothermal environmental review and leasing programs represent the region's primary institutional mechanism for resource development. Unfortunately, these federal programs have been slowed by staff and budgetary constraints, competitive bidding requirements, and most significantly, by lengthy environmental procedures mandated by the National Environmental Policy Act of 1969. The extent and complexity of the federal programs are depicted in Charts 1 and 2,* which respectively describe the pre- and post-leasing processes. In summary, the BLM administers the leasing process on BLM and Forest Service lands, with each agency being responsible for environmental assessments on their respective lands, and with the Geological Survey being responsible for supervising post-lease production operations on all federal lands. Some of the specific concerns in recent years over improving federal geothermal resource management include:

1. Greater resource education and training for federal field managers;
2. Increased program priority and management commitment to geothermal development;
3. Shortened time limits for processing lease applications;
4. Amendment of the leasing process to allow more noncompetitive awards in certain areas;
5. Expediting of environmental reviews and prioritizing of areas with high geothermal potential;
6. Allowance for local governments and nonprofit entities to receive certain preferential treatment in nonelectric projects on federal lands; and
7. Allowance for federal agencies to develop and utilize geothermal resources contained on their own land for their own purposes.

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*These are found in the map pocket on back cover.

The environmental impacts associated with geothermal resources will vary dramatically, depending upon reservoir characteristics, intended end-use (electric vs. nonelectric), local environmental sensitivities, and legal procedures. The geographic scope of this report makes a thorough environmental assessment of each resource site impossible and, likewise, it is impossible to generalize about expected impacts over such a large and varied region. At best, the major environmental issues which are common to geothermal development can be identified, including land use, air pollution, subsidence, water pollution, induced seismicity, blowouts, noise, archeological disturbance, fish and wildlife degradation, and socio-economic changes. Table 2 reviews these topics to explain specific environmental concerns and subsequent requirements for resource development and use. It should be emphasized that most experiences with these issues have resulted from geothermal electrical projects, which have considerably more environmental impact than nonelectric direct-use projects. Chart 3 depicts a generalized network of cause-and-effect relationships for both types of geothermal utilization.

Table 2. Environmental Concerns and Guidelines for Hydrothermal Systems

Concern	Guidelines
1. Release of Airborne Effluents	
Hydrothermal fluids typically contain a number of compounds such as CO_2, NH_3, H_2S, CH_4, Rn, Hg, and B. These and other chemicals such as salts in cooling tower drift may be released to the atmosphere; impacts may occur on local ecosystems and on human health. H_2S is of particular concern because of its disagreeable odor (above 5 ppb) and toxic effects (above 20 ppm).	1.1. Identify and measure the levels of effluents that may be discharged during exploration, development, and utilization. 1.2. Establish baseline and monitoring networks for the most significant effluents, and develop new instrumentation as needed. 1.3. Develop models necessary to predict the transport, diffusion, and transformation of pollutants in complex terrain. 1.4. Develop dose-response data for effects on native and agricultural ecosystems and on human health.

Table 2. (Cont.)

Concern	Guidelines
	1.5. Assess the potential effects of effluent releases within a regional context for full-scale development, and develop environmental design criteria.
	1.6. Develop control technologies as needed to meet regulatory standards and environmental design criteria.
2. <u>Release of Waterborne Effluents</u>	
Large volumes of spent geothermal fluids and cooling tower blowdown will be generated. They may contain dissolved volatile compounds and large quantities of dissolved solids. The concern is for long-term disposal of such fluids so that beneficial sources of water are protected. Treatment may be required that results in solid waste generation.	2.1. Identify and measure the levels of effluents that may be discharged during exploration, development, and utilization.
	2.2. Establish baseline and monitoring networks for the most significant effluents, and develop new instrumentation as needed.
	2.3. Develop dose-response data for effects on aquatic ecosystems and human health.
	2.4. Assess the potential effects of effluent releases within a regional context for full-scale development, and develop environmental design criteria.
	2.5. Assess the consequences of accidental releases of effluents.
	2.6. Develop control technologies (surface and subsurface) as needed to meet regulatory standards and environmental design criteria.
3. <u>Noise</u>	
Uncontrolled noise levels associated with exploration and drilling, well venting and testing, and operational processes can reach levels as high as 120 dBA at the site boundary and may have deleterious effects on human populations and local fauna.	3.1. Develop noise abatement technologies as needed to meet noise ordinances and standards and environmental dissign criteria.

Table 2. (Cont.)

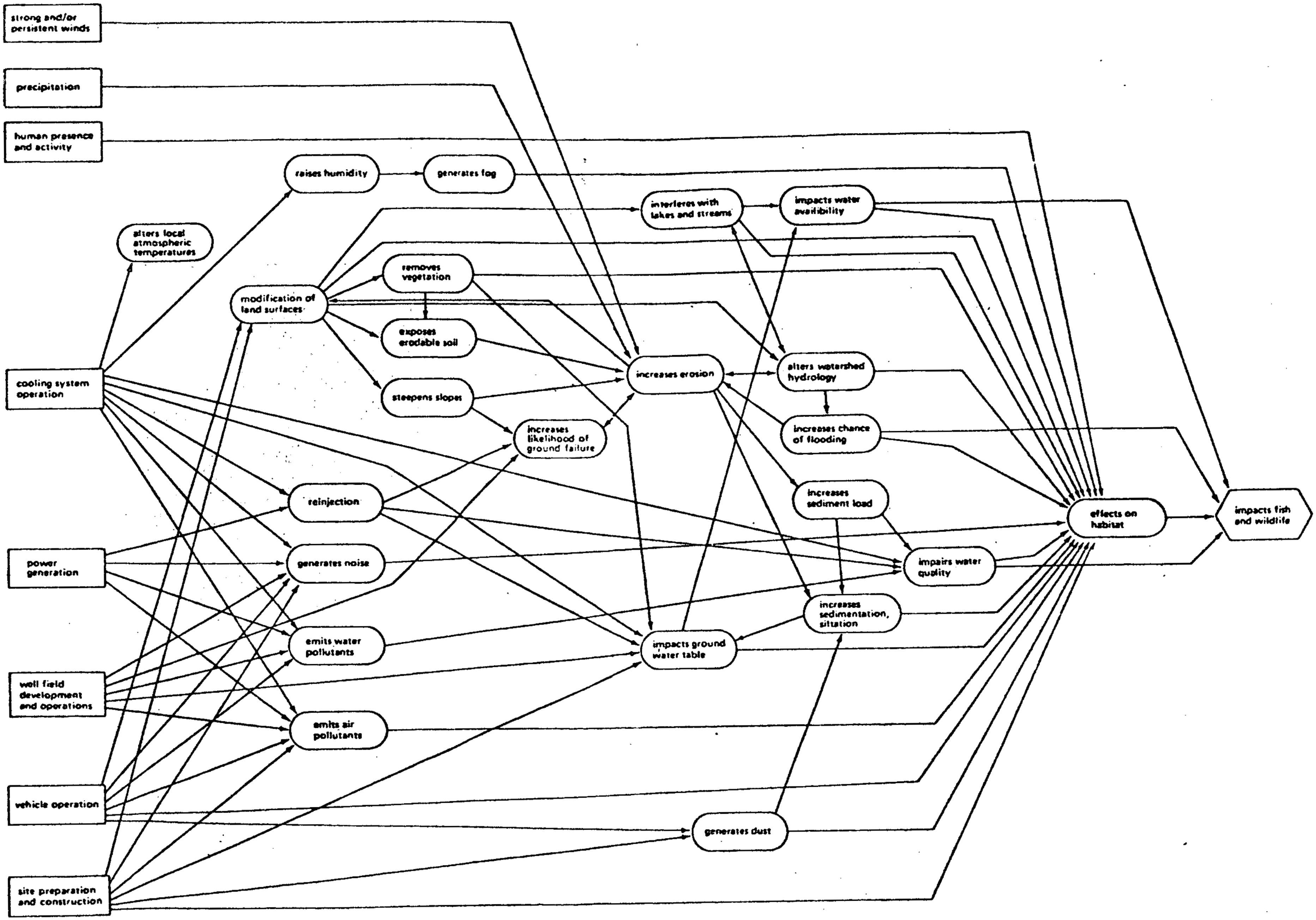
Concern	Guidelines
4. Subsidence	
The removal of large quantities of hydrothermal fluid may result in subsidence. The importance of subsidence will be site-specific; at locations such as the Imperial Valley, where the geothermal reservoirs are overlain with agricultural land, subsidence could have a significant impact.	4.1. Conduct preoperational and continuing measurements to establish rates of subsidence. 4.2. Conduct subsidence research program. 4.3. Verify efficacy of subsidence control techniques as needed.
5. Induced Seismicity	
The withdrawal and/or injection of hydrothermal fluids may enhance the frequency or magnitude of seismic events.	5.1. Conduct preoperational and continuing measurements to establish if seismicity is induced. 5.2. Develop and verify seismic control practices.
6. Water Use	
Many proposed methods of utilizing hydrothermal energy will require exogenous sources of water for cooling systems. As many hydrothermal resource areas are in semi-arid regions, conflicts may arise concerning the most beneficial uses of water.	6.1. Assess potential limitations on hydrothermal resource development due to water resource limitations.
7. Land Use	
Some hydrothermal developments may cause land use conflicts. They may threaten pristine wilderness areas; impact upon habitat of endangered, threatened, or recreationally important species; or conflict with other beneficial uses such as agriculture or recreation.	7.1. Identify local land-use policies and controls. 7.2. Assess site-specific conditions, including existing and proposed uses, and requirements for hydrothermal development. 7.3. Assist local authorities with integration of geothermal policies and performance standards into local plans and ordinances.

Table 2. (Cont.)

Concern	Guidelines
8. Flora and Fauna	
Some hydrothermal developments may threaten flora and fauna with habitat loss or disruption from construction and facility operations.	8.1. Identify flora and fauna baseline conditions in development areas. 8.2. Assess impacts on flora and fauna. 8.3. Develop mitigation strategies if appropriate.
9. Social Service and Community Structure	
All hydrothermal developments will have an impact through the demand for workers and the influx of money. This impact may be considered positive or negative depending upon the existing community structure and lifestyle, and may range from negligible to major depending upon the size of the development and the size and diversity of the local economy.	9.1. Conduct baseline surveys of demographic, social, economic, and political aspects of resource areas. 9.2. Assess labor requirements and secondary employment implications of full-scale development. 9.3. Predict local population shifts and assess housing requirements and increased community services needed to support a mature development. 9.4. Determine the relationship between expected revenues and expenditures for communities affected by development. 9.5. Develop strategies to mitigate adverse impacts and achieve maximum enhancement of beneficial impacts.
10. System Safety and Occupational Health	
The safety of hydrothermal energy extraction and utilization systems could become a major issue if early significant accidents occur. Problems relate to proper handling of the high-pressure fluids and secondary and tertiary fluids such as isobutane and propane that might be used in power plants.	10.1. Perform a system safety analysis of proposed methods for extracting and utilizing hydrothermal resources. 10.2. Develop safety design and occupational protection criteria to ensure safety of all aspects of facility construction and operation.

Chart 3.

Generalized Environmental Cause and Effect Relationships Attended to Geothermal Development



A detailed discussion of each state within the BPA market area follows below. The source of information includes USGS Circular 790 and various state geothermal reports. Personal contacts have been made with representatives in each state and with USGS personnel in order to supplement published information. The results are the most up-to-date summary available; however, the geothermal frontier is constantly expanding through field exploration and equipment development. Geothermal resource information changes almost daily, such that major discoveries and more efficient utilization techniques will certainly change the picture--most likely for the better.

B. OREGON

Oregon has a land area of 97,000 square miles and a population of slightly less than 2.5 million persons, the majority of which are located in the Willamette Valley. Agriculture, lumber products, manufacturing, mining, fishing, and tourism are the major industries. The state's population is projected to increase by 28 percent by the year 2000 to over 3.3 million persons.

There are five major provinces in the state that have potential for geothermal development: 1) Basin and Range, 2) High Lava Plains, 3) Owyhee Uplands, 4) Northeastern, and 5) the Cascade Range. Each of these is shown in Figure 2, and will be described in some detail below.

The Basin and Range area extends across southern Oregon from the Cascades to the Owyhee Upland, and is the northwestern portion of the Basin and Range province of the western United States. The topography is characterized by north-south trending normal faults creating alternating basins and ridges. The basins are covered with alluvial sediments and may contain shallow alkali lakes. The region has an outstanding potential for geothermal energy development with both electric and direct heat use possible. The source of geothermal energy is along these faults where hot water is brought to the surface by deep circulation. Two areas within

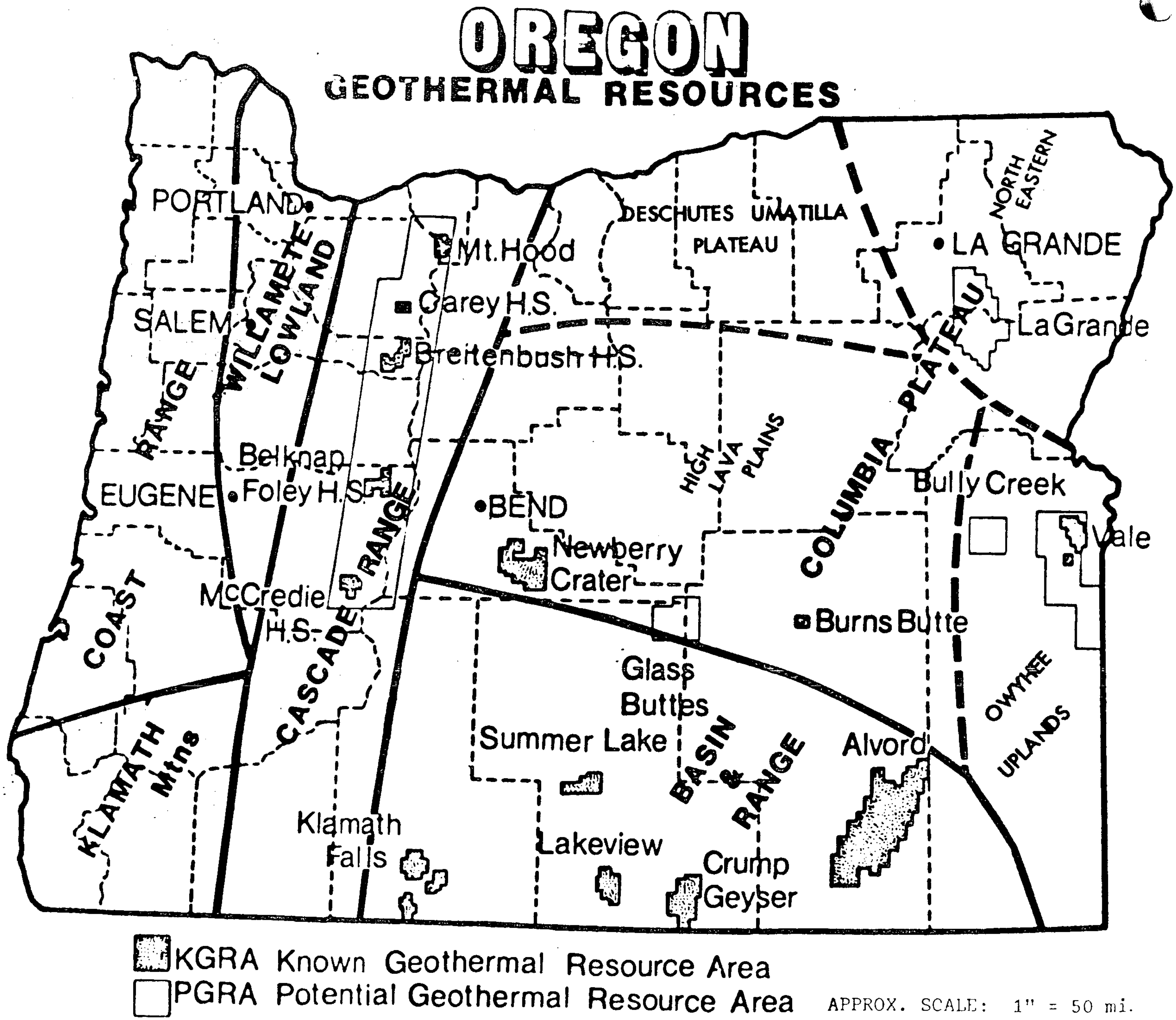


Figure 2. Oregon Geothermal Resources.

the region are presently using geothermal: Klamath Falls, where over 500 wells have been drilled and up to 38 MW_t (peak) is being used primarily for space heating; and Lakeview, where several wells are being used to heat a motel and a greenhouse complex. Both cities are planning district heating projects, with the Klamath Falls system presently under construction. Three other areas have potential: Summer Lake, Crump's Hot Springs, and Alvord Desert. Both Crump's Hot Springs and Alvord Desert have temperatures above 302°F (150°C).

The region is environmentally dominated by semi-arid range and grassland, and includes high air and water quality parameters, extensive wildlife habitat, widespread archaeological resources, and high scenic values. Land use is dominated by agriculture and stock grazing, with BLM managing a majority of the region's acreage. Urbanization is limited to the cities of Klamath Falls and Lakeview, and a few small ranching towns.

The High Lava Plains extend from the foot of the Cascade Range to the eastern border of the Harney Basin. The region is bounded on the north by the Blue Mountains and on the south by the Basin and Range province. The landscape is characterized by a smooth surface plain of lava flows marked in places by cinder cones and other volcanic surface features. The Brothers Fault Zone, a major structural lineament crossing the central area, appears to be related to the geothermal resources in the region. The main known geothermal source is Newberry Crater (caldera).* USGS suggests that Newberry Volcano has significant geothermal potential based on the probability of a shallow heat source situated directly under the caldera. The USGS is conducting an ongoing temperature gradient drilling program including holes within the caldera and on the flanks of the volcano. At present there is no use of the geothermal resources in this region; however, there

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*Powell Butte, near Bend has generated recent low-temperature interest; (Oregon Department of Geology and Mineral Industries and Francana Resources, Inc. of Denver.)

is interest at Burns and Hines to use a local geothermal resource, and there are numerous private leases that have been taken in the vicinity of the Brothers Fault.

Environmentally, the region is very similar to the Basin and Range province, with high natural values and urbanization limited to the cities of Bend and Burns. BLM is again the largest landowner. It should be noted that the Oregon Energy Facility Siting Council has declared the Newberry Crater as unsuitable for geothermal electric production because of environmental sensitivities; however, as noted above, this type of institutional constraint may be modified in the future under likely public pressure for energy resource development.

The Owyhee Upland area is east of the vast Snake River structural basin. The topography is similar to the Basin and Range region, except that the plateaus are generally older and more dissected and contain more sedimentary rocks. It is centered around the towns of Vale, Ontario, and Nyssa near the Idaho border. Geothermal potential appears to be high, especially at Vale, where a historical hot spring associated with the Oregon Trail is located, along with several geothermal wells used to heat homes and a greenhouse complex; district heating is also being considered. There also appears to be geothermal potential at Ontario and Nyssa; however, less is known of the resource there, as it has not been tapped. Agriculture (potatoes, sugar beets, and onions) are the main industry, and therefore nonelectric use of geothermal appears to have the highest near-term potential with electrical power generation the best long-term potential. The region's environment is composed primarily of privately owned row cropland and BLM range land; other environmental characteristics are similar to the foregoing regions.

The Northeastern portion of Oregon has some potential for geothermal development. Hot springs at Hot Lake, Medical Springs, Lehman Springs, and Haines have been used for years for bathing, therapeutical purposes, and limited space heating. Most of these springs outside of the Grande Ronde Valley appear to be associated with northwest-trending faults. Unfortunately, little is known about the extent and potential of the resource. Other geothermal uses in the area include a greenhouse complex at Cove used to raise tree seedlings and an alcohol plant operating near Hot Lake. Interest in geothermal space heating has been shown by the city of La Grande and Eastern Oregon College; however, the only resource confirmed in the La Grande area is at Hot Lake. The northeastern environment is heavily forested, with lesser amounts of agricultural and range land. Water and air quality is generally good and wildlife is extensive. Urbanization is limited to the cities of La Grande and Baker.

The Oregon Cascade Range is divided into two distinctive belts, the Western Cascades and the High Cascades. The latter belt on the eastern flanks of the range is composed of the youngest volcanic rocks, whereas the Western Cascades are older and more eroded. The major hot springs of the Cascades are founded in the older belt and are suggested to be controlled by a north-trending fault. The major thermal springs are Carey, Breitenbush, Belknap, Foley, and McCredie. In addition to the hot springs, many of the Cascade composite volcanoes have geothermal potential, the most notable being Mt. Hood. The actual Cascades are sparsely populated; however, approximately two-thirds of the state's 2.5-million population is situated within the western "shadow" of the geothermal resources, in the major population centers of Portland, Salem, and Eugene. A number of entities are actively investigating the geothermal potential of the area, including USGS, Oregon Department of Geology and Mineral Industries, Eugene Water and Electric Board, Northwest Natural Gas Company, the U.S. Forest Service, and the city of Oakridge. Drilling has started at two projects located on Mt. Hood, where Northwest National Gas Company hopes to supply hot water through a 40-mile, 42-inch diameter pipeline to the Portland area, and Wy'East Exploration is attempting to heat Timberline Lodge. The development of the Cascade Range geothermal resources has the greatest potential to assist Oregon's energy needs due to the relative proximity of the state's largest population centers.

However, this potential is severely constrained by the region's forested environment, which is principally managed by the Forest Service. The high natural values of this region, including its flora and fauna, scenic qualities, and often roadless character, present a formidable barrier to near-term resource development. A notable exception is the Cascade community of Oakridge (population 5,000), where geothermal investigations indicate a near-term feasibility for district heating.

A summary of the geothermal resource potential in the state is as follows:

	Electrical Potential MW_e Hydrothermal	Electrical Potential MW_e Igneous	Thermal Potential (wellhead) MW_t
1. 302°F (>150°C)	2,031	(361)	21,952
2. 302°-194°F (150°-90°C)	---	---	14,312
3. 194°F (<90°C)	---	---	68,107
Total	2,031	(361)	104,371
			$= 3.12 \times 10^{15}$ Btu/yr

Legal and institutional requirements for geothermal development in Oregon vary according to land and mineral estate ownership. Federal land access is controlled through BLM leases on both BLM and Forest Service lands. State-owned lands are administered through leasing by the Division of State Lands. Privately owned lands are accessible through subsurface leasing or outright purchase. All nonfederal projects are generally subject to the following explorational and developmental requirements:

1) Conformance with city or county land-use plans and ordinances;

2) Conformance with any applicable local building permit requirements;

3) Drilling permits from either the Deparment of Geology & Mineral Industries, if the well is expected to encounter temperatures above 250°F (121°C) or be drilled to depths greater than 2,000 feet, or from the Department of Water Resources, if the well is expected to encounter lesser temperatures or will be drilled to lesser depths;

4. Disposal permits from the Department of Environmental Quality for drilling mud, solid wastes, or geothermal fluids; and possibly for injection of spent geothermal fluids and;

5) Siting certificate from the Energy Facility Siting Council if a thermal power plant (>25 MW_e) or large pipeline (>5 mi. long and >6 in. diameter) is involved.

C. <u>WASHINGTON</u>

The state of Washington has an estimated population of over 3.5 million persons and a land area of over 68,000 square miles. The majority of the state's population (52 percent) is centered along Puget Sound in the Everett-Seattle-Tacoma area. Statewide population is projected to increase 30 percent to slightly over 5 million persons by the year 2000. The state has six main land regions: 1) the Olympic Mountains, 2) the Coast Range, 3) the Puget Sound Lowland, 4) the Cascade Range, 5) the Columbia Plateau, and 6) the Okanogan Highlands (see Figure 3). Only the Olympic Mountains, the Cascade Range, and the Columbia Plateau have significant geothermal potential, and are discussed in detail below.

The <u>Olympic Mountains</u> rise to almost 8,000 feet and are one of the most rugged parts of the United States. The majority of the area lies within the Olympic

Geothermal Resources of Washington

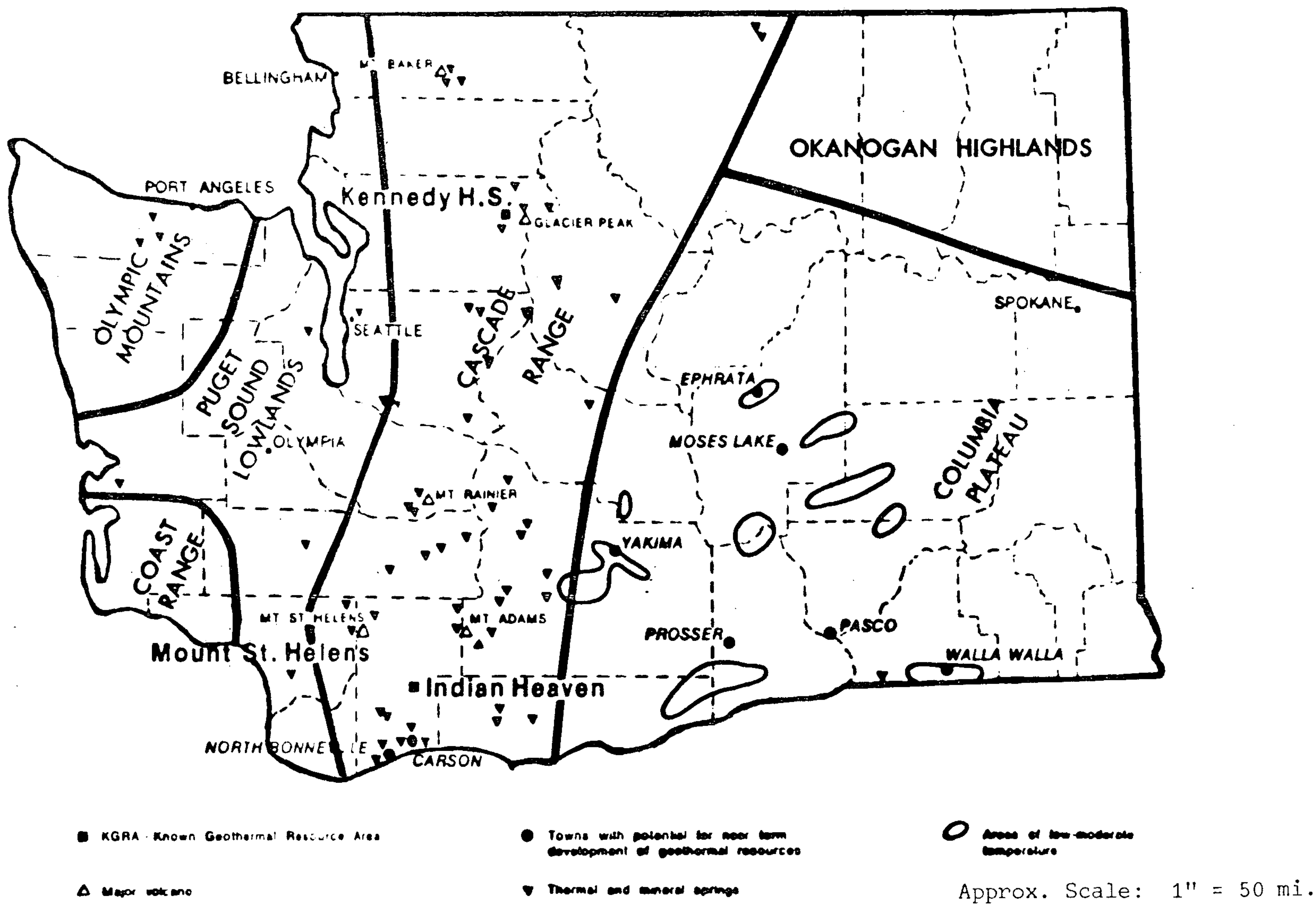

Figure 3. Geothermal Resources of Washington.

National Park and Olympic National Forest, with the chief industry of the region being logging. The identified geothermal resource is located at Olympic and Sol Duc Hot Springs within the northern boundary of the National Park; however, neither are classified as Known Geothermal Resource Areas (KGRA) by USGS. At one time both hot springs were developed resorts with pools and overnight accommodations, but Olympic has now been returned to its natural condition by the park service; Sol Duc still consists of one mineral and one freshwater pool, 62 overnight accommodations, and other support facilities. Plans to upgrade and modernize the facilities by the park service are now under consideration including using geothermal for space heating. Reservoir temperatures have been estimated at 194° to 302°F (90° to 150°C) based on geochemistry.* The heat is due to deep circulation along steeply dipping faults. The Olympic environment, as indicated by the National Park jurisdiction, is a pristine forested area with very high natural values which may likely impede any major resource development.

The Cascade Range separates the state into an east and west section and is part of the mountain chain that runs from California to British Columbia. The range is noted for many impressive andesitic strato-volcanic mountains including Mt. Rainier, Mt. Adams, Glacier Peak, Mt. St. Helens, and Mt. Baker. These peaks vary from slightly under 10,000 feet to slightly over 14,000 feet in elevation. Several have had major eruptions or exhibited hot spots in the past 100 years, including the recent St. Helens eruptions. The three known geothermal resources over 194°F (90°C) in Washington are located in this range: Gamma Hot Springs, 329°F (165°C), Baker Hot Springs, 273°F (134°C), and Ohanapecosh Hot Springs, 261°F (127°C). The latter is located in Mt. Rainier National Park and thus has been withdrawn from exploration or commercial development. In addition to the strato-volcanoes, a number of basaltic volcanic centers appear

*State of Washington data.

to be geothermally important. These are the Indian Heaven fissure zone area, the King Mountain fissure zone area, and the Simcoe Mountain area, all located in the southern part of the Washington Cascades (Reference: Washington #1). Indications that hot rocks and perhaps magma still exist at depth are shown by several thermal and mineral springs associated with the strato-volcanoes. No significant commercial developments have been made of the geothermal resources in the Cascades, despite this region having the greatest energy potential in the state.

But as with Oregon's Cascade region, the heavy forestation, with its inherent environmental sensitivities, may significantly impede near-term resource development. The combination of rugged topography, abundant flora and fauna ecosystems, high air and water qualities, and protective recreational interests, may require considerable predevelopment analysis and extensive mitigative measures during utilization. Urbanization, as in the Oregon Cascades, is limited to several small logging communities. Presently the only community associated with this region which is actively considering geothermal is the new city of Bonneville on the Columbia River, where district heating is a possibility; private developments at Bonneville Hot Springs are also active.

The Columbia Plateau covers most of central and southeastern Washington. This great basin lies from 500 to 2,000 feet above sea level and makes up part of the largest lava plateau in the world. Glacial-melt waters cut coulees (dry canyons) and eroded lava plateaus to form scablands north and east of the Columbia River. The greatest part of the area is devoted to productive agriculture based on dry farming and some irrigation. Fruit, grain, potatoes, and sugar beets are the major crops. The balance of the region is largely range or grassland supporting ranches and several small communities. Urbanization includes Yakima, Ellensburg, Moses Lake, Ephrata, Prosser, and Walla Walla. Large portions of the region are under the jurisdiction of the Yakima Indian Reservation and the U.S. Military

Firing Range. Common environmental characteristics include high air and water quality parameters, widespread archaeological resources, and high scenic qualities.

A low-temperature geothermal resource underlies the entire area (86°F or <30°C) as verified by more than 200 irrigation wells with depths under 2,000 feet. The source is due to circulation in the Yakima Basalt subgroup which is overlain by low-conductivity sediments, possibly a region of anomalously high heat flow from the mantel. Yakima, Ephrata, and Walla Walla are the urban areas identified with the resource. A proposal from the city of Ephrata is now pending with HUD for funding of a heat pump space heating system which will operate from hydrothermal water in the municipal drinking water system. There also appears to be low-temperature geothermal potential at Spokane in the north, near Prosser in the south, and Clarkston in the east.

A summary of the state's geothermal resource potential is as follows:

	Electrical Potential* MW_e		Thermal Potential (wellhead)* MW_t
	Hydrothermal	Igneous	
1. 302°F (>150°C)	27	(18)	332
2. 194°-302°F (90°-150°C)	---	---	285
3. <194°F (<90°C)	---	---	12,194
Total	27	(18)	12,811
			= 0.38 x 10^{15} Btu/yr

* Does not include National Parks.

The legal and institutional factors affecting geothermal development in Washington are similar to those described for Oregon, including a state regulatory distinction between high and low temperatures. The Department of Natural Resources exercises permitting authority over wells producing fluids capable of generating electricity, and the Department of Ecology is responsible for all other lower temperatures which are treated as ground water wells. Washington has not yet adopted leasing procedures for state-owned lands, but draft regulations are presently under consideration. In addition, state agencies are presently preparing a geothermal policy plan which will be submitted to the Legislature in August, 1980. A statewide geothermal symposium was held in June, 1980, and another conference specifically for local officials will be conducted in September, 1980.

D. IDAHO

Idaho has an approximate area of 84,000 square miles and a population of 820,000 persons, the majority of which are located in the Snake River Plain in the southern part of the state. The state's population is projected to increase 37 percent by the year 2000, to over 1.2 million people. The state can be subdivided into three main geologic provinces: 1) The Snake River Plain, 2) the Rocky Mountains, and 3) the Basin and Range region. These areas are delineated in Figure 4, and discussed in detail below.

The Snake River Plain follows the sweep of the Snake River across southern Idaho. This Plain was built up from many lava flows that erupted from fissures in the earth's surface and covers a 20- to 40-mile strip on each side of the Snake River. The Snake River Plain is a large volcanic-tectonic down-warp with young extrusive volcanics, particularly in the northeastern part. Thermal waters are found along the margins of the plain, but individual reservoir size and the resource extent under the volcanics are not known. Some deep drilling has been done in the plains to over 10,000 feet with limited success (Ore-Ida well at Ontario, Oregon, and INEL well near Idaho Falls). The main limitation appears to be available fluid for heat transfer and the depth of the basement rock. The area is dry, especially the southwestern portion; and, therefore, much of the

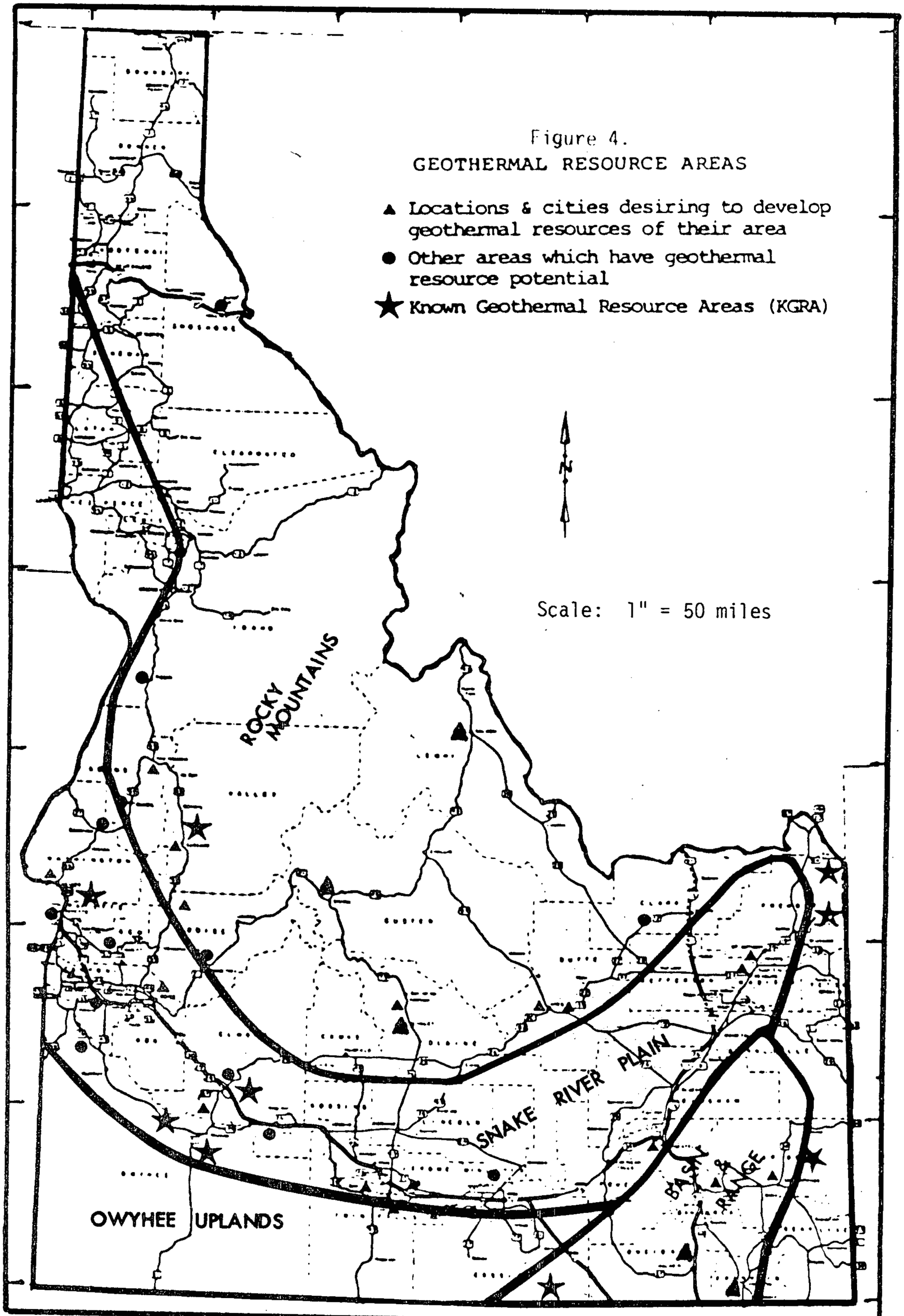
Figure 4.
GEOTHERMAL RESOURCE AREAS
▲ Locations & cities desiring to develop geothermal resources of their area
● Other areas which have geothermal resource potential
★ Known Geothermal Resource Areas (KGRA)
N
Scale: 1" = 50 miles
ROCKY MOUNTAINS
SNAKE RIVER PLAIN
BASIN & RANGE
OWYHEE UPLANDS

agriculture depends upon irrigation, with farming and livestock raising being the main industries. Two of the largest (energy potential) geothermal areas in Idaho are located in this province (Crane Creek-Cove Creek area and Bruneau-Grand View area). Outside of the Yellowstone caldera in Wyoming, the Bruneau-Grand View area has the largest energy potential in the United States (4.07×10^{11} Btu/hr or 1.19×10^5 MW_t). The Crane Creek-Cove Creek area has temperatures suitable for electrical generation; however, due to Federal Fish & Wildlife Service, environmental constraints, erosion, and steam siltation, this may be limited to 100 MW_e. Major uses of geothermal energy in the area include space heating at Boise, heating of greenhouses and a swimming pool at Weiser Hot Springs, and a catfish farm at Buhl. Geothermal water at 170°F (77°C) has been used in Boise for space heating since 1892. In addition to the homes being heated along Warm Springs Avenue, the State of Idaho Health & Agriculture Laboratories have been successfully converted from natural gas to geothermal water with resulting savings of about 60 percent over natural gas and no technical problems. Numerous other developments are being considered for the Boise area including federal, state, and locally funded district heating projects for the Capitol Mall and the central business district. Approximately 300×10^9 Btu/year (10 MW_t) of direct geothermal energy could be utilized by public buildings in the Boise Barracks and Capitol Mall areas by 1985. Other area developments presently being considered are space heating of a college and subdivision in Twin Falls; the expansion of a 65-home heating district in Ketchum; and an industrial park at Magic.

In comparison to most other Pacific Northwest geothermal regions, Idaho's Snake River Plain has a relatively more urbanized environment, with over ten cities colocated with geothermal resources. Nonetheless, the region as a whole is sparsely settled, and still retains high levels of natural environmental values.

This combination of population centers and attractive environment is certain to sustain the area's presently high growth rate and, therefore, may likely result in major near-term geothermal utilization.

The Rocky Mountain province has some of the most rugged areas in the United States, and some of the most pronounced and inhibiting environmental constraints. The rock units consist of intrusive granites forming a large batholith. High heat flow along with deep circulation of fluids along faults in the granitic rock account for most of the hot springs in the area. Big Creek Hot Springs is the highest temperature resource (324°F = 162°C); however, it is isolated in the Salmon River area along the Idaho-Montana border. The other major resource of interest in the Rocky Mountain province is the Island Park area adjacent to Yellowstone Park. This resource has over 5 quads* of wellhead thermal energy potential and is being investigated in detail by USGS, but there is environmental concern over its use, especially as to its effect on the natural phenomena of Yellowstone Park geysers. Numerous smaller resources (hot springs and wells) are located in the southern portion of the Idaho Wilderness area and along the Wyoming border. There appears to be very little resource in the northern panhandle region of the state. Outside of some bathing, little use is made of the resource in this province at present. There is very little urbanization, and natural environmental values are consistently high.

The Basin and Range region lies between the Snake River Plain and the Rocky Mountains, as a northern extension of the major geologic region of Utah and Nevada. Environmental characteristics are similar to those described for Oregon's Basin and Range province. Deep valleys and grassy plateaus lie among the region's mountains. Urbanization is limited to several small communities in the southeastern portion of the state. Natural environmental values remain high among

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*Estimated from USGS Circular 790 data on the thermal energy remaining on the igneous system.

local agricultural and ranching land uses, with several relatively small national forests located at upper elevations. The geothermal resources are somewhat limited, but major research and development has taken place at the U.S. Department of Energy (DOE) test facility at Raft River. Here, several wells have been drilled up to 5,500 feet, encountering up to 300°F (140°C) fluid. Production zones of geothermal fluid occur between 3,600 and 5,900 feet. Test facilities which have been built here include crop-growing and aquaculture projects, an alcohol plant, and a 5 MW_e dual-boiling, binary-cycle power plant (under construction). The work is under the direction of the Idaho National Engineering Lab (INEL) and EG&G Idaho Inc. Another area of interest is Lava Hot Springs south of Pocatello where low-temperature (140°F = 60°C) water and shallow wells (20 to 100 feet) are used to heat a health spa, swimming pool, and numerous buildings. The city of Malad plans to deepen their 610-foot deep high school well in the hopes of increasing the present 72°F (22°C) water temperature.

A summary of the geothermal resources in the state is as follows:

	Electrical Potential MW_e: Hydrothermal	Electrical Potential MW_e: Igneous	Thermal Potential (wellhead) MW_t
1. >302°F (150°C)	366	(6,432)	4,307
2. 302°-194°F (150°-90°C)	---	---	135,586
3. <194°F (90°C)	---	---	165,000
Total	366	(6,432)	304,893
			= 9.12×10^{15} Btu/yr

The legal treatment of geothermal resources in Idaho is premised on their potential for affecting water and, therefore, primary regulatory authority lies with the Department of Water Resources. As in Oregon and Washington, a distinction between high- and low-temperature resources is made with high temperatures (energy or mineral sources) requiring a geothermal resource permit, and low temperatures (specified by certain direct uses) requiring only a water right permit; however, it is often recommended that a single project obtain both types of permits in order to protect the project's appropriative water rights.

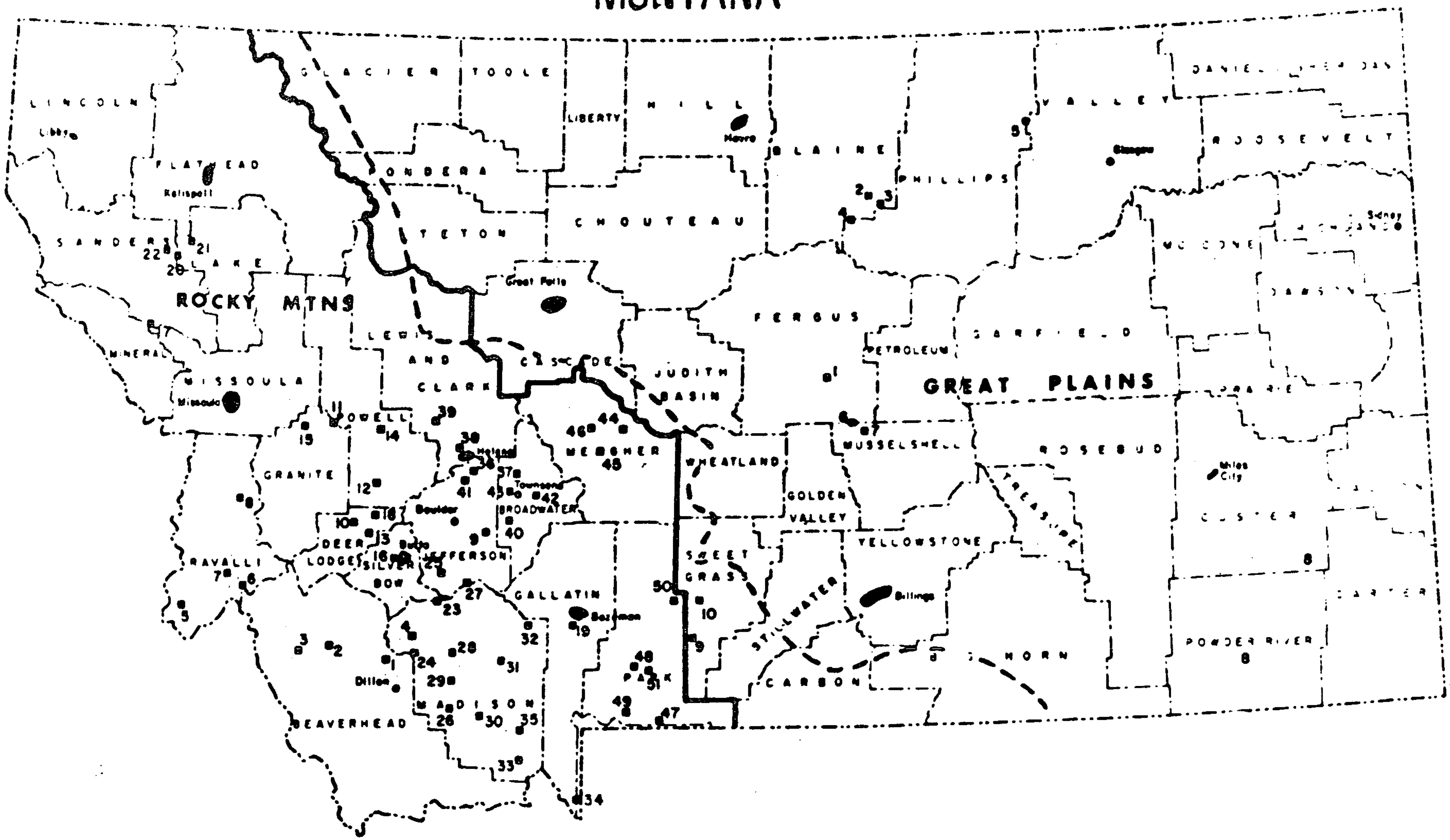
E. WESTERN MONTANA

Montana has two major land regions: the Great Plains in the eastern part of the state and the Rocky Mountains in the western part. The majority of the geothermal resources is located in the eastern portion of the state (see Figure 5). Lumber production is the prime economic force in the northwest and mineral production in the southwest. The majority of the mineral deposits is associated with the Boulder Batholith extending south of Helena. The western part of the state has a current population of slightly over 250,000 people, with major population centers of Missoula, Butte, Helena, and Bozeman. The statewide population is projected to increase 18 percent by the year 2000 with the western portion of the state increasing to slightly over 300,000 persons.

All of these urban areas, except Missoula, are located near confirmed geothermal resources, giving them potential for near-term utilization. The majority of the region's land area is rugged and heavily forested. Air and water quality is generally good, scenic qualities are high, wildlife is abundant, and recreational use is substantial. The Forest Service is the dominant federal land management agency in the region.

The geology of the region can be divided into two major rock types: crystalline rock of igneous and metamorphic in the southwest and metamorphic rock of argillite and quartzites with interbedded limestone in the northwest. All of these rock units were highly deformed in several major tectonic events.

MONTANA



GEOTHERMAL RESOURCES RELATIVE TO POPULATIONS DISTRIBUTION Approx. Scale: 1" = 60 mi.

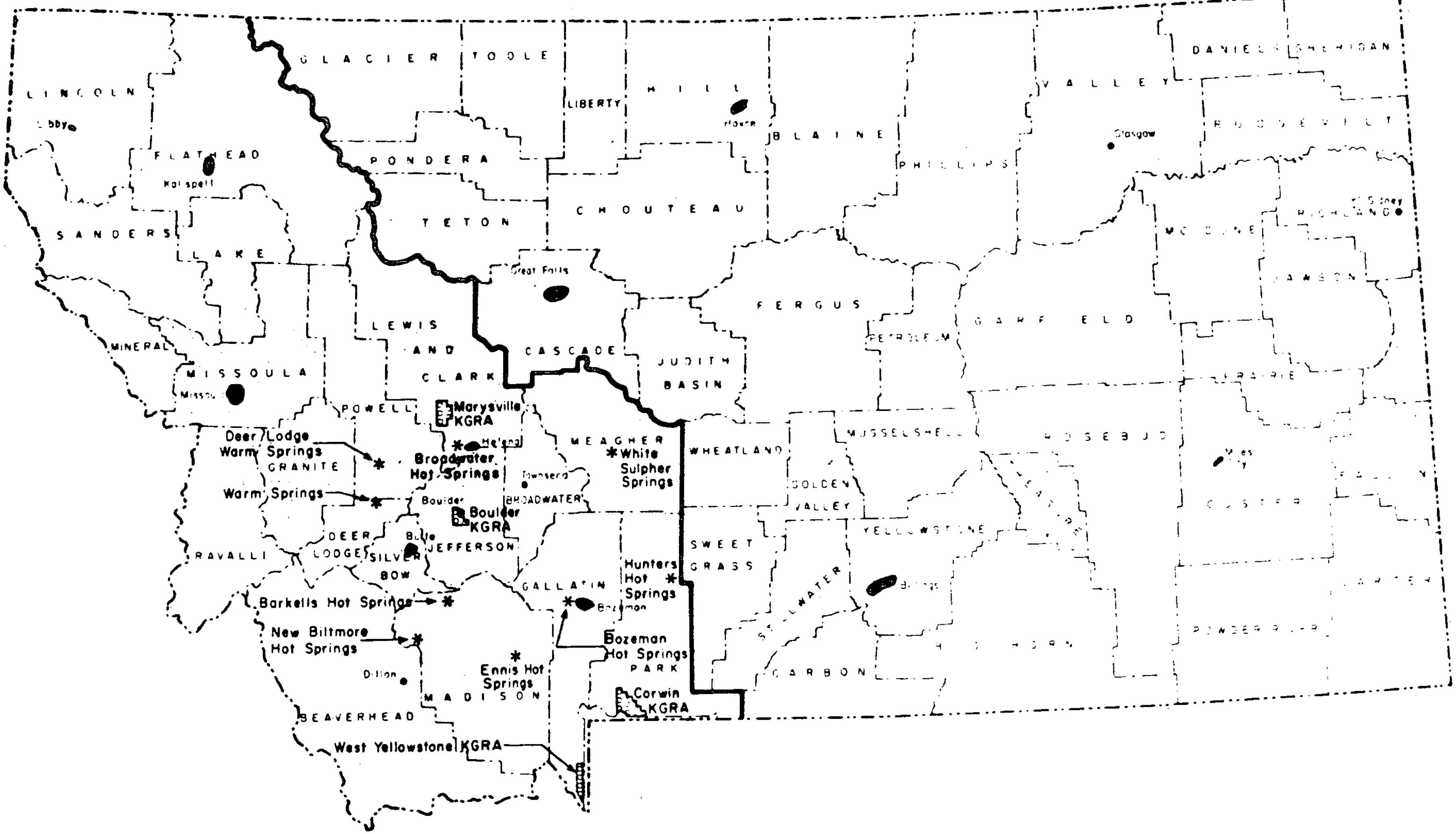
Figure 5. Geothermal Resources of Montana.

The geothermal resources are concentrated in the southwest, with surface manifestations consisting primarily of isolated, low-volume hot springs. So little is known about detailed subsurface geology in the complicated western region that estimates of reservoir capacity are questionable. A formation could be limited to slightly fractured granitic rocks which allow transport of minor amounts of water to deep levels, or a major fault system with massive fracturing and recent intrusives which could supply significant quantities of hot water. In addition, valley sediments would tend to mask any possible major resource. Geothermometry for the major spring areas in Yellowstone caldera indicates that subsurface temperatures as high as 400°F (204°C) are possible. The highest surface spring temperature outside of Yellowstone Park is slightly over 180°F (82°C). There are over 100 known thermal springs in Montana, falling into the following ranges:

>150°F	(66°C)	7 springs
130°-149°F	(54°-65°C)	6 springs
110°-129°F	(43°-54°C)	13 springs
90°-109°F	(32°-43°C)	7 springs
<90°F	(32°C)	remaining springs

Approximately 13 sites in Montana appear to have potential for geothermal development, mainly for direct application use as shown in Figure 6 (Reference: Montana #1). These include Barkells (Silver Star) Hot Springs, Boulder Hot Springs, Bozeman Hot Springs, Broadwater Hot Springs (Helena), Corwin Springs, Deer Lodge Warm Springs, Ennis Hot Springs (Thexton), Hunter's Hot Springs, Marysville KGRA, New Biltmore Hot Springs, Warm Springs, West Yellowstone KGRA, and White Sulfer Springs. A number of these sites have been used for heating swimming pools and adjacent buildings with some still in operation. A state mental hospital at Deer Lodge used Warm Springs for space heating for almost 100 years, but the system was abandoned in 1950. Much interest was focused on the Marysville KGRA in the early

MONTANA



GEOTHERMAL STUDY SITES Approx. Scale: 1" = 60 mi.

Figure 6.

1970's, when a 6,600-foot-deep well was drilled into a high heat flow anomaly (3 to 20 HFU). The site did not turn out as expected, as only 217°F (103°C) maximum was obtained, and the well was isothermal below about 3,500 feet. Interest has been expressed for greenhouse heating and space heating at many sites. At present, a U.S. DOE-funded project is renewing the heating of the State Mental Hospital at Deer Lodge; this demonstration includes drilling one production well to produce 170°F (77°C) water for space heating and domestic hot water, with the discharge water to be used for the creation of wetlands for migratory water fowl. Interest has also been generated at White Sulfer Springs for heating the First National Bank and other structures in the community.

Despite resources near Butte, Helena, and Bozeman, most of the geothermal resources in Montana are not located near major population centers. In addition, the majority of the industry in the western part of the state is concerned with mineral extraction, which would not require great amounts of low-temperature geothermal energy. The uses most suited for using low-temperature geothermal energy include crop drying; feed pelleting; greenhouse heating; aquaculture; space heating; and pulp, paper, and wood-product drying.

A summary of the geothermal resources in western Montana is as follows:

	Electrical Potential MW_e		Thermal Potential (wellhead) MW_t
	Hydrothermal	Igneous	
1. >302°F (150°C)	---	---	---
2. 302°-194°F (150°-90°C)	---	---	2,862
3. <194°F (90°C)	---	---	6,494
Total	---	---	9,356
			= 0.28×10^{15} Btu/yr

In Montana geothermal resources are treated as ground water for purposes of well permitting, which is administered by the Department of Natural Resources & Conservation (DNRC). In addition, all uses of geothermal waters (both high and low temperatures) are subject to a Facility Siting Act administered by DNRC, which is intended to assure that any geothermal construction or operation is environmentally sound; exemptions for certain small-scale, low-temperature uses are presently under consideration.

F. WESTERN WYOMING

Western Wyoming is a sparsely populated area dependent upon ranching, timber, and tourism for its economic livelihood. The area is part of the Rocky Mountains, with Grand Teton National Park and Yellowstone National Park located in its northwest corner. The entire area has less than 10,000 persons, with many residents being seasonal. Jackson, with a population of slightly over 2,000 persons, is the largest community. Natural environmental values are generally high throughout the region.

The Yellowstone caldera area in Yellowstone National Park is estimated to have a mean reservoir temperature of 513°F (267°C) and a mean reservoir thermal energy of 1,240 x 10^{18}J (1,240 quads), which represents the largest concentration of geothermal energy in the country. More than 10,000 geysers, hot springs, and fumaroles have been identified as surface manifestations of this hydrothermal system. At least one vapor-dominated system (Mud Volcano) of limited extent has developed over the hot-water system. The area is withdrawn from commercial exploration or development because of national park status (Reference: Wyoming #1).

Outside of the National Park, three resources between 194° and 302°F (90° and 150°C) have been identified: Huckleberry, Granite, and Auburn Hot Springs. Numerous other smaller hot springs also exist in the area. Auburn and Huckleberry

Hot Springs both are estimated to have the state's only potential for electrical generation;* however, Huckleberry Hot Springs is located in the John D. Rockefellar Jr. Memorial Parkway, and thus it is doubtful that any development other than recreation will be possible. Auburn Hot Springs (144°F = 62°C surface) is located on a major fault system. Subsurface temperature is estimated to 300°F (149°C), which is similar to Raft River where a 5 MW_e electrical generation plant is being constructed. As a result, several companies have acquired leases in the vicinity of the hot springs.

The only use of the geothermal water in the area is for swimming pools and heating water for a U.S. Fish and Wildlife Fish hatchery (near Jackson).

The state's geothermal resources are summarized as follows:

	Electrical Potential* MW_e		Thermal Potential (wellhead)* MW_t
	Hydrothermal	Igneous	
1. >302°F (150°C)	---	---	---
2. 302°-194°F (150°-90°C)	---	---	637
3. <194°F (90°C)	---	---	3,400**
Total	---	---	4,037
			= 0.12 x 10^{15} Btu/yr

*Does not include national parks (Yellowstone Caldera area).
**Numerous small springs exist, however their potential is questioned.

G. NORTHWESTERN UTAH

Northwestern Utah includes portions of the Basin and Range province (northwest), and is bordered on the east by the Rocky Mountains (northeast). The Great

*Wyoming Department of Energy Estimate.

Salt Lake is located in the center of the region. The area north of the 41st latitude and the west part of the panhandle consists of 5,000 square miles and a population of slightly under 10,000 persons. The region is a combination of range or grassland and mountainous forests. Natural environmental values are generally high throughout the region.

Numerous wells and hot springs of less than 194°F (90°C) temperature exist in northern Utah with the most promising area being in Cache Valley around Logan and along the Wasatch Front.* The Wasatch Front is the boundary between the Rocky Mountains and the Basin and Range physiographic province. The geothermal resources are mainly to the west of this front, in a series of north-trend grabens. The source of the geothermal heat is due to deep circulation along fault zones, with fluids having from 1,000- to 45,000-ppm dissolved solids. The highest known surface temperature encountered in the area is 120°F (49°C). A geothermal test well (drilled by Utah Power & Light and Geothermal Kenetics) in Lower Bear River Valley encountered 221°F (105°C) at 11,000 feet. Numerous oil and gas wells have been drilled in the region; however, none have encountered temperatures above 221°F (105°C). No significant geothermal resources appear to exist in the northwest corner of the state except for a possible relationship to the extension of the Battle Mountain High of Nevada.

The hot springs that appear to be of interest in the area are Udy (Belmont), Crystal (Madsen), Utah, and Little Mountain-South. The present owners of Udy Hot Springs (now Belmont Springs Park) are developing a resort where thermal water is used to heat a swimming pool and resort clubhouse.

In summary, the known occurrence of thermal water is found at the margins of grabens and where bedrock is relatively close to the surface over horsts that

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*See Utah Reference #1

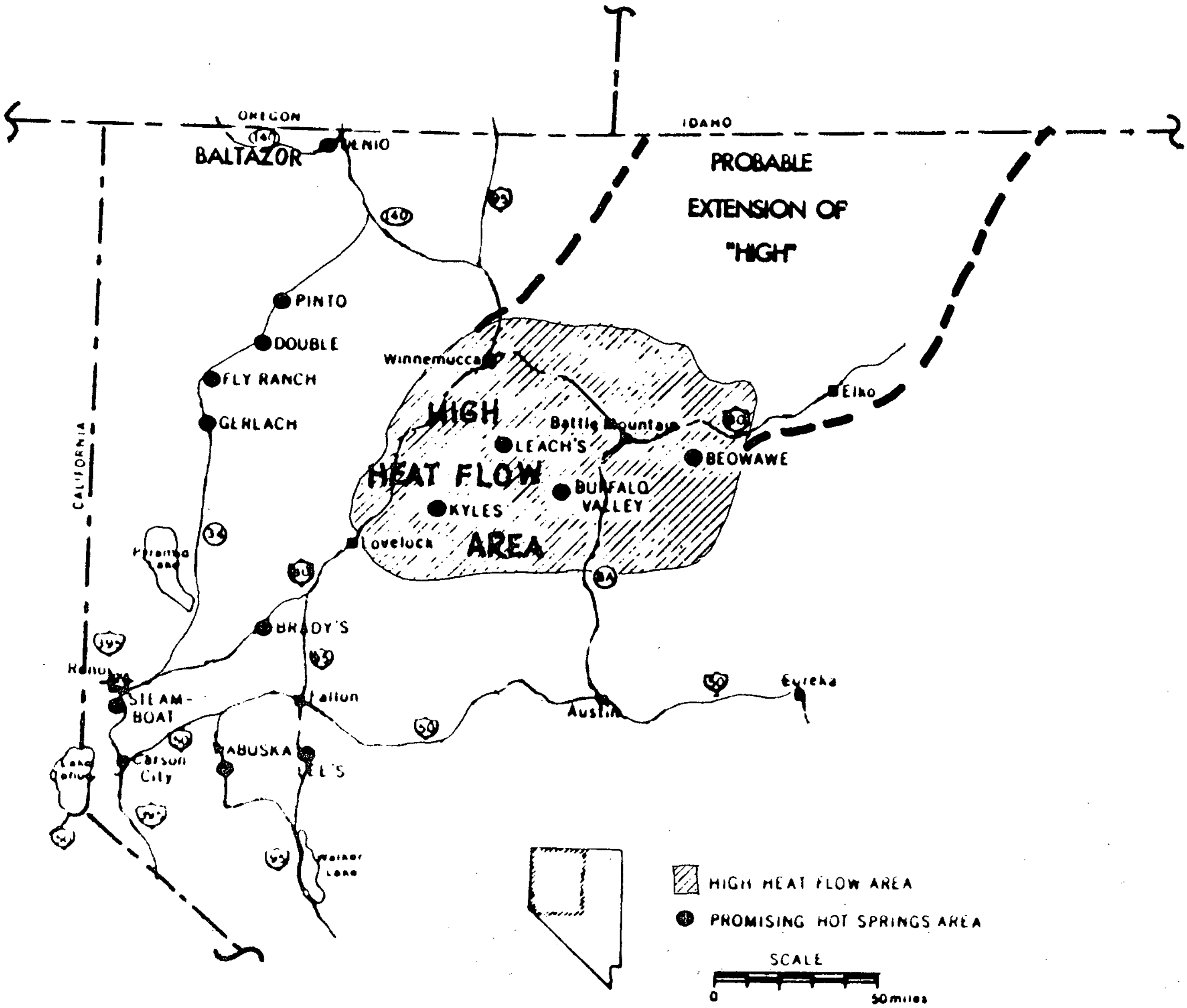
separate north-south-trending grabens. To date, thermal waters have not been encountered in the deep portion of the grabens.

No good estimate can be made of the energy potential of the area; however, an approximate value of 1,500 MW_t (0.05 x 10^{15} Btu/yr) can be assumed based on the areal coverage of wells and springs.

H. NORTHERN NEVADA

Northern Nevada is a dry and sparsely populated region. The main population centers of Winnemucca, Elko, and Wells lie along the main east-west transportation route of Interstate 84. The region's population is approximately 25,000 people, within an area of approximately 45,000 square miles (north of latitude 40). The region lies almost entirely within the Great Basin, a high desert area that covers much of the Western and Rocky Mountain states. The Snake River Plain covers a small portion in the northeastern corner of the state and the remainder of this area lies in the Basin and Range region. This latter region consists mainly of an upland area broken by more than 30 north-south mountain ranges. These mountain ranges are elongated fault-blocks with intervening basins. Land use is principally stock grazing, with BLM being the dominant federal land management agency in the area.

Active hot spring areas and potential geothermal resource sites in the Great Basin are in almost all cases associated with steeply dipping faults, often at the intersection of two major orientations of faulting. Centered within the area is the Battle Mountain High, an area of twice normal regional heat flow (2.5 to 3.8 HFU) that extends across northern Nevada to at least the southern boundary of the Snake River Plain (see Figure 7). Within this area most of the hot spring systems are probably not related to specific young igneous intrusions, but instead their high temperatures are due solely to deep circulations of meteoric water. The majority of Nevada's hot springs is found in the northern



Hot Springs in Northwestern Nevada

Figure 7. Location map, northwestern Nevada, showing prominent thermal spring areas within and outside of the Battle Mountain High heat flow region.

half of the state with Beowawe being one of the hottest (444°F = 229°C mean reservoir temperature) located in the BPA market area.

Much interest has been shown in Nevada's geothermal areas, with initial exploration drilling taking place from 1959 to 1965. The cessation of exploration drilling in the mid 1960's was due in large part to the problems of leasing federal land and the environmental requirements created by NEPA in 1969. Today, with changes in energy supply and investment attitudes and federal agency management procedures, exploration is once again being carried out. The main interest is in electrical potential due to the difficulty of using the isolated resources for direct thermal applications. Despite the area's remoteness, several direct-heat projects have been developed, including Brady's Hot Springs (vegetable dehydration) and Reno (space heating). Space-heating projects are also being investigated at Winnemucca and Elko. At present, Nevada appears to be one of the more actively explored areas in the western United States with Dixie Valley, Rye Patch, and Beowawe being of greatest interest.

Considering geothermal areas roughly north of the 41st latitude (75 miles south of the Idaho-Oregon border), the state has the following geothermal potential:

	Electrical Potential MW_e		Thermal Potential (wellhead) MW_t
	Hydrothermal	Igneous	
1. 302°F (>150°C)	163	---	2,235
2. 302°-190°F (150°-90°C)	---	---	4,994
3. 194°F (<90°C)	---	---	43,188
Total	163	---	50,417
			= 1.50×10^{15} Btu/yr

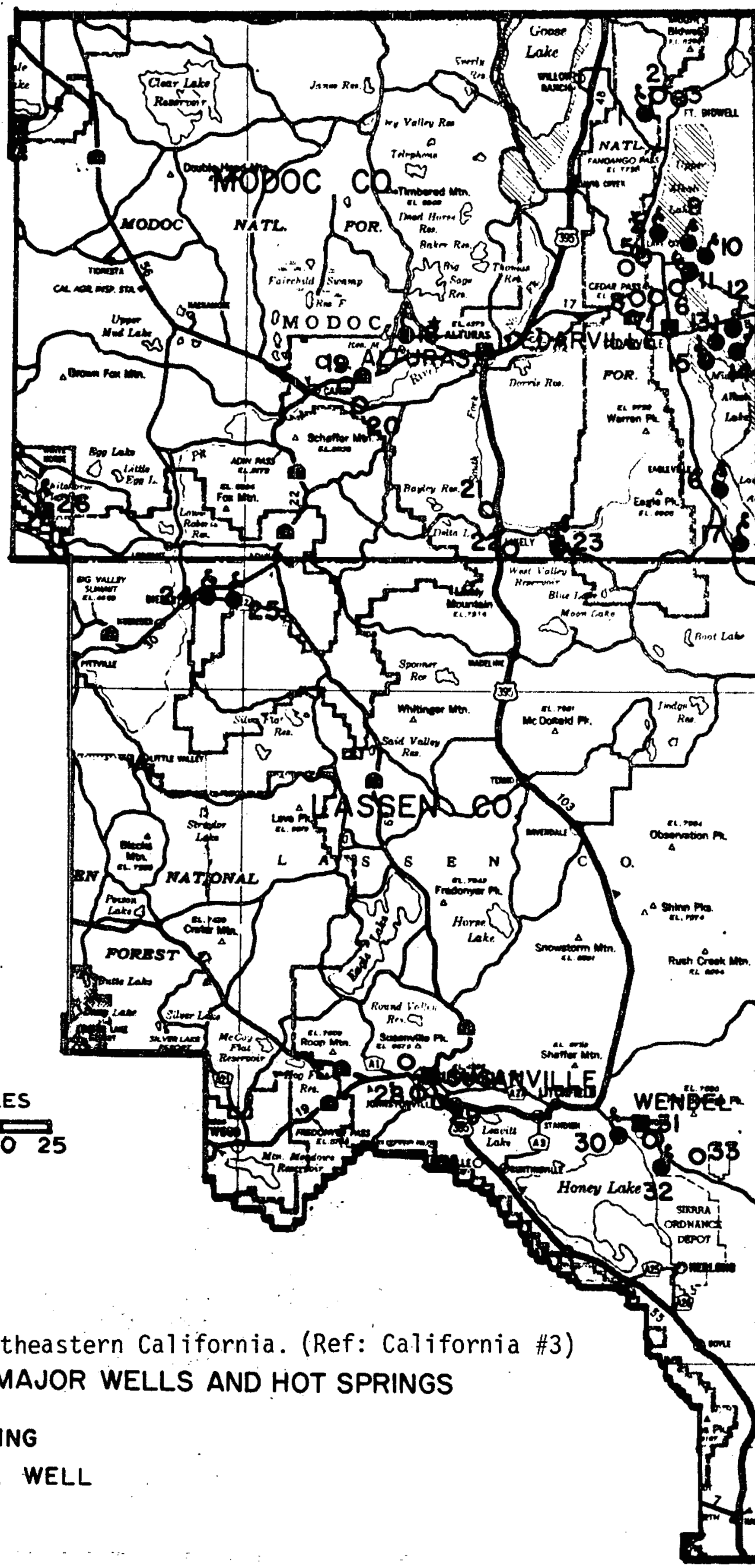
I. NORTHEASTERN CALIFORNIA

Lassen and Modoc counties of northeastern California have a total population of approximately 25,000 persons. The only major urban centers are Susanville (7,000 persons) and Alturas (3,000 persons). The natural environment is a mixture of range or grassland and high-elevation forestry. Air and water quality is generally good, wildlife is extensive, and archaeological resources are widespread. The major industries in this area are associated with timber and ranching.

The geology of the area is composed of volcanic and minor nonmarine sediments, most of which were deposited within the last 100 million years. The structural features are associated with three main geological provinces: Cascades (Medicine Lake highlands); Modoc Plateau (Devil's Garden); and the Basin and Range (Warner Mountains and Surprise Valley). Many of the shallow lakes and plains in the area are associated with ancient Lake Lahanton, formed during the last ice age.

All of the major geothermal springs in the region are related to water circulation along deep-scaled faults. Some of these faults have had relative displacement of as much as 6,000 feet. The major fault-related geothermal resources are Surprise Valley/Fort Bidwell, Kelly Hot Springs (Likely Fault), and Wendel-Amadee. Three major volcanic centers are Medicine Lake Highlands, Mt. Shasta and Lassen Peak, the latter of which is estimated to have a "dry steam" field.

An area having no surface geothermal manifestation is Susanville, where shallow wells are used for space heating on a limited scale and a small municipal district heating project is being planned. The other major use of geothermal energy in the region is at Wendel on the northeast side of Honey Lake near Susanville, where 30 greenhouses, heated by two shallow wells, are being used for raising tomatoes and cucumbers. A total of 205 greenhouses are planned by Geo Products, Inc., for the area, along with a hybrid power plant, which will use



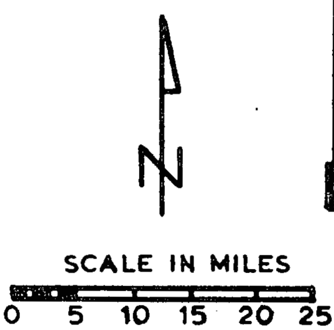


Figure 8. Northeastern California. (Ref: California #3)

LOCATION OF MAJOR WELLS AND HOT SPRINGS

- HOT SPRING
- O THERMAL WELL

geothermal water peaked by burning wood waste to generate 55 MW_e. A combined agriculture/aquaculture project is planned for the Kelly Hot Springs near Canby; this project will be a totally enclosed swine-raising complex, initially handling 1,200 sows and eventually expanding to 4,800-sow capacity.** Space heating and cooling, hydroponic-sprouted grain raising, methane generation and protein extraction will also be investigated in this project.

The majority of the springs in the region has a total dissolved solids of 300 to 1,200 ppm, the majority of which is sodium (Na) and sulfate (SO_4).

A summary of the resource potential in the northeastern California area is as follows:

	Electrical Potential* MW_e Hydrothermal	Electrical Potential* MW_e Igneous	Thermal Potential (wellhead) MW_t
1. 302°F (>150°C)	1,490	(181)	20,504
2. 302°-194°F (150°-90°C)	---	---	2,109
3. 194°F (<90°C)	---	---	30,102
Total	1,490	(181)	52,715
			= 1.58×10^{15} Btu/yr

*The potential of Mt. Shasta and Lassen Peak were not considered due to environmental constraints, national park status, and locations very near the boundary of the BPA market area.

**More recently, only an interest in greenhouse construction has been expressed by the owners.

III. GEOTHERMAL ECONOMICS AND FINANCING

A. DIRECT-USE ECONOMIC CONDITIONS AND FEASIBILITIES

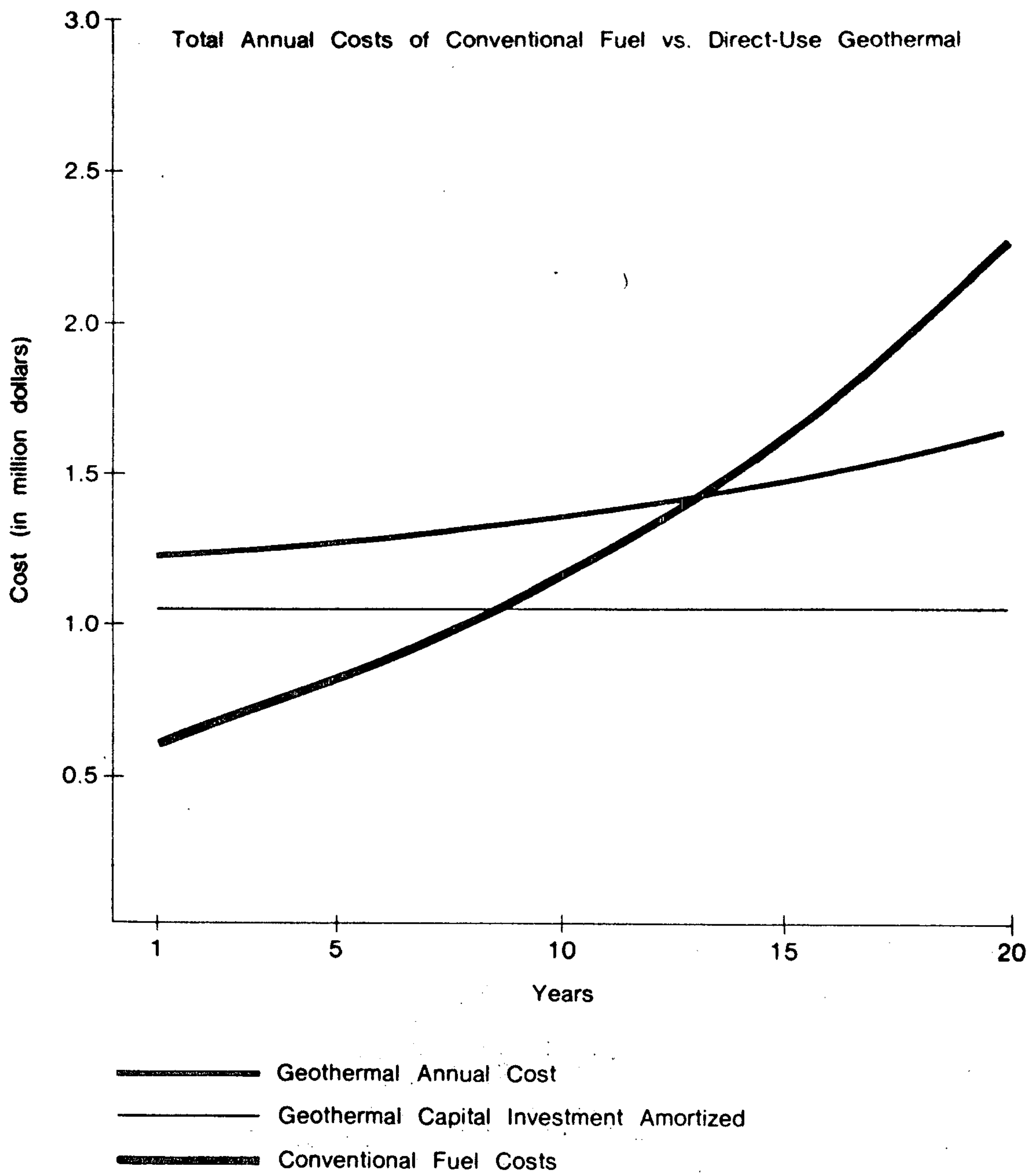
The applications of geothermal energy are as widely varied as the resource temperature ranges and existing technology allow. Geothermal applications range from generating electricity with steam turbines using resources as high as 600°F (316°C) to warming ponds for aquaculture with resources as low as 60°F (16°C). Experience indicates that transmission of geothermal fluid through pipelines is extremely expensive. Therefore, the demand for direct use of geothermal energy (nonelectric) needs to be located in close proximity to the resources.

The cost structure of geothermal energy requires a relatively large capital investment at the beginning of the project, with small annual operating costs occurring throughout the life of the project.

Figure 9 compares the annual costs of a conventional system with a geothermal system. Notice that the total cost of a conventional system is much lower in the early years of the project. As the annual operating costs of the conventional system escalate more rapidly than the geothermal system, the two systems reach a point where annual operating costs are equal, and from that time forward, the geothermal system has lower total annual costs.

Performing economic analysis involving alternative energy systems becomes more complicated due to the fact that different forms of energy are escalating at different rates and all forms of energy are escalating more rapidly than the economic inflation rate. Therefore, inflation rates for these energies must be projected over the life of the project.

Forecast data is frequently inaccurate. Forecasting conventional energy prices is even more speculative and unreliable due to the multitude of variables which affects the price of this energy. There are numerous publications available



Total Annual Costs of Conventional Fuel vs. Direct-Use Geothermal
3.0
2.5
2.0
1.5
1.0
0.5
Cost (in million dollars)
1
5
10
15
20
Years
Geothermal Annual Cost
Geothermal Capital Investment Amortized
Conventional Fuel Costs

Figure 9.

from state and federal agencies, trade associations, and even private firms which project conventional fuel prices. These publications can serve as an aid in forecasting energy costs, but the reader should be cautioned to select conservative rates.

Table 3 is a guide to the cost data that should be normally considered in a geothermal nonelectric feasibility study. In effect, we are evaluating two alternatives. Alternative one is the system which uses conventional fuel, calculating a series of annual cash flows over the estimated life of the project. Alternative two is the geothermal system with annual cash flows calculated over the life of the project. The annual cost of the geothermal system is subtracted from the annual costs of the conventional system, and the resulting net cash flows will indicate the annual savings or expenses resulting from the geothermal system as opposed to a conventional system.

In attempting to justify the capital investment of the geothermal system, the time value of money must be considered. The concept of the time value of money simply states that savings or revenues received at some future date are of less value than savings or revenues received today. For example, a series of annual savings of $10,000 per year projected over the next 20 years would have a present value of $851,000 if the cost of capital were 10 percent annually. For a 20-year project, the projected annual cost of each system would be forecast for each year and the net cash flow, which is the difference between the two systems, would be discounted back to the present worth using either the cost of capital or the minimum attractive rate of return. If the calculated present worth in favor of the geothermal project was equal to or greater than the additional capital investment required for the geothermal project, the project is economically feasible. If the calculated present worth of the savings resulting from the geothermal project is less than the additional investment required for the geothermal system, then the project is not economically feasible.

TABLE 3.

BASICS OF ECONOMIC ANALYSIS

When performing economic feasibility studies for geothermal applications, the following data are required:

I. Capital investment of the geothermal system
    A. Wells and wellhead equipment
        1. Production well(s) and injection well(s)
        2. Production well pumps
        3. Wellhead buildings
        4. Power hookup and controls
    B. Piping network
        1. Primary supply pipeline
            a. Excavation, bedding, and backfill
            b. Concrete tunnels where applicable
            c. Pipeline
            d. Fittings
            e. Insulation
            f. Installation
            g. Special costs such as highway crossings, railroad crossings, riverbed crossings, etc.
        2. Secondary distribution system
            a. Excavation, bedding, and backfill
            b. Concrete tunnels where applicable
            c. Pipeline
            d. Fittings
            e. Insulation
            f. Installation
    C. Heat exchanger system
        1. Heat exchanger
        2. Circulation pumps
        3. Heat exchanger building
        4. Control system and power hookups
        5. Other equipment
            a. Expansion surge tanks
            b. Flashers
            c. Reservoirs, etc.
    D. Space heating equipment, new or retrofit
        1. Piping
        2. Space heaters
            a. Fan coil units
            b. Convectors
        3. Controls and hookup
        4. Other special equipment required
    E. Overhead costs
        1. Engineering
        2. Contingencies
        3. Other

TABLE 3. (Continued)

II. Annual costs of the geothermal system
   A. Operating costs
      1. Power requirements (kilowatt hours plus cost per kwhr)
         a. Pumping
         b. Circulation
         c. Controls
         d. Operating personnel salaries
      2. Operators' salaries
      3. Other
         a. Billing
   B. Maintenance costs
      1. Periodic maintenance
         a. Wells
         b. Pipelines
         c. Heat exchangers
         d. Pumps
      2. Maintenance personnel salaries
      3. Shops
   C. Insurance and taxes
   D. Debt service

III. Costs of conventional system
   A. Capital investment (for existing conventional systems, this cost would be zero)
   B. Annual operating costs
      1. Units required in kwhr, gallons of oil, tons of coal, or cubic feet of natural gas, etc., and cost per unit
      2. Salaries
      3. Other
   C. Annual maintenance cost
      1. Periodic maintenance
      2. Salaries
      3. Shops
   D. Insurance and taxes
   E. Debt service

Table 4 presents the 20-year cash flows for a proposed district heating system to be developed by a municipality. This city wants to develop a geothermal heating system to provide space heating for two schools, city hall, city shops, a fire station, and the post office. These buildings are being heated by electricity, heating oil, and propane. The total capital investment for the geothermal system was estimated to be $837,700. It was assumed the city would finance this project with 8 percent tax-free municipal bonds paying interest annually and maturing in 20 years. The actual life of the system will probably be in excess of 30 years, and the city will be able to reduce its annual heating costs considerably over this time period. The project would pay for itself in the 20-year period and has a present value of $239,539 over and above the capital investment, debt service, and operating and maintenance costs.

Table 5 presents the same data for an identical system, but assumes that a geothermal developer drilled the wells and installed the system selling the energy to the city at the same price as the city was currently paying for conventional fuel. The gross sales column is a composite of all conventional fuels used, inflated at their projected inflation rates over a 20-year period. Columns 2 and 3 apply depletion allowances and 10-year, straight-line depreciation assuming the developer has numerous ongoing projects and can take advantage of these tax write-offs. Column 4 combines the electrical pumping costs and the system maintenance costs. Federal income tax is paid based on the assumption that the corporation is in a 48 percent effective tax bracket and can write off losses against other income.

The second portion of Table 5 presents an after-tax cash flow of the project which includes an investment tax credit taken in the first year of $209,425. When evaluated at 7 percent, the cash flows indicate that $1,179,442 could be spent today on this project. The discounted cash flow at 12.22 percent indicates that the

TABLE 4.

CITY DEVELOPMENT

TOTAL PRESENT ELECTRICAL COST	TOTAL PRESENT OIL COST	GEOTHERMAL PUMPING COSTS	GEOTHERMAL OPERATION & MAINTENANCE COSTS	BOND INTEREST AT 8%	ANNUAL CASH FLOW	PRESENT VALUE AT 8%
35,308.	30,955.	2,667.	10,700.	67,016.	-14,121.	-13,075.
38,662.	33,586.	2,921.	11,449.	67,016.	-9,138.	-7,834.
42,335.	36,441.	3,198.	12,250.	67,016.	-3,689.	-2,928.
46,357.	39,539.	3,502.	13,108.	67,016.	2,269.	1,668.
50,760.	42,899.	3,835.	14,026.	67,016.	8,783.	5,978.
55,583.	46,546.	4,199.	15,007.	67,016.	15,906.	10,023.
60,352.	50,502.	4,559.	16,058.	67,016.	23,221.	13,549.
65,530.	54,795.	4,951.	17,182.	67,016.	31,176.	16,844.
71,152.	59,452.	5,375.	18,385.	67,016.	39,829.	19,924.
77,257.	64,506.	5,837.	19,672.	67,016.	49,239.	22,807.
83,886.	69,989.	6,337.	21,049.	67,016.	59,473.	25,507.
91,083.	75,938.	6,881.	22,522.	67,016.	70,602.	28,037.
98,898.	82,393.	7,472.	24,098.	67,016.	82,705.	30,410.
107,384.	89,396.	8,113.	25,785.	67,016.	95,866.	32,639.
116,597.	96,995.	8,809.	27,590.	67,016.	110,177.	34,732.
126,601.	105,239.	9,564.	29,522.	67,016.	125,738.	36,702.
137,464.	114,185.	10,385.	31,588.	67,016.	142,659.	38,556.
149,258.	123,890.	11,276.	33,799.	67,016.	161,057.*	40,304.
162,064.	134,421.	12,244.	36,165.	67,016.	181,060.	41,954.
175,969.	145,847.	13,294.	38,697.	67,016.	-634,891.	-136,215.
					537,920.	239,582.

*Payback

TABLE 5.

GEOTHERMAL DEVELOPMENT CORPORATION

GROSS SALES	DEPLETION ALLOWANCE	STRAIGHT-LINE DEPRECIATION 10% SALVAGE	GEOTHERMAL PUMPING & MAINTENANCE COSTS	NET INCOME BEFORE TAXES	FEDERAL INCOME TAXES	NET INCOME AFTER TAXES
66,263.	14,578.	75,393.	13,368.	-37,075.	-17,796.	-19,279.
72,249.	14,450.	75,393.	14,370.	-31,964.	-15,343.	-16,621.
78,7771	14,180.	75,393.	15,449.	-26,246.	-12,598.	-13,648
85,896.	13,743.	75,393.	16,611.	-19,851.	-9,529.	-10,323.
93,661.	14,049.	75,393.	17,861.	-13,642.	-6,548.	-7,094.
102,129.	15,319.	75,393.	19,207.	-7,790.	-3,739.	-4,051.
110,855.	16,628.	75,393.	20,618.	-1,784.	-857.	-928.
120,326.	18,049.	75,393.	22,133.	4,751.	2,280.	2,470.
130,606.	19,591.	75,393.	23,761.	11,861.	5,693.	6,168.
141,764.	21,265.	75,393.	25,509.	19,598.	9,407.	10,191.
153,876.	23,081.		27,387.	103,408.	49,636.	53,772.
167,023.	25,053.		29,404.	112,565.	54,031.	58,534.
181,292.	27,194.		31,571.	122,527.	58,813.	63,714.
196,781.	29,517.		33,899.	133,365.	64,015.	69,350.
213,594.	32,039.		36,400.	145,154.	69,674.	75,480.
231,842.	34,776.		39,088.	157,978.	75,830.	82,149.
251,650.	37,748.		41,975.	171,928.	82,525.	89,402.
273,151.	40,973.		45,077.	187,101.	89,808.	97,292.
296,488.	44,473.		48,411.	203,604.	97,730.	105,874.
321,819.	48,273.		51,993.	221,553.	106,345.	115,208.
			TOTAL	112,150.25		

TABLE 5. (CONTINUED.)

GEOTHERMAL DEVELOPMENT CORPORATION

ADD DEPLETION AND DEPRECIATION	AFTER-TAX CASH FLOW INCLUDES 25% INVESTMENT TAX CREDIT	PRESENT VALUE AT 7%	PRESENT VALUE AT 12.22%	LEVELIZED CASH FLOW PROVIDED BY THE PROJECT
89,971.	280,117.	261,791.	249,614.	111,299.
89,843.	73,211.	63,954.	58,143.	111,299.
89,573.	75,925.	61,978.	53,725.	111,299.
89,136.	78,814.	60,127.	49,696.	111,299.
89,442.	82,348.	58,713.	46,270.	111,299.
90,712.	86,661.	57,746.	43,391.	111,299.
92,021.	91,093.	56,728.	40,644.	111,299.
93,442.	95,912.	55,822.	38,134.	111,299.
94,984.	101,152.	55,020.	35,838.	111,299.
96,658.	106,848.	54,316.	33,734.	111,299.
23,081.	76,853.	36,512.	21,622.	111,299.
25,053.	83,587.	37,114.	20,955.	111,299.
27,194.	90,908.	37,724.	20,309.	111,299.
29,517.	98,867.	38,342.	19,682.	111,299.
32,039.	107,519.	38,970.	19,074.	111,299.
34,776.	116,925.	39,607.	18,483.	111,299.
37,748.	127,150.	40,252.	17,911.	111,299.
40,973.	138,265.	40,908.	17,356.	111,299.
44,473.	150,347.	41,572.	16,817.	111,299.
48,273.	163,480.	42,246.	16,295.	111,299.
	TOTALS	1,179,442.	837,693.	

corporation would earn this rate after taxes. It is doubtful that the city would agree to pay conventional fuel rates for the next 20 years. It should also be emphasized on this particular project that retrofit costs were not considered for the individual buildings.

Typical Direct-Use Costs

The cost of the various components for the direct use of geothermal energy will vary depending upon many factors as outlined in the previous section. The general categories that have the greatest influence are well drilling and completion costs, transmission costs, and distribution costs. End-use costs (heat exchangers, retrofit, etc.) must also be considered; however, these are often assumed by the user rather than the supplier. All of these are, in turn, influenced by the water temperature, chemical composition, and the ΔT used.

In the Reykjavik and Akureyri district heating projects in Iceland, these costs are distributed as follows:

Production (wells and wellhead pumps)	15 to 25 percent
Transportation (main pipelines from fields)	18 to 20 percent
Storage and distribution (tanks, pumping stations, local pipelines)	58 to 66 percent

The comparable figures for the Klamath Falls district heating project are:

Production	18 percent
Transmission	31 percent
Distribution	51 percent

The production costs are lower than in Iceland due to shallower wells in Klamath Falls, and the transmission costs are higher due to designing for an expanded future load in Klamath Falls.

In the United States, a number of studies have been completed that summarize these categories of costs. Examples of these are as follows (all of the data are based on 1979 dollars unless otherwise stated):

1. Well Drilling.

   Figure 10 indicates the cost of shallow, low-temperature water well drilling and casings costs typical of Klamath Falls. The main variable is the amount of soft and hard rock encountered. The range as well as a typical average (1/3 hard rock and 2/3 soft rock) are shown. Figure 11 is an expansion of the previous graph showing greater well depth. Well depths up to 2,000 to 3,000 feet can be drilled with conventional water well drilling equipment; however, deeper wells normally would require larger and more expensive oil field drilling rigs. The lower curve is similar to that in Figure 10, whereas the upper two lines are based on the oil field type of drilling. These data are typical of results in Idaho and surrounding states. Figure 12 presents the shallow water well drilling data in terms of annual costs. Allowance is made for federal and state (Oregon) tax credits. Figure 13 is based on work done at Battelle (Pacific Northwest Laboratory). Here production costs include well and pumping costs and are presented in terms of cost per unit of energy used.

2. Transmission Costs.

   Figure 14 is based on buried insulated asbestos cement transmission lines. Steel lines would be slightly higher. If the transmission line is to be placed in a concrete tunnel for ease of access and maintenance, as well as providing space for the placement of other utilities, the cost of the tunnel must be added to the pipeline. Figure 15 is based on recent experiences in Klamath Falls using either precast sections or cast-in-place

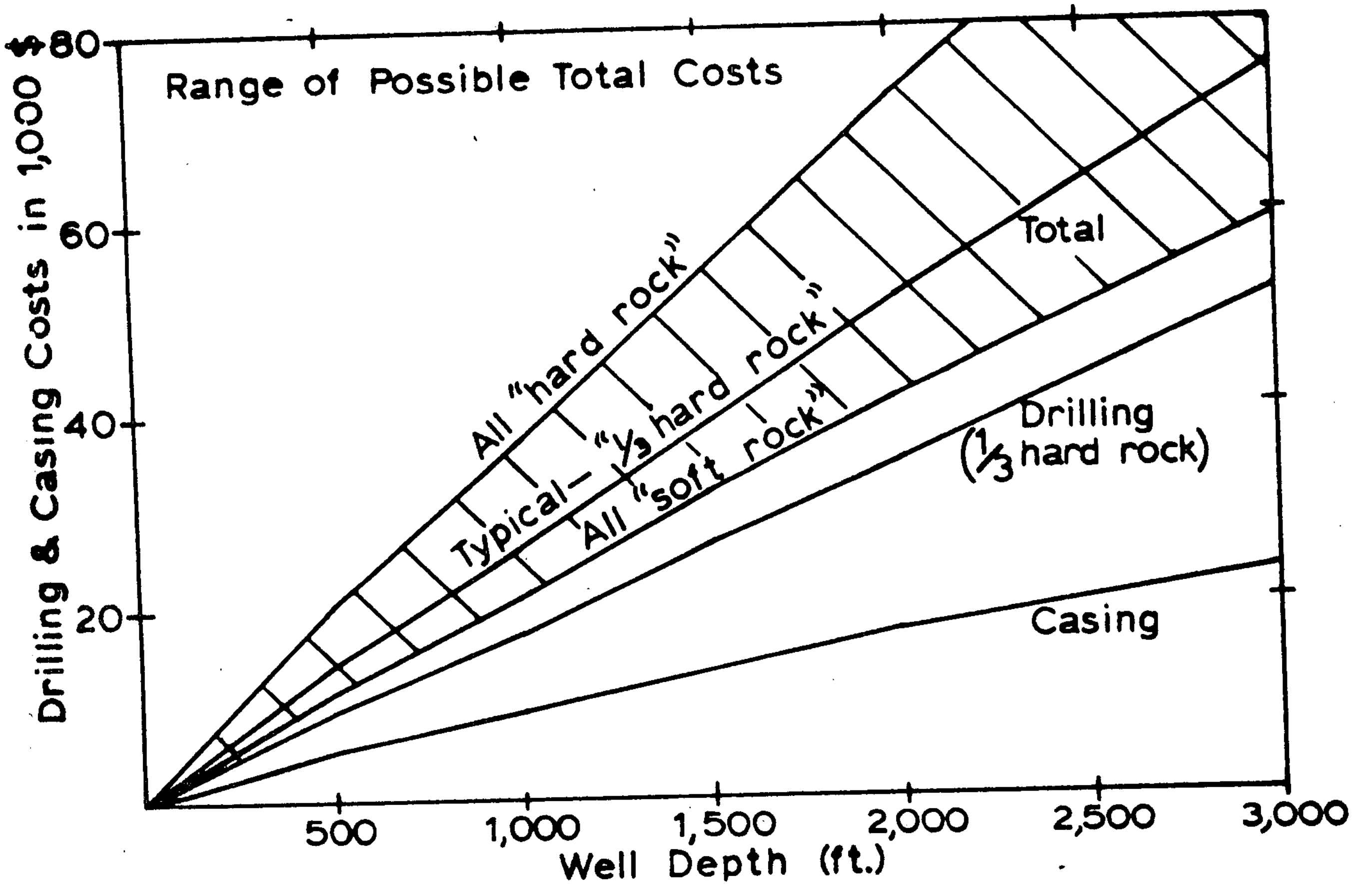


Figure 10. Drilling and casing capital costs.

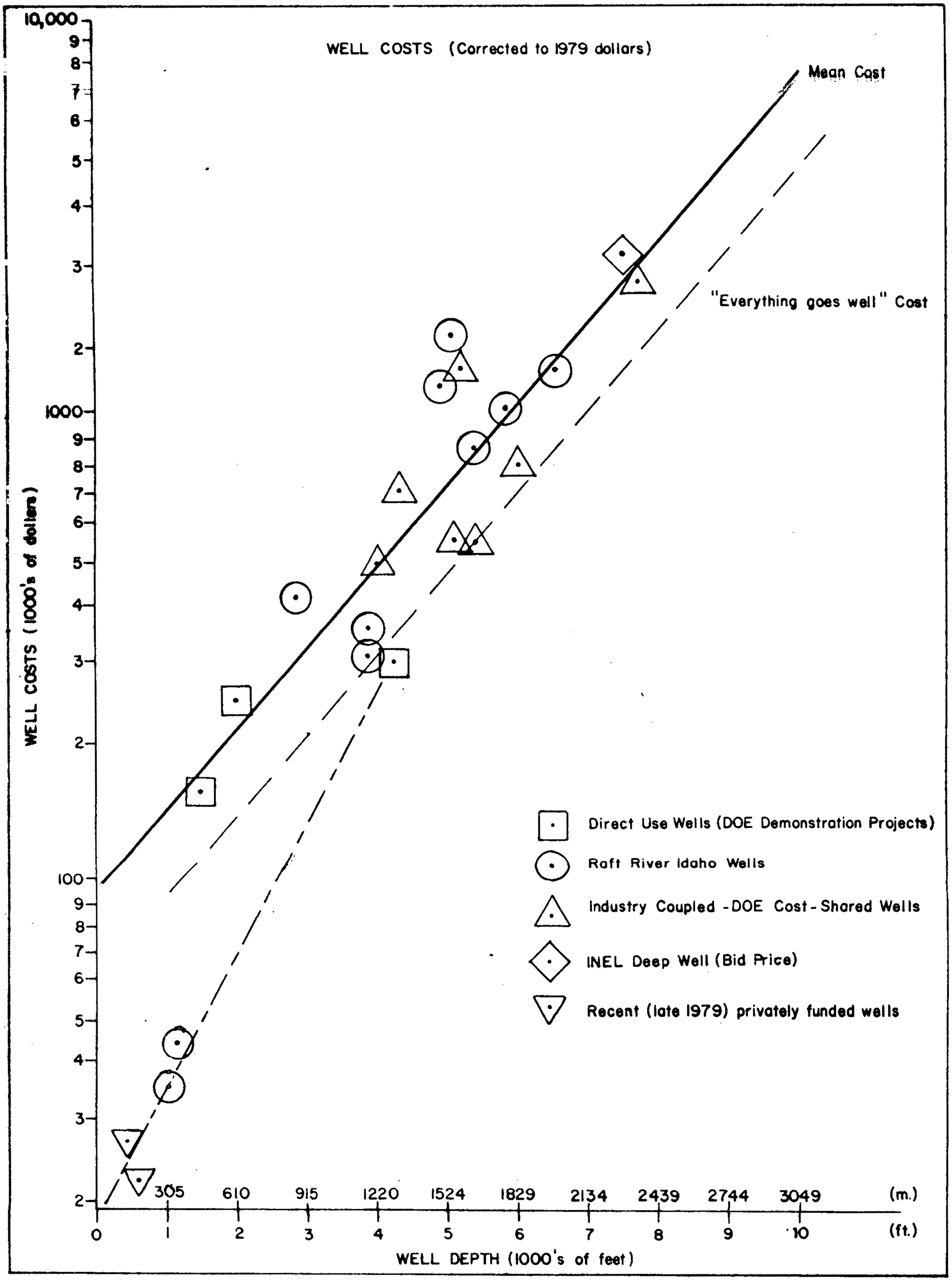


Figure 11. Typical drilling costs for geothermal wells (corrected to 1979 dollars).

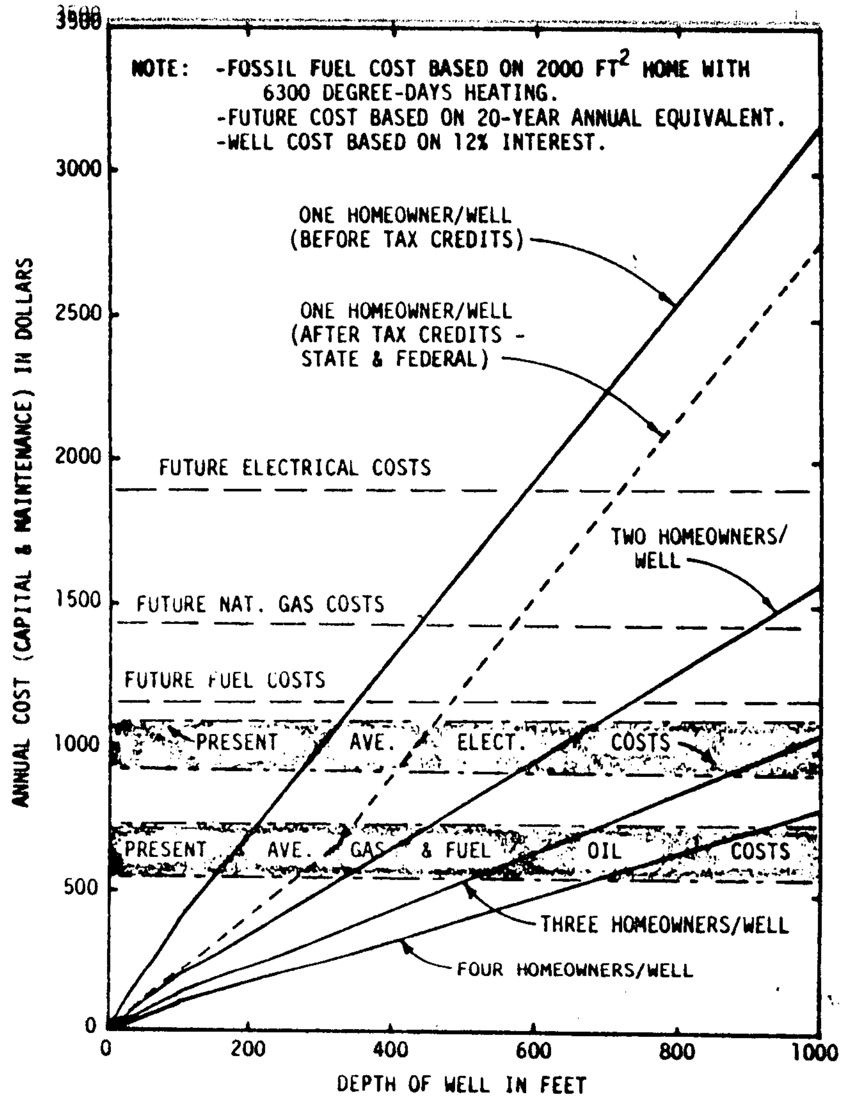


Figure 12. Annual geothermal well cost (based on Klamath Falls data).

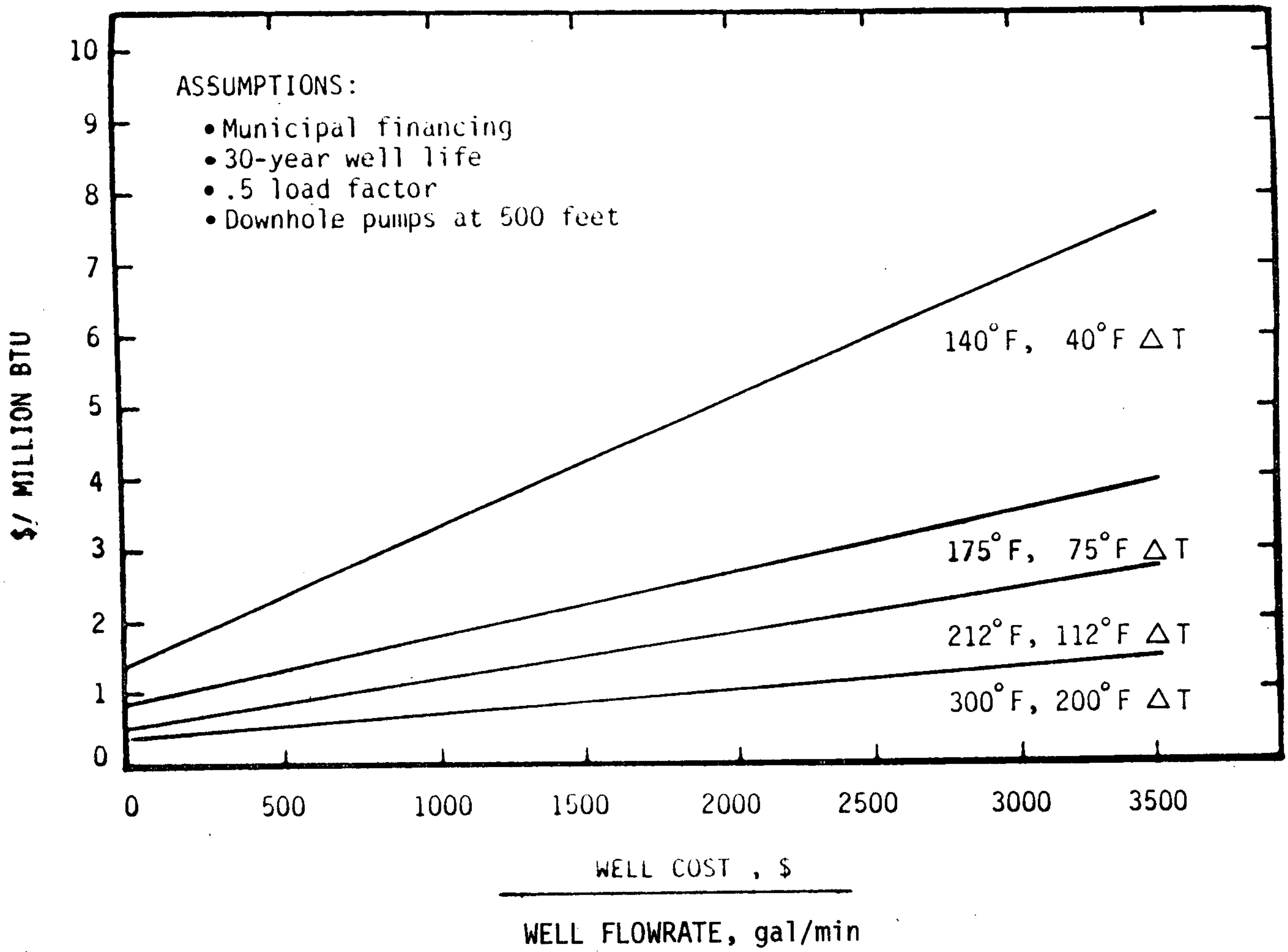


Figure 13. Geothermal Energy Production Costs.

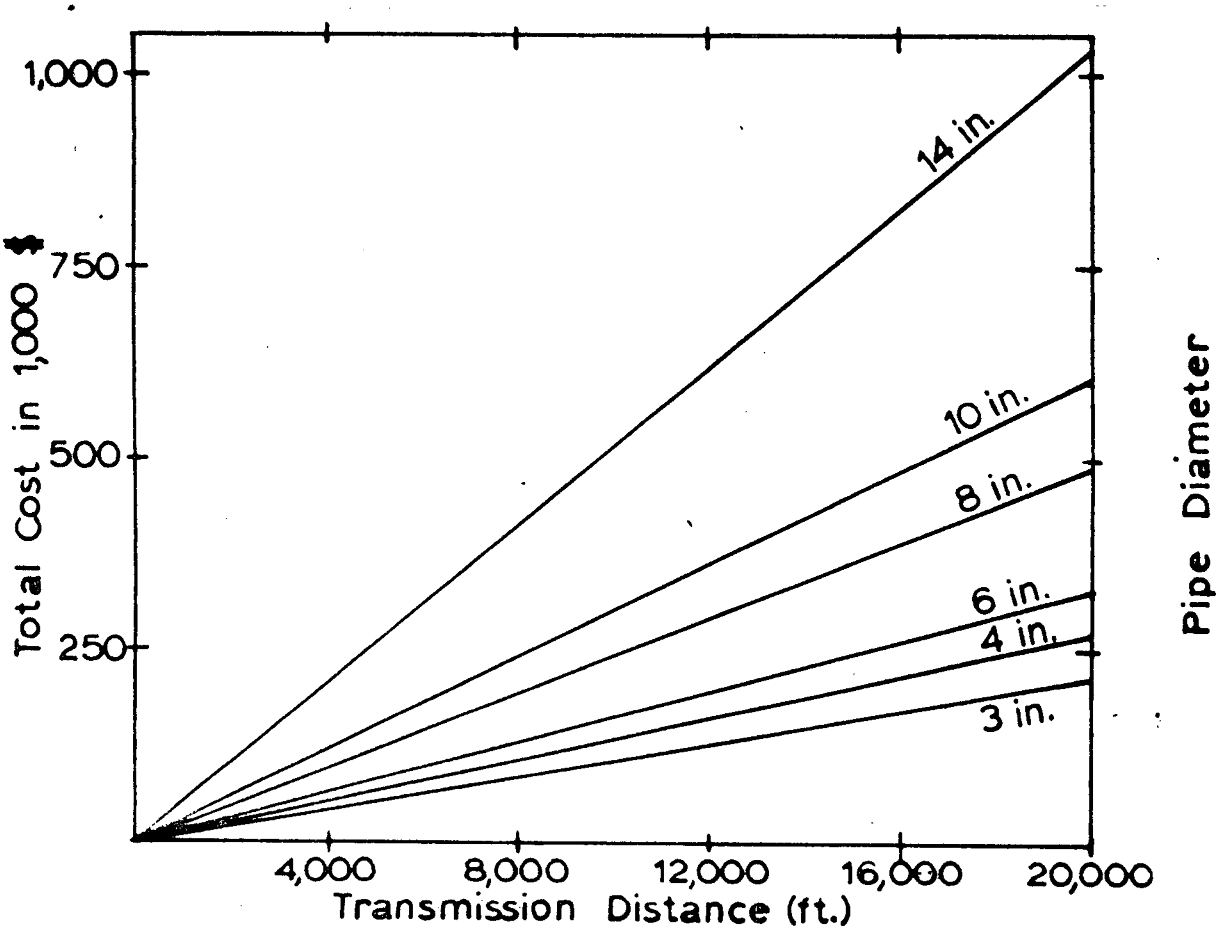


Figure 14. Insulated pipe costs
(asbestos cement pipe with urethane insulation).

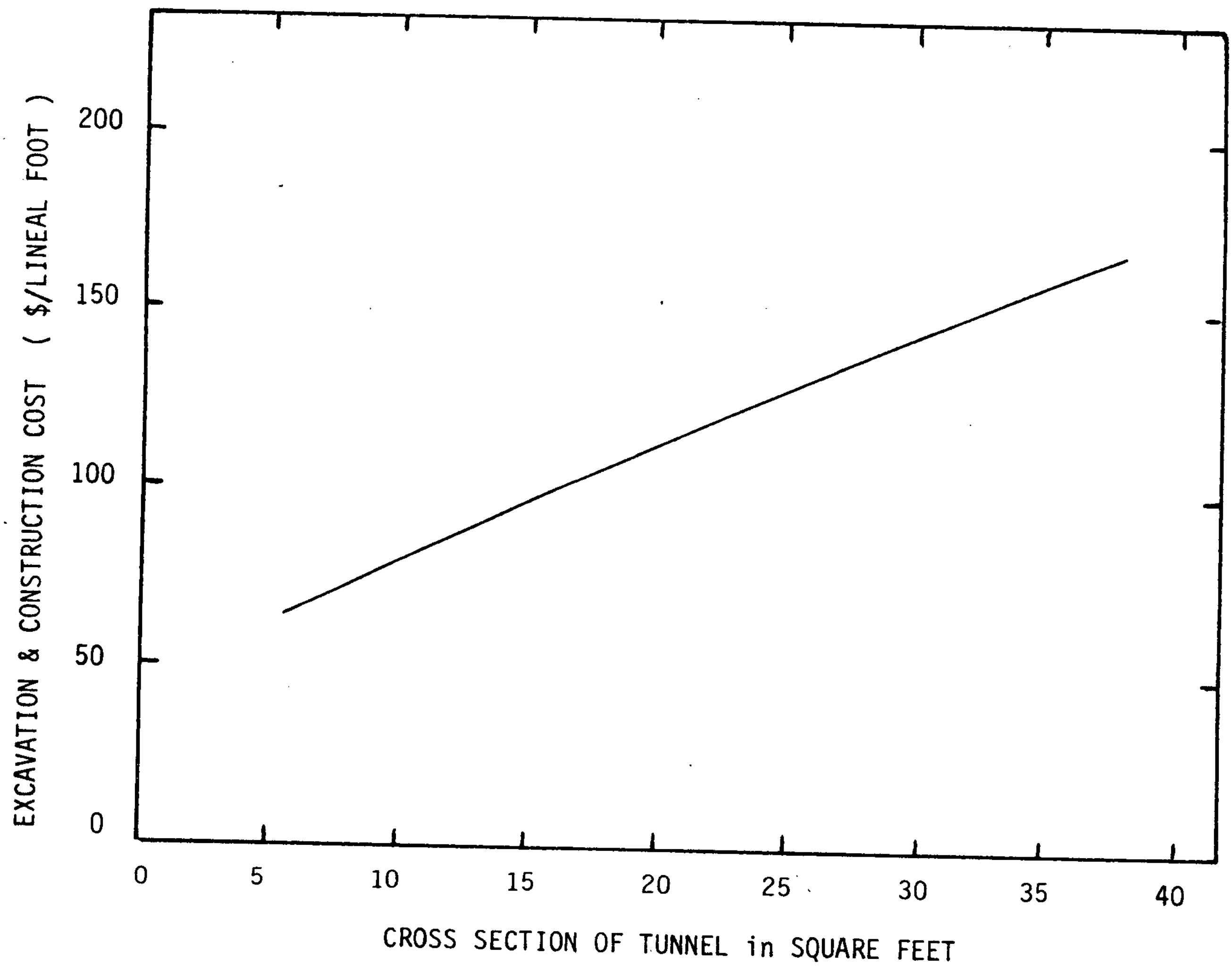


Figure 15. Concrete transmission tunnel cost.

construction. The tunnel cost includes excavation, placement, and backfill. The roof could either be buried or constructed flush with the surface. These are typical of Oregon in terms of cost per unit of energy.

3. Distribution Cost.

Distribution costs are more difficult to quantify as they are dependent upon the density of the population served in the case of a district heating project. Most district heating systems are a two-pipe system with the water being recycled in a closed loop. If a single-pipe system is used, disposing of the fluid after use would reduce the cost about 20 percent. Industrial-processing use would have a small distribution cost since the load is usually concentrated at one location or plant site.

4. End-Use Costs.

These costs are usually assumed by the user as they involve designing or converting a facility to utilize geothermal fluids. The most common item used to adapt a facility to geothermal are heat exchangers, either plate or shell-in-tube type. The plate is currently the most popular due to lower cost, higher efficiency, and ease of maintenance and expansion. Typical costs for commercial-sized plate heat exchangers range in price from $2,000 to $2,500 per million Btu of peak load. Shell-and-tube type would be approximately 25 percent higher. These heat exchangers would be used to isolate corrosive geothermal water from a noncorrosive water used in a closed secondary loop. Circulation pumps, control valves, etc., would be additional.

The retrofit cost to modify existing heating or process systems to geothermal must also be considered. In the case of space heating, forced air or hot water circulation systems are fairly easy and inexpensive to retrofit. High-pressure steam and electrical resistance heating systems are more difficult to convert and may have to be completely replaced. Since only 26 percent of the total regionwide electric heat is by electric furnace (forced air), the remaining 74 percent would be the more difficult portion to retrofit. The forced air or hot water system retrofit will cost $300 to $500 for an average home, and $10,000 to $30,000 for a large public or commercial building. Industrial-process retrofit will vary from plant to plant and thus must be analyzed in detail on a case-by-case basis.

5. Heat Pumps.

Heat pumps are being considered for many sites where the geothermal water is of low temperature (<100°F = 38°C). These water-to-air heat pumps can be used for both heating and cooling and to boost the temperatures to meet a peak load. The only disadvantage with using a heat pump is that some electrical energy must be used to run the compressor. The ratio between the energy output from the heat pump and the electrical energy input is referred to as the coefficient of performance or COP. For most water-to-air heat pumps, the COP is above 3.0. Typical costs for a residential heat pump system as compared to other energy forms are (Klamath Falls):

Type of System	Capital Investment	20-year Amortization	First-Year Operating Costs	Total 20-Year Annual Equivalent Costs
Oil Furnace	$2,775	$304	$866	$1,965
Electric Furnace	$1,950	$261	$782	$1,696
Heat Pump Using Domestic Water	$3,640	$487	$261	$ 967
Heat Pump With Well	$7,760	$905	$261	$1,385

Another comparison of heat pump costs is as follows:

Natural gas	(49¢/therm)	\$4.94/MBtu
Oil	(92¢/gal)	\$6.80/MBtu
Electricity	(2.94¢/kwhr)	\$8.61/MBtu
Heat pump		
COP = 3		\$2.87/MBtu
COP = 2.5		\$3.45/MBtu
COP = 2.0		\$4.31/MBtu

Some industrial heat pumps for large applications will have COP as high as 7.0. The price of residential-sized heat pumps range from \$2,000 to \$4,000 (approximately \$50 per 1,000 Btu/hr of peak load) and commercial-sized will range from \$30 to \$40 per 1,000 Btu/hr of peak load.

Summary

A number of curves for the Klamath Falls district heating project is shown in Chapter 5 of Reference 9. These illustrate the relationship between annual load factor, transmission line length, heat extracted (ΔT), time, competing fossil fuel, and the cost per million Btu. This is an excellent summary of these interrelationships that must be considered in any project. Four of these curves are shown in Figures 16 through 19.

B. ELECTRIC ECONOMIC CONDITIONS AND FEASIBILITIES

As was stated previously, direct-use geothermal energy is capital intensive, requiring large sums of money to develop the reservoir and construct the system to deliver heat. Economic viability of the project is largely dependent on recovering the capital investment through annual savings of the geothermal system as compared to conventional fuels. This problem is multiplied many times over for geothermal power production sites. A direct-use system delivering 50 megawatts

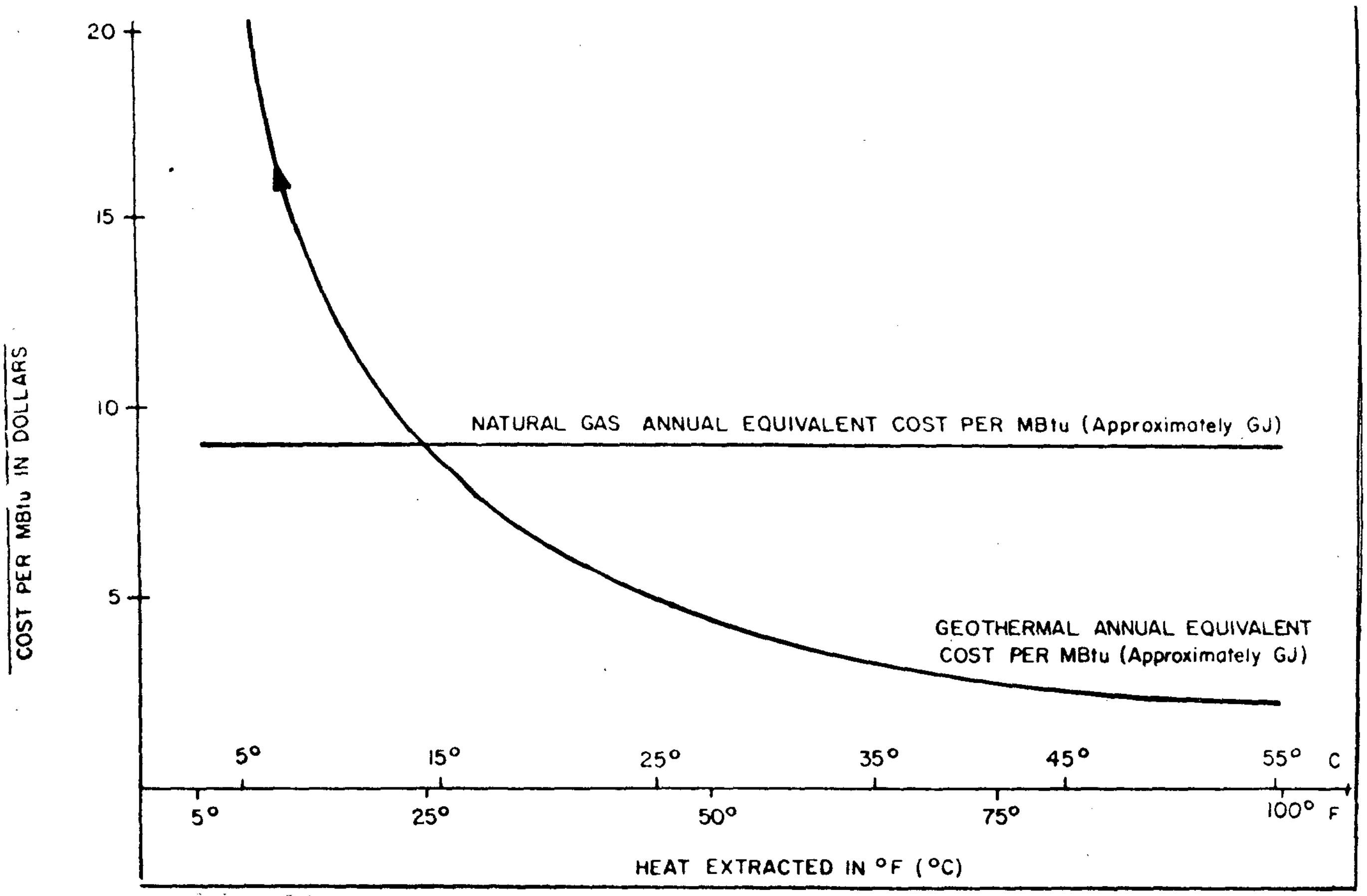


Figure 16. KF Model with a 25% annual load factor showing 20-year annual equivalent costs per MBtu at 15% cost of capital as the heat extracted varies from 5°-100°F (3°-56°C).

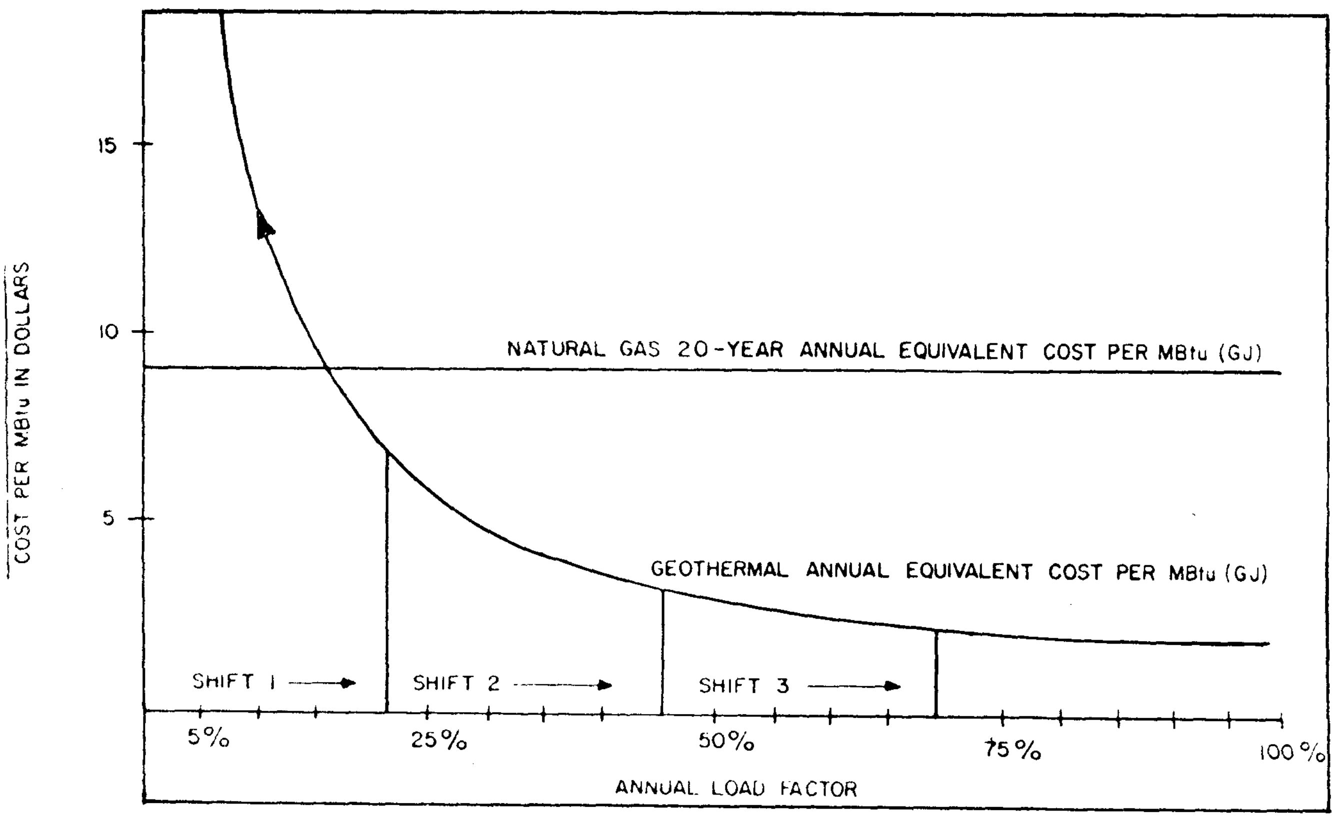


Figure 17. KF Model 20-year annual equivalent cost at 15% cost of capital as the annual load factor varies from 5% to 100%.

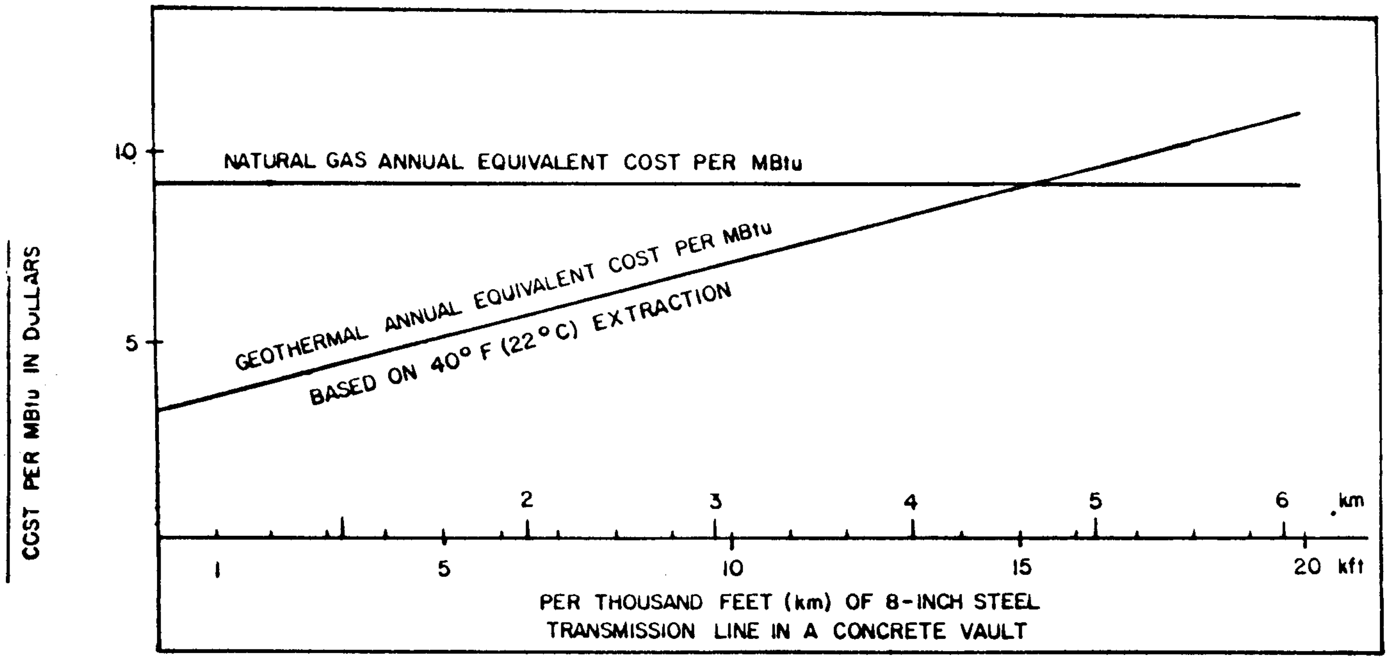


Figure 18. KF Model 20-year annual equivalent cost per MBtu (GJ) per thousand feet (km) of 8-inch (20-cm) transmission line in a concrete vault. Evaluated at 15% cost of capital.

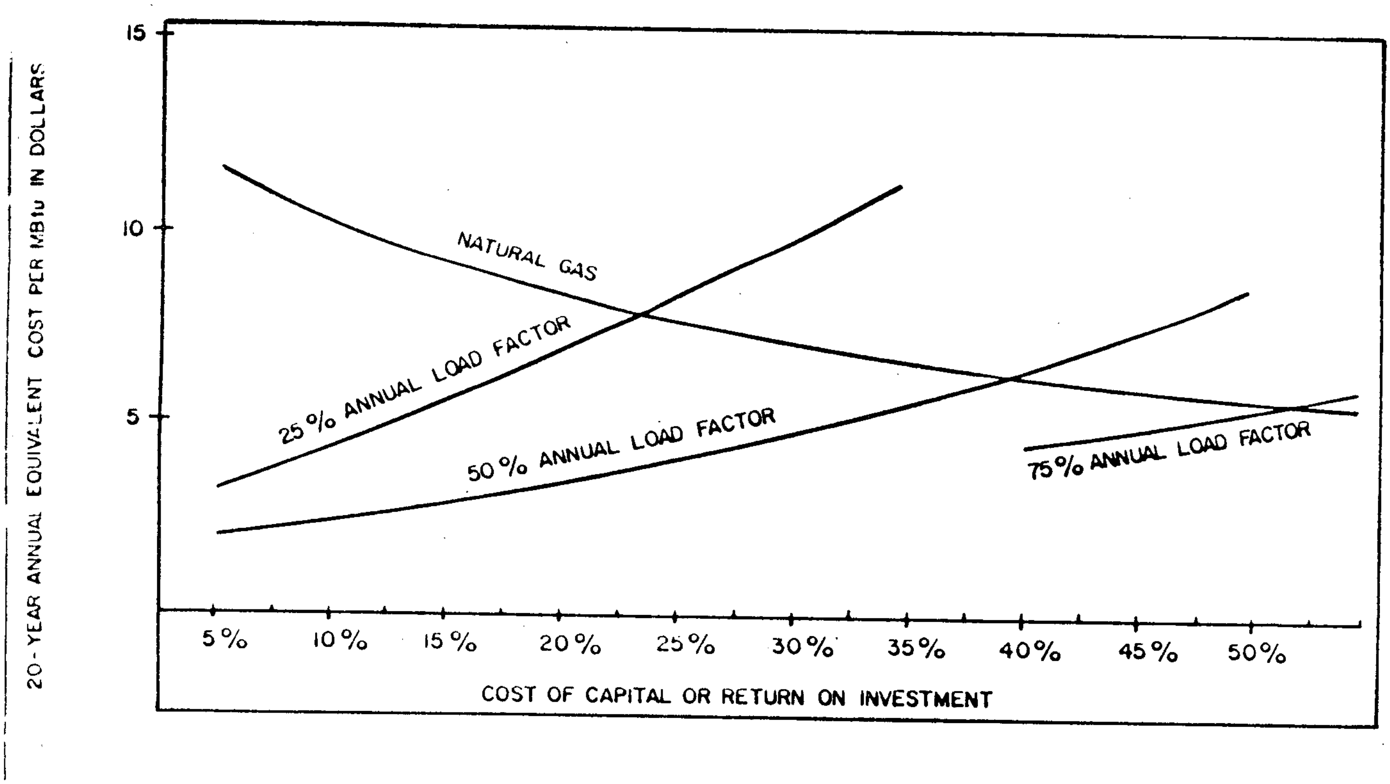


Figure 19. Natural gas vs. cost of capital vs. annual load factors.

of heat energy could be developed for $3.5 million to $5 million capital investment. A geothermal power production facility to deliver 50 megawatts requires $35 million to $50 million capital investment (Reference 21 and tabulation on bottom of this page).

With current technology, the most economical geothermal resource for electric power production would be a dry steam field with a temperature of 450°F (232°C) or higher. The Geysers in California is such a reservoir. In 1979, The Geysers produced electricity at 17.5 mills per kilowatt hour.

Pacific Gas and Electric plant #15 is expected to cost $320 per kilowatt with provisions for H_2S treatment. This is an increase of 250 percent over the average of the 1961-1974 period. In the same period, the cost of electricity generated averaged about 5.6 mills per net kilowatt hour. 1979 operating costs will have increased the bus bar price to 25 to 30 mills per kilowatt hour.[1]

A tabulation of prices of electricity for oil, coal, and nuclear versus geothermal follows:[2]

	Oil	Coal	Nuclear
Fuel mills per kilowatt hour	20-23	9-11	6-7
Plant $/kw	400-500	780-1000	1000-1200
Electricity bus bar mills/kwhr	33-34	38-40	38-40

	Geothermal		
	Steam	Flash @ 450°F	Binary
Fuel mills per kilowatt hour	17.5	18-22	26-30
Plant $/kw	320	450-475	500-1000
Electricity bus bar mills/kwhr	25-30	27-32	40-48

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[1]Greider, B. "Economic Risk of Geothermal Projects," March, 1980, page 13.
[2]Ibid--These figures are based on costs in 1979 of projects under construction or under design, thus are costs for potentially successful, (economically competitive) projects (personal communication with B. Greider).

The figures below (adjusted for 1979 costs) from C. Heinzelman's presentation of October 15, 1977 illustrates exploration techniques and associated costs. The overall amount of money (per successful prospect) required is 3 million to 4.75 million 1977 dollars. This provides for limited failure and followup costs, but does not include the other exploration failures and land costs.

Exploration Techniques and Approximate Costs *

Objective	Technique	Approximate Cost ($)
Heat Source and Plumbing	Geology	$ 20,000
	Microseismicity	15,000
Temperature Regime	Gravity	20,000
	Resistivity	25,000
	Tellurics and magneto-tellurics	50,000
	Magnetics	15,000
	Geochemistry (hydrology)	12,000
	Land analysis and permitting	25,000
	Temperature gradient - 20 holes (500' or less)	100,000
	Stratigraphic holes - 4	160,000 - 240,000
Reservoir Characteristics	Exploratory and confirmation tests - 3	1,800,000 - 4,000,000
	Reservoir testing	250,000

To establish a discovery approximately $2,500,000 - $5,000,000 will be required. This is probably the minimum expenditure needed to change a portion of the resource base into an area of reserve with production potential.[3]

"A summary of estimated development costs after exploration expenses for the field supply, power plant, and ancillary equipment for a 50 megawatt hot water flash unit is as follows."[4]

Development wells - 12	$14,400,000
Injection wells - 6	6,000,000
Pipelines	2,800,000
Miscellaneous field expense (includes interest and working capital)	9,000,000
Power Plant	35,000,000
	$67,200,000

[3]Ibid, page 7.
[4]Ibid, page 9.
*See additional data on page 164 and in the Appendix.

Geothermal

"Comparison of conventional electricity prices with geothermal steam prices are [sic] a matter of public record. Geothermal steam is the least expensive of all thermal systems employed in the United States. To obtain a comparison of hot water flash steam plants, it is necessary to use developments outside the United States for performance factors. Economics of hot water flash to steam projects continue to be impressive. Cerro Prieto's development is very encouraging as exploratory work confirms this development can exceed 500 MW.* The improvement in heat recovery with double flash units would reduce the cost of electricity and increase the size of reserves significantly. Seventy-five megawatts have now been developed and work is underway on the next 75 megawatts. The first unit of 75 megawatts was developed for $264/kw and produced electricity for approximately $.008, tax free. Today, costs would be about twice that amount. The cost includes the well field operation as this is an integrated operation. It is estimated the second 75 megawatt plant will produce electricity for about 16 mills, tax free."[5]

"It is possible to use the development work at Momotombo, Nicaragua to evaluate the costs of developing a hot water flash field today. DeGolyer McNaughton, the international consulting firm, and Herman Dykstra, a reservoir engineering consultant, have completed examination of all the field test data from Momotombo. Tests using bottom hole pressure devices in selected wells were combined with field flowing tests. The firm concluded that double flash turbines could produce 96 megawatts for more than 30 years using the portion of the reservoir developed. Subsequent completion tests have demonstrated more than 100 megawatt capacity."

*It is estimated that Cerro Prieto's power may be sold to the United States for as high as 50-60 mills/kwhr (personal communication with B. Greider).
[5]Ibid, page 12.

"Turbine specifications prepared provide for a plant turbine with 80 psig first stage and 20 psig second stage. The power plant for this 437°F (225°C) field may have two 35 megawatt units in operation by mid-1980. The estimated cost for the electricity generating plant installed will be $460 per kilowatt. A savings of $26 million in foreign exchange would result from this development."[6]

Summary

The cost of geothermal power production plants increases significantly as the temperature of the resource decreases. Lower temperatures require much larger volumes of fluid to supply the required heat. As with conventional fuels, if the Btu content per unit volume becomes significantly low, it is not economically usable for power production. It is very difficult to establish specific costs for electricity produced by geothermal resources of varying temperatures. B. Greider presents a "probable range of prices* for electricity generated from steam and hot water reservoirs" as follows:[7]

Steam 450°F (232°C) and above	24-30 mills/kwhr
Hot water flash--below 400°F (204°C)	36-50 mills/kwhr
Hot water flash--above 400°F (204°C)	27-32 mills/kwhr
Binary (below 375°F = 190°C)	40-48 mills/kwhr

The preliminary roster of BPA geothermal electric sites is in the range of 300° to 400°F (149° to 204°C) with no site above 400°F (204°C). Therefore, these sites would fall in the 36-50 mills/kwhr or 40-48 mills/kwhr for binary power production.

Figures from a recent report by the U.S. Department of Energy (Fourth Annual Report, Geothermal Energy, Research, Development and Demonstration Program, by

*These figures are based on costs in 1979 of projects under construction or under design, thus are costs for potentially successful, (economically competitive) projects (personal communication with B. Greider).
[6]Ibid, page 12.
[7]Ibid, page 12.

Interagency Geothermal Coordinating Council, June 1980) gives the following projected costs for geothermal electric power development at various northwest sites:

Site	Produce Costs* Capital $M	O&M $M/Yr	Utility Costs* Capital $M	O&M $M/Yr	Bus Bar Cost** Mills/kwhr
California					
Surprise Valley	71.1	1.6	39.0	1.4	77
Oregon					
Alvord H.S.	79.5	1.8	37.4	1.3	81
Crump's H.S.	70.0	1.6	38.0	1.3	75
Hot (Borax) Lake	45.3	1.1	37.0	1.3	55
Mickey H.S.	46.3	0.8	30.9	0.9	50
Neal H.S.	71.0	1.6	37.1	1.3	76
Newberry Caldera***	47.2	0.9	27.6	0.8	49
Trout Creek	144.2	3.0	38.8	1.4	131
Vale H.S.	46.8	1.2	38.6	1.4	58
Idaho					
Big Creek H.S.	80.9	1.8	38.3	1.3	83
Crane/Cove Creek	45.5	1.1	37.8	1.3	56
Nevada					
Baltazor H.S.	88.2	2.0	38.6	1.4	89
Pinto H.S.	62.5	1.4	37.7	1.3	69

*Based on a 50 MW_e power plant in 1978 $.
**Costs are levelized over an assumed life of 30 years for the generating plant (1978-2008 time frame).
***Environmental restraints may preclude development.

These figures assume that the initial plant size at each site would be 50 MW_e and 100 MW_e for following plants with three- to five-year interplant lead time. The average bus bar cost of the 13 sites is 73 mills/kwhr. This is considerably higher than the 36-50 Mills/kwhr presented by B. Greider. However, Greider's data are based on 1979 costs and the DOE data are based on a levelized cost over 30 years (1978-2008), which would be an average inflated cost (at 10 percent) around 1993.

Recent developments in geothermal electric power production include a well-head generator of a shear torque turbine type (American Thermal Resources, Inc.).

Instead of a single 50 to 100 MW_e generator, 5 to 6 MW_e wellhead generators are considered instead. As a result, where 14-15 wells are needed to produce 50 to 55 MW_e, these same wells have the potential of producing 90 MW_e using the wellhead generator. The total development cost is the same; however, the cost per kw of installed capacity is estimated to be reduced to about 60 percent of the conventional 50 to 55 MW_e plant and the installation time is anticipated to be reduced from 6 to 8 years to 2 to 2-1/2 years. This plant type has not been proven on a commercial basis and is still in the developmental stage. The cost and time savings make it an extremely attractive investment possibility. Additional details will be given in section VI.

A group of five western utilities, known as Northern Nevada Geothermal Group (NORNEV), is formulating plans to develop geothermal power generation in northern Nevada (Dixie Valley area). They plan to install a 10-MW_e generator and associated equipment in the first project at a cost of $12 million. The unit is a wellhead generator type using a hydrocarbon fluid, developed by Howe-Baker Associates, Tyler, Texas. The generator could be moved to a new location if the supply of geothermal fluid from a well drops below power generation requirements. This generator could go into commercial operation by 1982, with plans for a larger generating station of about 55 MW_e also under review.*

A report by the Electric Power Research Institute (EPRI, PS-1201-SR, Special Report, July, 1979--Technical Assessment Guide) states that geothermal binary power plants of 50 MW_e output will be available for commercial order by 1986 and have the first commercial service by 1992. Recent correspondence with Vasel W. Roberts, Program Manager for Geothermal Power Systems (September 23, 1980) states that these figures may be conservative. He states that a binary demonstration power plant of commercial design and size will come on-line by mid 1984. It is thus possible that binary cycle commercial availability could come as early as 1985 (see Appendix for copy of letter).

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*Regional Hydrothermal Commercialization Progress Monitoring, September, 1980, EG&G, Idaho Falls.

IV. FEASIBILITY AND DISPLACEMENT EVALUATIONS

A. GEOTHERMAL RESOURCE POTENTIAL EVALUATION

Approximately 200 geothermal resource sites were initially identified within the BPA market area. These site locations were based on information from USGS Circular 790, individual state geological and geothermal reports, and from personal contacts with knowledgeable persons in each state.* Data on the resource, local geographic characteristics, size and distance to load centers, and institutional jurisdiction, and environmental characteristics were collected for each site.

Using this information, an initial screening was conducted to reduce the number of sites; this first-round elimination was based upon population, heating load, availability of resource data, and severe environmental impediments. The minimum population load was set at 100 residents within a 25-mile radius of the geothermal resource; even though the resource may eventually be used by the local population, a load size of less than 100 residents was not considered sufficient for the scope of this study. However, potential electrical generation sites were not eliminated because of a lack of adjacent population, since electricity can be transmitted to other locations via transmission lines. These screening criteria reduced the number of sites to about 100.

The remaining 100 sites include high (>302°F = 150°C), intermediate (302°-194°F = 150°-90°C), and low (<194°F = 90°C) temperature hydrothermal resources, along with igneous systems which are designated as KGRA's. Since the load area for sites was considered to be 25 miles, many of these load areas overlapped; as a result, adjacent resources that had the potential of serving the same general population were grouped together for evaluation purposes. This

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*Reports are listed in the References and state contacts are listed in the Acknowledgements.

grouping resulted in 52 composited resources to be evaluated in detail for energy potential. The final composite resources are distributed as follows:

State	Composite Resource Sites: Preference Customers	Composite Resource Sites: Nonpreference Customers	Total
Idaho	4-3/4**	14-1/4	19
Oregon	6	6	12
Washington	4-3/4	4-1/4	9
W. Montana	1-1/4	6-3/4	8
N. Nevada	3	0	3
N. California	2	0	2
W. Wyoming	0	0	0
N. Utah	0	0	0
TOTAL	21-3/4	31-1/4	53*

It should be noted that the 25-mile radius was selected as the probable maximum distance hot water can be economically piped for direct thermal applications. This is expected to hold true until the year 2000; after 2000, fossil fuel prices may make it economical to extend this distance up to 50 miles or more. There may be near-term exceptions to the 25-mile limitation, as studies have shown in Iceland. The main exception would be a large, concentrated load with a high-load factor (constant use all year), typical of industrial loads. In the BPA market area very few sites would meet these criteria, and because the development of these are still in question, such as Northwest Natural Gas' Portland-Mt. Hood project, none were considered for evaluation purposes. In addition, extremely low temperature sites (<100°F = 38°C) were considered to be usable only within five miles from the resource. This low temperature is in the heat pump range, and thus the economics of piping are not as favorable as with higher temperatures.

The initial resource potential estimates were calculated from USGS Circular 790. As an example, the composite Oregon resource site of Little Valley, Neal

*Two sites are split along state lines.
**Utility jurisdiction estimated to nearest one-fourth of site area.

Hot Springs, Vale Hot Springs, and the Western Snake River Basin (202, 203, 204, and ID9) have the following potential according to Circular 790:

Site	Electrical Energy	Beneficial Heat	Temp. Range
202	---	0.061×10^{18}J*	302°-194°F (150°-90°C)
203	36	---	>302°F (>150°C)
204	870	---	>302°F (>150°C)
ID9	---	---	<194°F (<90°C)

Unfortunately, these data only give part of the picture. For site 202 (302°-194°F = 150°-90°C) the beneficial heat is based on a heat utilization factor of 0.24 [90°F and 68°F (50°C and 38°C) temperature drop for a 302°F and 212°F (150°C and 100°C) resource, respectively]. Since the electric generating potential is based on temperatures above 302°F (150°C), none is estimated for this site. The direct-use energy is thus calculated for the resource below 302°F (150°C) and is:

$$\frac{0.061 \times 10^{18}\text{J}}{1{,}055\text{J/Btu} \times 30 \text{ yrs}} = 2.0 \times 10^{12} \text{ Btu/yr.}$$

Sites 203 and 204 are high-temperature sites (>302°F = 150°C) and thus have no estimates for beneficial heat below 302°F (150°C). There is obviously usable energy below 302°F (150°C), especially as waste water from the power plant (only about 20 percent on the thermal potential would be used). Thus, using the remaining information given in Circular 790:

Site	Wellhead Thermal Energy	Wellhead Available Work
203	0.39×10^{18}J	0.084×10^{18}J
204	11.2×10^{18}J	2.0×10^{18}J

*J = Joule = 0.000948 Btu.

An estimate of the remaining direct-use energy can be made. Using site 203 for example:

	0.390×10^{18}J	thermal energy
-	0.084×10^{18}J	available work
	0.306×10^{18}J	remaining energy

converting to an annual basis:

$$\frac{0.306 \times 10^{18}\text{J}}{1{,}055\text{J/Btu} \times 30 \text{ yrs}} = 9.67 \times 10^{12} \text{ Btu/yr}$$

Using a 0.24 utilization factor (since the remaining fluid will probably be below 302°F = 150°C), the beneficial heat is:

$$0.24 \times 9.67 \times 10^{12} \text{ Btu/yr} = \underline{\underline{2.32 \times 10^{12} \text{ Btu/yr}}}$$

The corresponding beneficial heat figure for site 204 is:

$$\underline{\underline{69.76 \times 10^{12} \text{ Btu/yr}}}$$

Finally, Site ID9, the low-temperature site (194°F = 90°C), must be considered. USGS Circular 790 did not estimate the energy for low-temperature sites. USGS felt that the energy at these sites came from aquifers whose nature and extent were then unknown, and therefore they did not make an energy estimate; however, they did feel that these sites represent a significant fraction of the total low-temperature energy in the BPA region. Low-temperature resources located on the USGS maps represent areas generally greater than 20 km^2 (7.7 mi^2) in which low-temperature geothermal waters are believed to occur in extensive aquifers within 1 km (3,000 ft) of land surface. In addition, selection of these sites was based on a surface temperature 18°F (10°C) above mean annual air temperature, having a thermal gradient exceeding 87°F/mi (30°C/km); and heat flows generally above 60 mW/m^2 (4.65×10^9 Btu/yr/mi^2). In many cases, this information was lacking, and thus only a generalized knowledge of the geohydrology was available to guide the location of areal boundaries. The presence of wells and springs was the main criteria for boundary determination.

USGS is presently working on the problem of estimating the energy in these low-temperature resources. Conversations with personnel at USGS, Menlo Park, and the University of Utah Research Institute (UURI), who have assisted in writing Circular 790, revealed that no new information is presently available; in fact, these personnel expressed concern as to the method of accomplishing the task (outside of physically drilling and/or measuring each site).

Since reasonable estimates of low-temperature energy potential were needed for this project, an approximate and simplified method was suggested to the USGS and UURI personnel, and they agreed that it represents the best methodology within the project's time and budgetary constraints.

The low-temperature methodology is as follows: Since much is known about the Klamath Falls resource, based upon numerous wells in the area and extensive field observations by Geo-Heat Center personnel, the base data were derived from this experience. Three estimates of the beneficial heat were made and averaged, as follows:

1. Based on USGS Circular 790

   a. Area of resource (1978 Oregon Geothermal Map) = 350* mi^2

   b. Beneficial heat energy (USGS Circular 790) for sites 186 and 187 = $1.977 \times 10^{18} J = 1.87 \times 10^{15}$ Btu

   c. $\frac{\text{Energy}}{\text{Area}} = \frac{1.87 \times 10^{15}}{350} = 5.34 \times 10^{12}\ \text{Btu/mi}^2$

   d. Assuming a 30-year life:

   $$\frac{\text{Energy}}{\text{Area x Time}} = \frac{5.34 \times 10^{12}}{30} = \underline{\underline{178 \times 10^{9}\ \text{Btu/yr/mi}^2}}$$

*This exceeds the 200 mi^2 used in the example in Section II of this report. The larger figure is based on Oregon DOE map and is felt to be more comprehensive. Also see note on page 83.

2. Based on OIT well pumping data and district heating recommendations

   a. 1,000-1,200 ft minimum spacing between wells or 16 wells/mi^2 maximum (40 acres/well)

   b. Average sustained output per well $\approx$ 250 gals/min (500 gpm maximum)

   c. Assume a wellhead temperature of 180°F (82°C) or a maximum bottom hole or resource temperature of 200°F (93°C) and a usable temperature loss (ΔT) at heat exchangers at 40°F (22°C). (This is for retrofit of existing systems; new systems designed for geothermal could obtain a ΔT of 80°F = 44°C).

   d. The beneficial heat is then:

$$\frac{250 \text{ gals}}{\text{min x well}} \times \frac{8.33 \text{ lbs}}{\text{gal}} \times \frac{1 \text{ Btu}}{\text{lb °F}} \times 40°\text{F} \times \frac{5.256 \times 10^5 \text{ min}}{\text{yr}} \times \frac{16 \text{ wells}}{\text{mi}^2}$$

$$= \underline{\underline{700 \times 10^9 \text{ Btu/yr/mi}^2}}$$

3. Based on a typical aquifer

   a. Assume 1,000 ft thick aquifer with a 20 percent effective porosity (saturated) and 25 percent recovery factor (sweep process).

   b. 200°F (93°C) resource temperature referenced to 60°F (15°C) for energy recovery or a ΔT of 140°F (78°C).

   c. 24 percent utilization factor and 30-year life.

   d. The beneficial heat is then:

$$1{,}000 \text{ ft} \times \frac{5280 \text{ ft}^2}{\text{mi}^2} \times 0.20 \times 0.25 \times \frac{62.4 \text{ lbs}}{\text{ft}^3} \times 140°\text{F} \times \frac{1 \text{ Btu}}{\text{lb °F}} \times \frac{0.24}{30 \text{ yrs}}$$

$$= \underline{\underline{97.4 \times 10^9 \text{ Btu/yr/mi}^2}}$$

These three figures appear to vary widely; however, assumptions under methods 2 and 3 could vary the results in the following manner:

2. Sixteen wells per square mile is probably a maximum that would ever be realized due to possible adverse interference and the need for separation from injection wells. A spacing of nine wells per square mile might be more reasonable, giving a beneficial heat of:

   $= 394 \times 10^9$ Btu/yr/mi^2

3. An aquifer thickness of 1,000 ft may be conservative, since USGS figures low temperature reservoirs could be exploited economically to a depth of 1 km (3,000 ft). Using this thickness gives a beneficial heat of:

   $= 292 \times 10^9$ Btu/yr/mi^2

These two figures along with the 178×10^9 Btu/yr/mi^2 from method 1 are in closer agreement. Averaging the results by the first assumption gives:

$$\frac{178 + 700 + 97.4}{3} = 325 \times 10^9 \text{ Btu/yr/mi}^2$$

by the second set of assumptions gives:

$$\frac{178 + 394 + 292}{3} = 288 \times 10^9 \text{ Btu/yr/mi}^2$$

Since these two averages are in close agreement, a final average is probably justified giving:

$$\frac{325 + 288}{2} = 306 \times 10^9 \text{ Btu/yr/mi}^2$$

$$\simeq \underline{\underline{300 \times 10^9}} \text{ Btu/yr/mi}^2$$

The 300×10^9 Btu/yr/mi^2 average areal beneficial heat was based on a resource temperature (or maximum well bottom temperature) of 200°F (93°C) and a usable wellhead (or entering heat exchanger) temperature of 20°F (11°C) less or 180°F (82°C). Other resource temperatures must be corrected by the usable ΔT to give a beneficial heat value to be used in the areal reservoir evaluation. These figures would either be based on retrofitting existing heating systems or new construction designed for geothermal fluids. Below 100°F (38°C) wellhead temperature, heat pumps would be used. The results are summarized in Table 6 and shown graphically in Figure 20.

The assumptions made for these calculations obviously leave much to be desired; however, the results appear reasonable. Until USGS can complete its evaluation of low-temperature resources, the preceding calculations will represent the best available information to date.

Note: A review of these assumptions and calculations by USGS (P. Muffler) indicate they are conservative and could be considerably higher. Method 1 is probably low by a factor 10 (29.4 mi^2 vs. 350 mi^2 according to Circular 790 and method 3 by a factor 4 (25 percent recovery factor is a heat recovery factor and thus not relevant). Since the areal extent and temperatures of these low-temperature resources used in subsequent calculations are estimated based on sparce or questionable data, the 300 x 10^9 Btu/yr/mi^2 at 200°F (93°C) will be retained to be on the conservative side.

Table 6

Estimates for Low-Temperature Reservoir Evaluation

Resource Temperature °F (°C)	Wellhead Temperature °F (°C)	Retrofit: ΔT in °F(°C)	Retrofit: Areal Beneficial Heat x10^9 Btu/yr/mi^2	New Construction: ΔT in °F(°C)	New Construction: Areal Beneficial Heat x10^9 Btu/yr/mi^2
220 (104)	200 (93)	50 (28)	375	100 (56)	750
200 (93)	180 (82)	40 (22)	300	80 (44)	600
180 (82)	160 (71)	30 (17)	225	60 (33)	450
160 (71)	140 (60)	20 (11)	150	40 (22)	300
140 (60)	120 (49)	15 (8)	112.5	30 (17)	250
120 (49)	100 (38)	15* (8)	112.5	15* (8)	112.5
100 (38)	80 (27)	10* (6)	75	10* (6)	75
80 (27)	60 (16)	10* (6)	75	10* (6)	75

*Heat pump range (recent equipment developments may increase the ΔT).

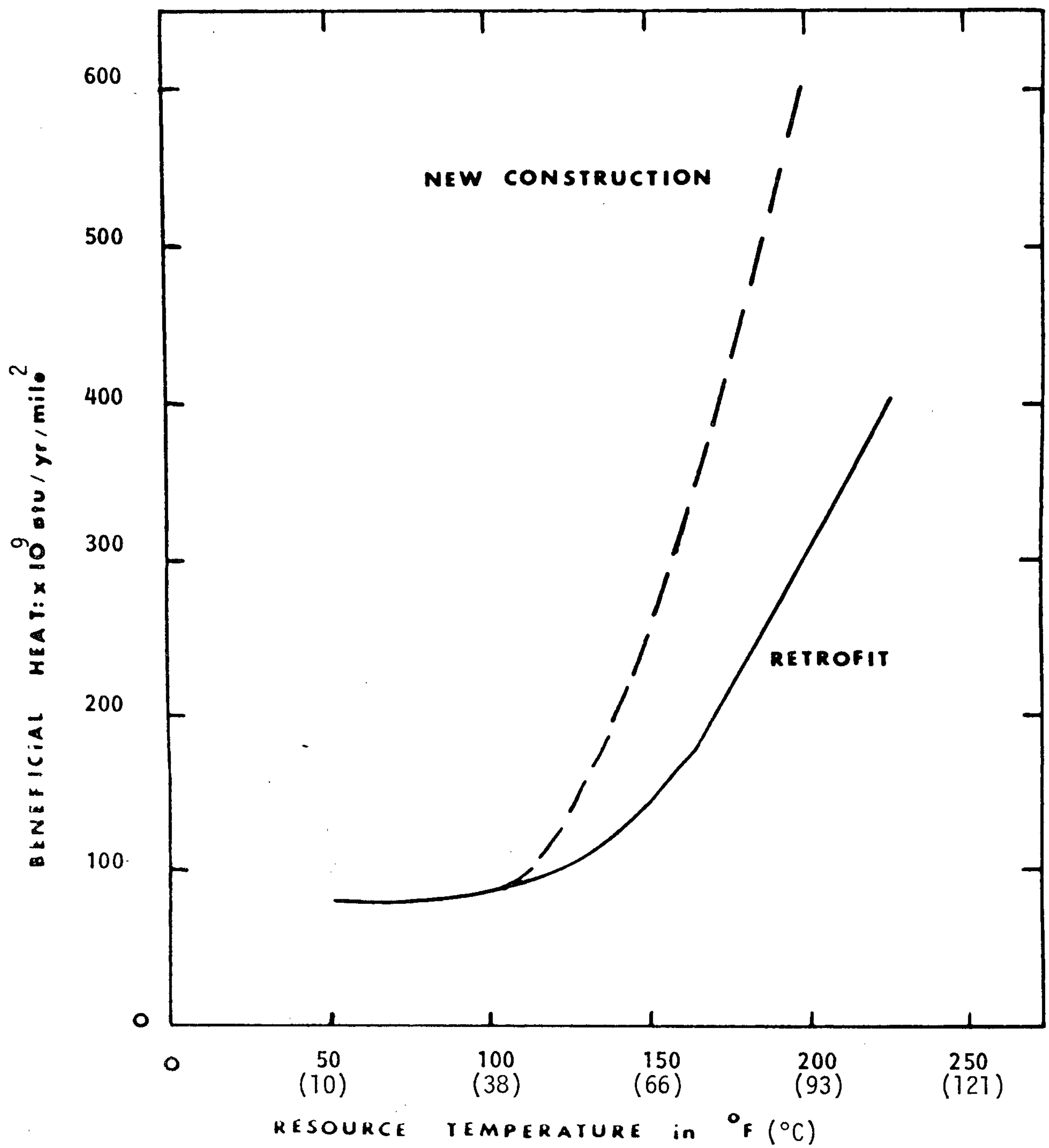

Figure 20. Low-temperature resource potential.

The graphical representation uses a smooth curve through the points and thus will give slightly different results than the table. The graph figures will be used in subsequent calculations.

Finally, after all of the discussion for the low-temperature resource evaluations, the value for ID9 in our example can be determined.

1. Area (1978 Oregon Geothermal Map) = 300 mi^2 (in Oregon only)
2. Use 200°F (93°C) resource temperature
3. From Figure 24, the areal beneficial heat = 300 x 10^9 Btu/yr/mi^2
4. The total resource beneficial heat = 300 x 300 x 10^9 = 90 x 10^{12} Btu/yr

Summarizing the results of the calculations for the composite resource gives:

Beneficial Heat (10^{12} Btu/yr)

Site	>302°F (150°C)	302°-194°F (150°-90°C)	<194°F (90°C)
202	---	2	---
203	2.3	---	---
204	69.8	---	---
ID9	---	---	90

The total beneficial heat available for direct use is then:

= 164.1 x 10^{12} Btu/yr

Similar calculations are made for each of the 50 remaining composite resource sites. The results are summarized in Table 7. A summary by state is as follows:

State	Total Beneficial Heat
Idaho	1,323.4 x 10^{12} Btu/yr
Oregon	782.0 x 10^{12} Btu/yr
Washington	284.2 x 10^{12} Btu/yr
W. Montana	34.8 x 10^{12} Btu/yr

State	Total Beneficial Heat
N. Nevada	326.7×10^{12} Btu/yr
N. California	346.0×10^{12} Btu/yr
TOTAL	$3{,}097.1 \times 10^{12}$ Btu/yr
	$\simeq$3.0 quad/yr

or 90 quads over a conservative 30-year life for the resources.

This is the usable geothermal resource potential that has significant direct-use loads within 25 miles. There is obviously greater energy potential in each state because half of the resource sites were initially eliminated due to impediments or constraints described earlier. In addition, no direct-use potential was estimated for the igneous systems (KGRA's) and certain other high temperature resources for the range >302°F (150°C), because very little information was available on these resources. However, state personnel did feel these sites had electrical potential based upon recent drilling or leasing activity. Therefore, these sites were only estimated for electrical potential; a question mark follows these estimates in Table 7.

Individual resource sites, and the 25-mile radius of potential load displacement for composite sites, are shown on the two foldout maps attached at the end of the report.

B. GEOTHERMAL LOAD AND DEVELOPMENT SCHEDULE

Two types of geothermal energy loads were considered: electric and direct use (nonelectric). Electric use is essentially independent of the geothermal resource location. The main limitation is the lack of power transmission lines within a reasonable distance of a resource. In most cases, this is not a problem, and therefore all sites with environmental conditions conducive for geothermal electrical power production were considered. On the other hand, nonelectric uses must be located relatively near a geothermal resource due to piping distance limitations.

TABLE 7.
GEOTHERMAL RESOURCE POTENTIAL OF BPA STUDY AREA

Resource No.	Resource Name	Temperature, °F Reservoir	Wells/Springs	Conversion Potential (Beneficial Heat) x 10^{12} Btu/yr >302°F	302-194°F	<194°F	Total	Electrical Potential MWe Prob.	Poss.*	Utility Jurisdiction (%)
OREGON										
177-179	Hood/Carey/Breitenbush	219-257	194-198	?	5.5	--	5.5	0	(250)	Portland G.E. (75) / Consumers Power, Inc. (25)†
180	Kahneetah H.S.	228	126	--	1.7	--	1.7	--	--	Pacific Power & Light
181-183/ OR1-2	Belknap/Foley/McCredie	196-235	57-163	?	3.1	40.5	43.6	0	(250)	Lane Co. Elec. Coop†
186/187/ OR9	Klamath Falls/K. Hills	232-255	199-235	--	65.9	105.0	170.9	--	--	Pacific P & L Co.
189/OR8	Lakeview	302	205	?	11.0	18.0	29.0	0	(200)	Pacific P & L Co.
190/191	Crump's/Fisher	333	250	4.5	1.8	--	6.3	61	(0)	Surprise Valley Elec. Coop†
193/194/ OR5-6	Harney/Crane	230-243	70-172	--	3.6	102.6	106.2	--	--	Harney Elec. Coop†
196-199/ OR7	Mickey/Alvord/Borax/ Trout	309-401	61-205	20.6	--	67.5	88.1	324	(0)	Harney Elec. Coop†
201/OR3	Medical/Craig-Cove	205	75-180	--	1.5	19.5	21.0	--	--	California Pacific U.C.
202-204/ ID9a	Little Valley/Neal/ Vale/W.Snake	315-370	68-189	72.1	2.0	90.0	164.1	906	(0)	Idaho Power Co.
GB KGRA/ OR4	Glass Butte	>300?	64-118	?	?	12.6	12.6	0	(50)	Central, Midstate & Harney E.C.†
OSR1	Milton-Freewater	130?	75	--	--	33.0	33.0	--	--	Pacific Power & Light (25) / Milton-Freewater City (75)†
TOTAL							682.0	1291	(750)	
NEVADA										
130-132/ NV2,5	Baltazor/Dyke/Pinto	223-343	70-199	10.2	1.6	225.0	236.8	136	(0)	Harney E.C.†
167/NV4	Mineral/Jackpot	212-228	77-147	--	1.7	57.6	59.3	--	--	Wells REC†
168/NV7	Hot Sulfur/Wells	221-289	100-131	--	3.3	7.8	11.1	--	--	Wells REC†
TOTAL							307.2	136	(0)	

*Includes igneous system estimates, and speculations based on interest in the area; does not include probable.
†BPA Preference Customer.

TABLE 7.
GEOTHERMAL RESOURCE POTENTIAL OF BPA STUDY AREA

Resource No.	Resource Name	Temperature, °F Reservoir	Wells/ Springs	Conversion Potential (Beneficial Heat) x 10^{12} Btu/yr >302°F	302-194°F	<194°F	Total	Electrical Potential MWe Prob.	Poss.*	Utility Jurisdiction (%)
CALIFORNIA										
034/035/ CA1	Ft. Bidewell/Surprise	231-306	70-320	123.6	2.2	192.0	317.8	1490	(0)	Surprise Valley E.C.†
036/038/ CA2	W. Valley/Kelly	244	81-241	--	4.2	24.0	28.2	--	--	Surprise Valley E.C.†
TOTAL							346.0	1490	(0)	
IDAHO										
ID8	Ketchum	185	144-160	--	--	7.7	7.7	--	--	Idaho Power Company
ID9b	Boise Front	174	68-169	--	--	20.0	20.0	--	--	Idaho Power Company
ID9c	Nampa-Caldwell	99-158	68-122	--	--	28.0	28.0	--	--	Idaho Power Company
114/ ID9e-f	Banbury/Hollister/ Artesian	167-243	95-138	--	14.7	20.0	34.7	--	--	Idaho Power Company
ID12/GL KGRA	Blackfoot/Grays Lake	122	73-108	?	?	20.0	20.0	0	(100)	Utah Power & Light Co.
ID13	Pocatello	140	68-106	--	--	3.3	3.3	--	--	Idaho Power Company
087	Riggins H.S.	216	108	--	1.6	--	1.6	--	--	Idaho Power Company
091	Carbarton H.S.	223	158	--	1.6	--	1.6	--	--	Idaho Power Company
093/094	Crane-Cove/Weiser	266-340	170-199	24.9	2.8	--	27.7	340	(0)	{Idaho Power Company (25) Weiser City (75)
095	Roystone	275	131	--	2.2	--	2.2	--	--	Idaho Power Company
099-102 ID9d	Latty/Radio/Gravel Bruneau-Grand View/ Mt. Home	217-257	93-131	--	905.5	14.0	919.5	--	--	Idaho Power Company
104/105	Owl Creek/Big Creek	259-324	122-199	2.0	2.0	--	4.0	26	(0)	Idaho Power Company
107/108/ ID3	Sunbeam/Slate/Stanley- Challis	131-234	100-169	--	3.4	16.5	19.9	--	--	Salmon River E.C.†
109-112/ ID10	Magic/Worswick/Wardrop/ Barron's/Camas	194-300 347††	70-178	?	6.9	172.8	179.7	0	(200)	{Idaho Power Company (50) Prairie Power Coop(50)†

*Includes igneous system estimates, and speculations based on interest in the area; does not include probable.
†BPA Preference Customer.
††Reference: Geothermal Investigations of Idaho (Part 7) for Magic.

TABLE 7.
GEOTHERMAL RESOURCE POTENTIAL OF BPA STUDY AREA

Resource No.	Resource Name	Temperature, °F Reser-voir	Wells/ Springs	Conversion Potential (Beneficial Heat) x 10^{12} Btu/yr >302°F	302-194°F	<194°F	Total	Electrical Potential MWe Prob.	Poss.*	Utility Jurisdiction (%)
IDAHO (Continued)										
115	Raft River	300	297	--	14.7	5.0	19.7	10	(200)	Raft River REC†
116/117/ ID11	Ashton/Newdale	167-212	70-106	--	42.0	5.1	47.1	--	--	Fall River REC†
118-121	Maple/Riverdale/ Wayland/Squaw	199-246	111-190	?	6.6	--	> 6.6	0	(200)	Utah Power & Light Co.
IP KGRA	Island Park	>300?	?	?	?	?	?	0	(1000)	Fall River REC†
WSR1	Lewiston	(Resource in Washington-Clarkston)				--	0	--	--	Washington Water Power Co.(75 / Clearwater Power Co. (25)†
TOTAL							1343.3	376	(1700)	
WASHINGTON										
WA2	Yakima	124-147?	79-86	--	--	10.5	10.5	--	--	Pacific Power & Light Co.
WA3	Ephrata	?	77-86	--	--	5.4	5.4	--	--	Grant Co. PUD†
WA4	Walla Walla	?	79-82	--	--	33.0	33.0	--	--	Pacific P & L Co. (50) / Columbia REA (50)†
WSR1	Clarkston	?	80	--	--	8.0	8.0	--	--	Washington Water Power Co. (75 / Clearwater Power Co. (25)†
WSR2	Prosser	?	80?	--	--	19.2	19.2	--	--	Benton Co. PUD (75)† / Richland City Light (25)†
WSR3-4	N. Bonneville/Carson	<176	90-120	--	--	6.0	6.0	--	--	Skamania Co. PUD†
WSR5	King County	>300?	?	?	?	?	?	0	(200)	Puget Sound P&L Co.
212/MB KGRA	Baker H.S./Mt. Baker	273	111	--	2.1	--	2.1	0	(200)	Puget Sound P&L Co.
MS KGRA	Mt. St. Helens	?	?	?	?	?	?	0	(200)	Skamania Co. PUD†
TOTAL							84.2	0	(600)	

*Includes igneous system estimates, and speculations based on interest in the area; does not include probable.
†BPA Preference Customer.

TABLE 7.
GEOTHERMAL RESOURCE POTENTIAL OF BPA STUDY AREA

Resource No.	Resource Name	Temperature, °F Reservoir	Temperature, °F Wells/Springs	Conversion Potential (Beneficial Heat) x 10^{12} Btu/yr >302°F	302-194°F	<194°F	Total	Electrical Potential MWe Prob.	Poss.*	Utility Jurisdiction (%)
MONTANA										
126/MT4 MSR10	Gregson/Warm Springs/ Anaconda	170-244	163-170	--	1.8	7.5	9.3	--	--	Vigilante Elec. Coop (25)† Montana Power Company (75)
MT5/128	Pipestone/Barkels	192-268	135-163	--	2.1	7.5	9.6	--	--	Vigilante Elec. Coop (25)† Montana Power Company (75)
MT7	Bozeman	185	131	--	--	3.5	3.5	--	--	Montana Power Company
123/124	Broadwater/Alhambra	205-244	138-151	--	3.3	--	3.3	--	--	Vigilante Elec. Coop (25)† Montana Power Company (75)
125	Boulder	277	169	--	2.2	--	2.2	--	--	Vigilante Elec. Coop (25)† Montana Power Company (75)
129/MT10	Ennis (Thexton)	264	181-192	--	2.1	--	2.1	--	--	Vigilante Elec. Coop (25)† Montana Power Company (75)
MSR46	White Sulfur	158-298	114	--	--	2.4	2.4	--	--	Montana Power Company
MSR50	Hunters	140-237	139	--	--	2.4	2.4	--	--	Montana Power Company
TOTAL							34.8	0	(0)	

*Includes igneous system estimates, and speculations based on interest in the area; does not include probable.
†BPA Preference Customer.

Initially, direct-use loads (residential, commercial, or industrial) within 50 miles of a resource were considered. This was later reduced to 25 miles for high and intermediate temperature resources (>194°F = 90°C), and within 5 miles for low-temperature resources. These distances were felt to be the maximum that would be economically feasible by the year 2000. At the present time, worldwide, the maximum distance geothermal water is piped for direct use is about 20 km or 13 miles, in Iceland. Projects up to 75 km (50 miles) are currently under active consideration, but none have been constructed. One project of this magnitude is being considered in the United States, which is Northwest National Gas Company's Mt. Hood to Portland pipeline; however, this project is still in the resource confirmation phase. Projects of this distance are heavily dependent upon a large, concentrated load and a high load factor. Space heating alone does not satisfy these criteria, with a typical load factor of 0.25; therefore, an industrial process base load is generally necessary.

Direct-Use Loads

The direct-use load has four major components:

1. Residential space heating and water heating;
2. Commercial space heating and water heating;
3. Public and institutional space heating and water heating; and
4. Industrial process heating.

No space or water heating was considered for the industrial load, due to the difficulty of estimating this item, the use of internal waste heat to meet most of these demands, and the estimated low figure for this use. These four types of loads were further subdivided into the portions provided by electricity and those provided by fossil fuel. Normally, this breakdown would not be necessary; however, the electrical load was of special interest as BPA supplies its customers in the region with energy in this form. In addition, the fossil fuel load was of interest as this load would be part of the conventional displacement in any non-electric geothermal project.

Initially, these load figures were requested from BPA area offices. Unfortunately, these figures were generally not available in the form necessary for this project. In a few cases only publically owned utility information was available, and not for investor-owned utilities. BPA data normally gives the total electrical load for a utility's jurisdiction or a city, or gives an average load for each customer. However, this information does not identify the lights and appliances portion of the electric load, which cannot be replaced by geothermal direct use. Also, the saturation or capture rate of electric space and water heating vs. fossil fuel was not known.

Residential Use

An average residential structure size of 1,800 square feet and household of 2.8 persons were used, based upon national census and homebuilding averages.

Space heating varies according to climate and is a function of the degree days of heating (DD)* and the outside design temperature (T),** and a correction factor of C_D.*** Based upon the Klamath Falls experience, a peak heating rate of 25 Btu/hr/ft^2 was used for an average home based on an older outside design temperature of 0°F. This is approximately equivalent to home construction using R19 ceiling insulation, double glazing, and R13 wall insulation as shown by the dashed line next to graph B in Figure 22. Using the current residential outside design temperature of 4°F (-15°C), a corrected peak heating load of 23.5 Btu/hr/ft^2 is obtained for Klamath Falls. This gives an annual heating load using the following ASHRAE**** relationship:

$$SHL = \frac{\text{Peak load/hr} \times 24 \times DD \times C_D}{65 - T}$$

*Reference 7.
**Reference 12, see Table 8.
***Reference 12, see Figure 21.
****American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., (Reference 12).

TABLE 8.

Weather Data and Design Conditions

TABLE 1 CLIMATIC CONDITIONS FOR THE UNITED STATES[a]

Col. 1	Col. 2		Col. 3		Col. 4	Winter[d] Col. 5		Summer[e] Col. 6			Col. 7	Col. 8		
	Latitude[b]		Longitude[c]		Elevation[c]	Design Dry-Bulb		Design Dry-Bulb and Mean Coincident Wet-Bulb			Mean Daily	Design Wet-Bulb		
State and Station	°	'	°	'	Ft	99%	97.5%	1%	2.5%	5%	Range	1%	2.5%	5%
IDAHO														
Boise AP(S)	43	3	116	1	2842	3	10	96/65	94/64	91/64	31	68	66	65
Burley	42	3	113	5	4180	−3	2	99/62	95/61	92/66	35	64	63	61
Coeur d'Alene AP	47	5	116	5	2973	−8	−1	89/62	86/61	83/60	31	64	63	61
Idaho Falls AP	43	3	112	0	4730r	−11	−6	89/61	87/61	84/59	38	65	63	61
Lewiston AP	46	2	117	0	1413	−1	6	96/65	93/64	90/63	32	67	66	64
Moscow	46	4	117	0	2660	−7	0	90/63	87/62	84/61	32	65	64	62
Mountain Home AFB	43	0	115	5	2992	6	12	99/64	97/63	94/62	36	66	65	63
Pocatello AP	43	0	112	4	4444	−8	−1	94/61	91/60	89/59	35	64	63	61
Twin Falls (AP (S)	42	3	114	3	4148	−3	2	99/62	95/61	92/60	34	64	63	61
MONTANA														
Billings AP	45	5	108	3	3567	−15	−10	94/64	91/64	88/63	31	67	66	64
Bozeman	45	5	111	0	4856	−20	−14	90/61	87/60	84/59	32	63	62	60
Butte AP	46	0	112	3	5526r	−24	−17	86/58	83/56	80/56	35	60	58	57
Cut Bank AP	48	4	112	2	3838r	−25	−20	88/61	85/61	82/60	35	64	62	61
Glasgow AP (S)	48	1	106	4	2277	−22	−18	92/64	89/63	85/62	29	68	66	64
OREGON														
Albany	44	4	123	1	224	18	22	92/67	89/66	86/65	31	69	67	66
Astoria AP (S)	46	1	123	5	8	25	29	75/65	71/62	68/61	16	65	63	62
Baker AP	44	5	117	5	3368	−1	6	92/63	89/61	86/60	30	65	63	61
Bend	44	0	121	2	3599	−3	4	90/62	87/60	84/59	33	64	62	60
Corvallis (S)	44	3	123	2	221	18	22	92/67	89/66	86/65	31	69	67	66
Eugene AP	44	1	123	1	364	17	22	92/67	89/66	86/65	31	69	67	66
Grants Pass	42	3	123	2	925	20	24	99/69	96/68	93/67	33	71	69	68
Klamath Falls AP	42	1	121	4	4091	4	9	90/61	87/60	84/59	36	63	61	60
Medford AP (S)	42	2	122	5	1298	19	23	98/68	94/67	91/66	35	70	68	67
Pendleton AP	45	4	118	5	1492	−2	5	97/65	93/64	90/62	29	66	65	63
Portland AP	45	4	122	4	21	17	23	89/68	85/67	81/65	23	69	67	66
Portland CO	45	3	122	4	57	18	24	90/68	86/67	82/65	21	69	67	66
Roseburg AP	43	1	123	2	505	18	23	93/67	90/66	87/65	30	69	67	66
Salem AP	45	0	123	0	195	18	23	92/68	88/66	84/65	31	69	68	66
The Dalles	45	4	121	1	102	13	19	93/69	89/68	85/66	28	70	68	67
WASHINGTON														
Aberdeen	47	0	123	5	12	25	28	80/65	77/62	73/61	16	65	63	62
Bellingham AP	48	5	122	3	150	10	15	81/67	77/65	74/63	19	68	65	63
Bremerton	47	3	122	4	162	21	25	82/65	78/64	75/62	20	66	64	63
Ellensburg AP	47	0	120	3	1729	2	6	94/65	91/64	87/62	34	66	65	63
Everett-Paine AFB	47	5	122	2	598	21	25	80/65	76/64	73/62	20	67	64	63
Kennewick	46	0	119	1	392	5	11	99/68	96/67	92/66	30	70	68	67
Longview	46	1	123	0	12	19	24	88/68	85/67	81/65	30	69	67	66
Moses Lake, Larson AFB	47	1	119	2	1183	1	7	97/66	94/65	90/63	32	67	66	64
Olympia AP	47	0	122	5	190	16	22	87/66	83/65	79/64	32	67	66	64
Port Angeles	48	1	123	3	99	24	27	72/62	69/61	67/60	18	64	62	61
Seattle-Boeing Fld	47	3	122	2	14	21	26	84/68	81/66	77/65	24	69	67	65
Seattle CO (S)	47	4	122	2	14	22	27	85/68	82/66	78/65	19	69	67	65
Seattle-Tacoma AP (S)	47	3	122	2	386	21	26	84/65	80/64	76/62	22	66	64	63
Spokane AP (S)	47	4	117	3	2357	−6	2	93/64	90/63	87/62	28	65	64	62
Tacoma-Mc Chord AFB	47	1	122	3	350	19	24	86/66	82/65	79/63	22	68	66	64
Walla Walla AP	46	1	118	2	1185	0	7	97/67	94/66	90/65	27	69	67	66
Wenatchee	47	2	120	2	634	7	11	99/67	96/66	92/64	32	68	67	65
Yakima AP	46	3	120	3	1061	−2	5	96/65	93/65	89/63	36	68	66	65

Ref: ASHRAE HANDBOOK 1977 FUNDAMENTALS

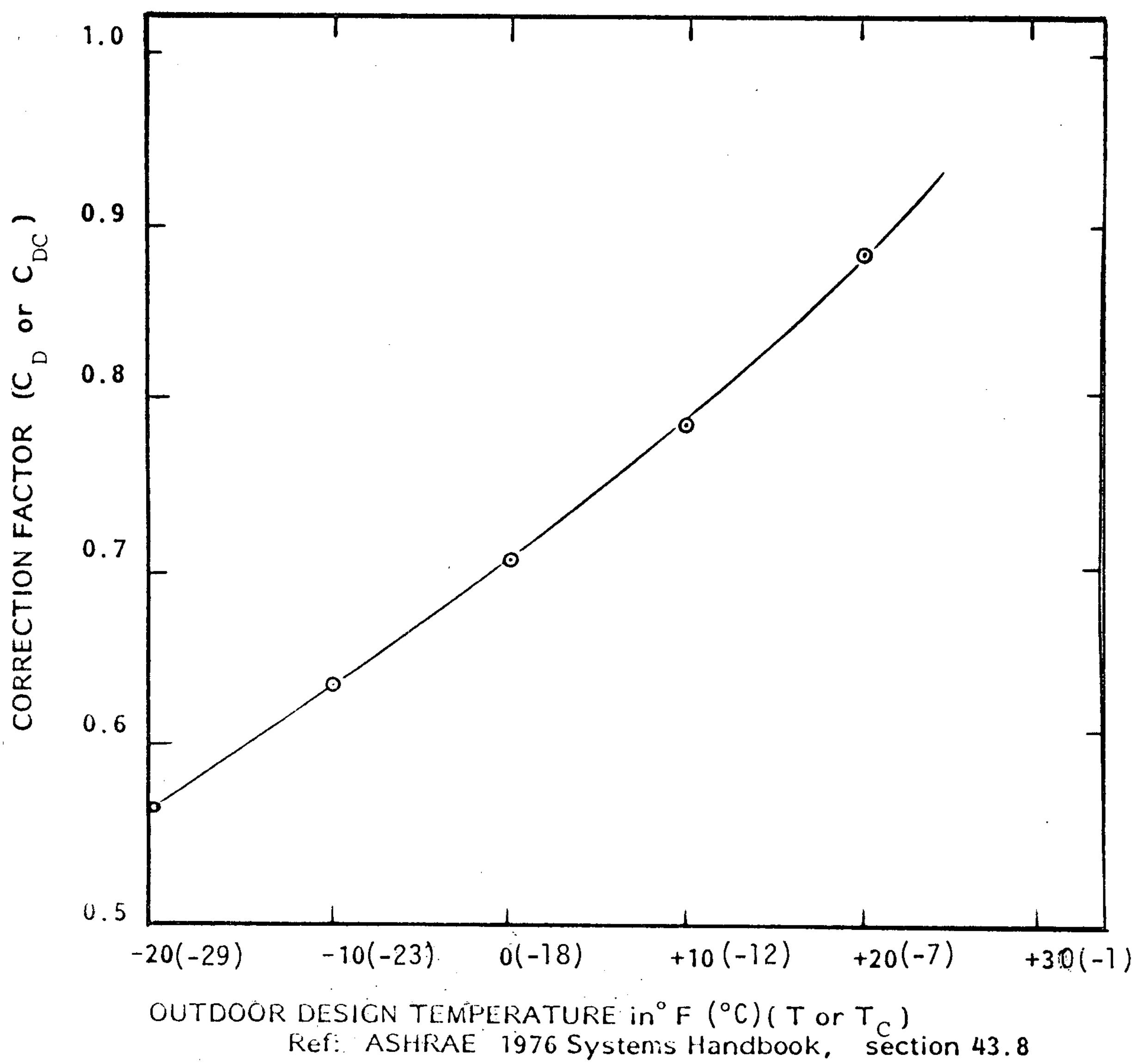

Figure 21. Outdoor design temperature correction factor.

(For Klamath Falls: DD = 6,516 °F-days/year, current outside design temperature, T = 4°F, C_D = 0.74, and the peak heating load = 23.5 x 1,800 = 42.3 x 10^3 Btu/hr.)

$$SHL = \frac{42.3 \times 10^3 \times 24 \times 6{,}516 \times 0.74}{65 - 4} = 80.2 \times 10^6 \text{ Btu/yr}$$

$$80.2 \times 10^6 \frac{\text{Btu}}{\text{yr}} \times \frac{1}{3{,}413} \frac{\text{kwhr}}{\text{Btu}} = 23{,}500 \text{ kwhr/yr}$$

From the Klamath Falls peak heating load, an expression can be developed to determine the peak heating load for any other area based on the residential outside design temperature, T, and the dashed line in Figure 22. This relationship is:

$$PHL = 25 - 0.385 \times T \quad \text{(in Btu/hr/ft}^2\text{)}$$

$$= 45{,}000 - 693 \times T \quad \text{(in Btu/hr for an 1,800-ft}^2\text{ house)}$$

Thus, the annual heating load relationship can be written as follows:

$$SHL = \frac{(45{,}000 - 693 \times T) \times 24 \times DD \times C_D}{65 - T} \quad \text{(in Btu/yr)}$$

$$= \frac{(13.2 - 0.203 \times T) \times 24 \times DD \times C_D}{65 - T} \quad \text{(in kwhr/yr)}$$

Checking this relationship against available figures for Walla Walla and Eugene, the results are as follows:

1. Columbia REA (Walla Walla) use of 16,000 kwhr/yr estimated by BPA:

   (DD = 4,835, T = 7°F, C_D = 0.77)

$$SHL = \frac{(13.2 - 0.203 \times 7) \times 24 \times 4{,}835 \times 0.77}{65 - 7}$$

$$= 18{,}146 \text{ kwhr/yr or approximately a +13 percent difference.}$$

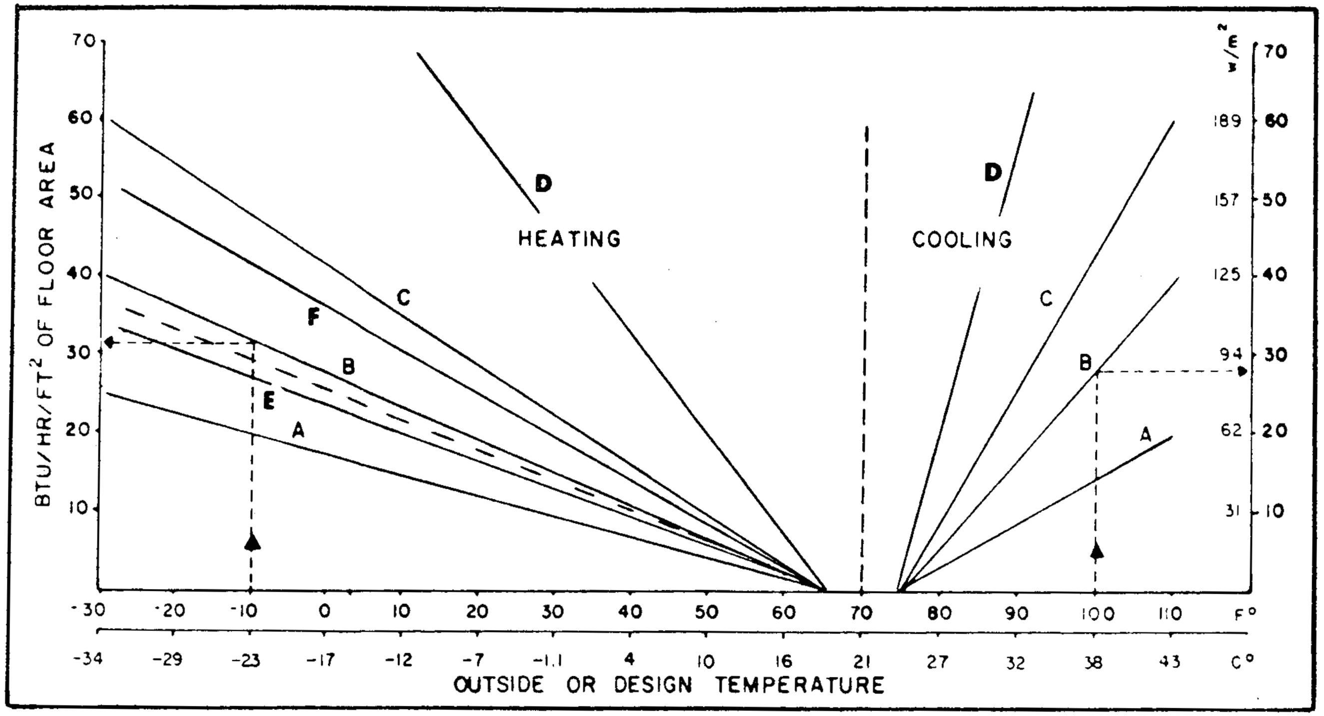

Figure 22. Design curves for heating and cooling loads.

<u>Curve Description</u>

A. Well insulated building (most rigid ASHRAE code design)
B. "Normally" insulated modern building (R-19 ceiling, R-13 walls, double glazing)
C. Older home (R-13 ceiling, frame construction--no wall insulation, single glazing)
D. Poor insulation (no insulation, single glazing)
E. Newer commercial (65°F interior, 11-foot ceiling)
F. Average commercial (65°F interior, 11-foot ceiling)

2. Eugene's use of 16,310 kwhr/yr for 1,700- to 1,800-ft^2 home, and 21,184 kwhr/yr for 1,800- to 1,900-ft^2 home (average of 18,747 kwhr/yr) in a survey by EWEB:*

$$(DD = 4{,}739,\ T = 22°F,\ C_D = 0.91)$$

$$SHL = \frac{(13.2 - 0.203 \times 22) \times 24 \times 4{,}739 \times 0.91}{65 - 22}$$

= 21,022 kwhr/yr or approximately a +12 percent difference.

These comparisons indicate our space heating load estimates are on the high side, but reasonable.

The remaining energy use in an average residence is based on 1980 data from BPA. These include domestic water heating and other electric appliances, which are essentially independent of location. The data for these loads are based on the following information:

Domestic Water Heating

Single-family residence: 4,360 kwhr/yr

Multi-family residence: 3,229 kwhr/yr

All other electrical load (lights, appliances, etc.)

Single-family residence: 7,667 kwhr/yr

Multi-family residence: 6,862 kwhr/yr

Single-family residences account for 74.2 percent of the residences in the BPA market area, and thus a weighted average for the above figures is:

Domestic water heating: 4,068 kwhr/yr

All other electric load: 7,459 kwhr/yr

This figure for water heating load reasonably agrees with PGE's estimate of 4,800 kwhr/yr for an average family, and EWEB's estimate of 5,400 kwhr/yr for an

*EWEB = Eugene Water and Electric Board.

average family. All other electrical load estimated by EWEB is 7,200 kwhr/yr. FP&L* estimates Portland's domestic hot water usage at 4.2 kwhr/day/person, or 4,292 kwhr/yr for 2.8 persons. Rocket Research Company (1979) estimates 5,377 kwhr/yr for water heating (by all forms of energy), and 6,540 kwhr/yr for all other electrical use for an average house in the BPA market area (1971 data based upon 3.1 persons per dwelling). Considering only electric hot water heat, the average was 4,785 kwhr/yr. Table 9 is reproduced from the Rocket report summarizing the load figures found in their study.

Using our estimates, the residential energy load for two cities in the northwest gives a range of space heating loads as follows:

	Klamath Falls	Walla Walla
DD of heating (°F)	6,516	4,835
Total energy load	35,027 kwhr/yr	29,673 kwhr/yr
Space heating load	23,500 kwhr/yr	18,146 kwhr/yr
Percent space heating	67	61
Percent water heating	12	14
Percent others (electrical)	21	25

The 1979 Rocket Research report gives a northwest regional average energy use for residences of 74 percent for space heating, 12 percent for water heating, and 14 percent for all other electrical use (1971 data). Rocket's space heating percentages are higher than those used in this report, because trends since 1971 have been towards better insulation and conservation, thus reducing the space heating component.

The 1979 Rocket report also gave a range of energy consumption for a typical residence. The values ranged from 50 to 150 million Btu's per year (14,650 to

* PP&L = Pacific Power and Light Company.

TABLE 9.

RESIDENTIAL ENERGY CONSUMPTION IN THE NORTHWEST REGION

Region: Pacific Northwest

Sector: Residential

Year: 1971

Population: 6,339,000 (1970)

Occupied Housing: 2,016,178 (170)

A: Amount (x 10^{12} Btu)

S: Saturation ratio

P: Percent of energy source consumed by the end use category

End Use	Energy Source															
	Electricity			Natural Gas			Fuel Oil			L-P Gas			Coal			Total	
	A	S	P	A	S	P	A	S	P	A	S	P	A	S	P	A	P
Cooking	8.4	0.88	8.2	1.3	0.07	1.8	0.07	0.004	0.06	0.6	0.03	6.8				10.0	3.3
Space heating	32.0	0.28	31.0	66.0	0.24	88.0	120.00	0.41	99.0	7.1	0.03	81.0	6.3	0.02	96.0	232.0	74.0
Water heating	27.0	0.82	27.0	7.9	0.11	10.0	1.2	0.02	1.0	1.1	0.01	12.0	0.2	0.001	3.5	37.0	12.0
Clothes washer	0.6	0.78	0.6	–	–	–										0.6	0.2
Clothes dryer	4.6	0.61	4.5	0.1	0.01	0.2										4.7	1.5
Dish washer	0.9	0.32	0.8													0.9	0.3
Freezer	4.0	0.44	3.9													4.0	1.3
Television	4.0	1.2	3.9													4.0	1.3
Air conditioner	0.9	0.12	0.9													0.9	0.3
Lighting	7.5	1.0	7.4													7.5	2.4
Refrigerator	8.6	1.0	8.4													8.6	2.7
Fans	3.6	0.72	3.5													3.6	1.1
Totals	102.0			75.0			122.0			8.7			6.5			314.0	
Control totals	106.0			67.0			126.0			13.6			6.2			319.0	

SOURCE: Energy Consumption in the Pacific Northwest, 1971, Hinman, et. al.

43,950 kwhr/yr) with 80 million Btu's per year for the study average (23,440 kwhr/yr). As it points out, this is dependent upon age of the community, size of the homes, the degree of insulation, the altitude, the annual heating degree days, and the type of fuel used for heating.

The final factor utilized for the residential calculations is the saturation or capture rate of electrical energy vs. fossil fuel. The 1979 Rocket report gave data for various subregions within the Pacific Northwest (see Table 10 and Figure 23) based upon 1973 data. BPA 1980 data have revised these figures and include domestic water heating and electrical penetration rates as well. The newer figures are either based on state averages, or degree days of heating and cooling. The 1980 BPA figures are:

		Electrical	
Climate Zone	Annual Degree Days Heating + Cooling(°F)	Percent Penetration of Water Heating	Percent Penetration of Space Heating
I	<6,000	85.4	45.6
II	6,000-7,000	91.0	55.1
III	7,000-8,000	91.0	44.5
IV	>8,000	52.6	22.7
State			
Idaho	---	83.9	39.7
Montana	---	37.5	13.5
Oregon	---	84.1	42.1
Washington	---	88.3	52.9

A preliminary degree day map of the region is provided as Figure 24. The degree day list was used for this report, except for Montana, where unique energy use necessitated using the state rate.

TABLE 10.
DISTRIBUTION OF OCCUPIED HOUSING UNITS IN SUBREGIONS OF THE NORTHWEST BY SPACE HEATING FUEL, 1970

Heating Fuel	Regions															
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)	8 (%)	9 (%)	10 (%)	11 (%)	12 (%)	Wash (%)	Ore (%)	Ida (%)	PNW (%)
Electricity	28	33	37	28	41	18	6	13	7	14	7	27	30	30	10	27
Natural gas	25	24	14	13	16	31	30	17	57	14	38	24	23	24	32	25
Fuel oil	43	38	32	41	37	41	45	51	24	46	38	35	41	38	40	39
L-P gas	2	1	6	4	2	2	4	8	6	10	5	7	2	3	5	3
Coal	0.3	0.2	0.1	1	2	5	6	6	0.7	6	12	0.2	1	0.3	9	2

SOURCE: Hinman, George, Larry Kimmel, and John Wiesniewski, "Residential Energy Consumption in the Pacific Northwest, 1971", Pullman, Washington (August 17, 1973).

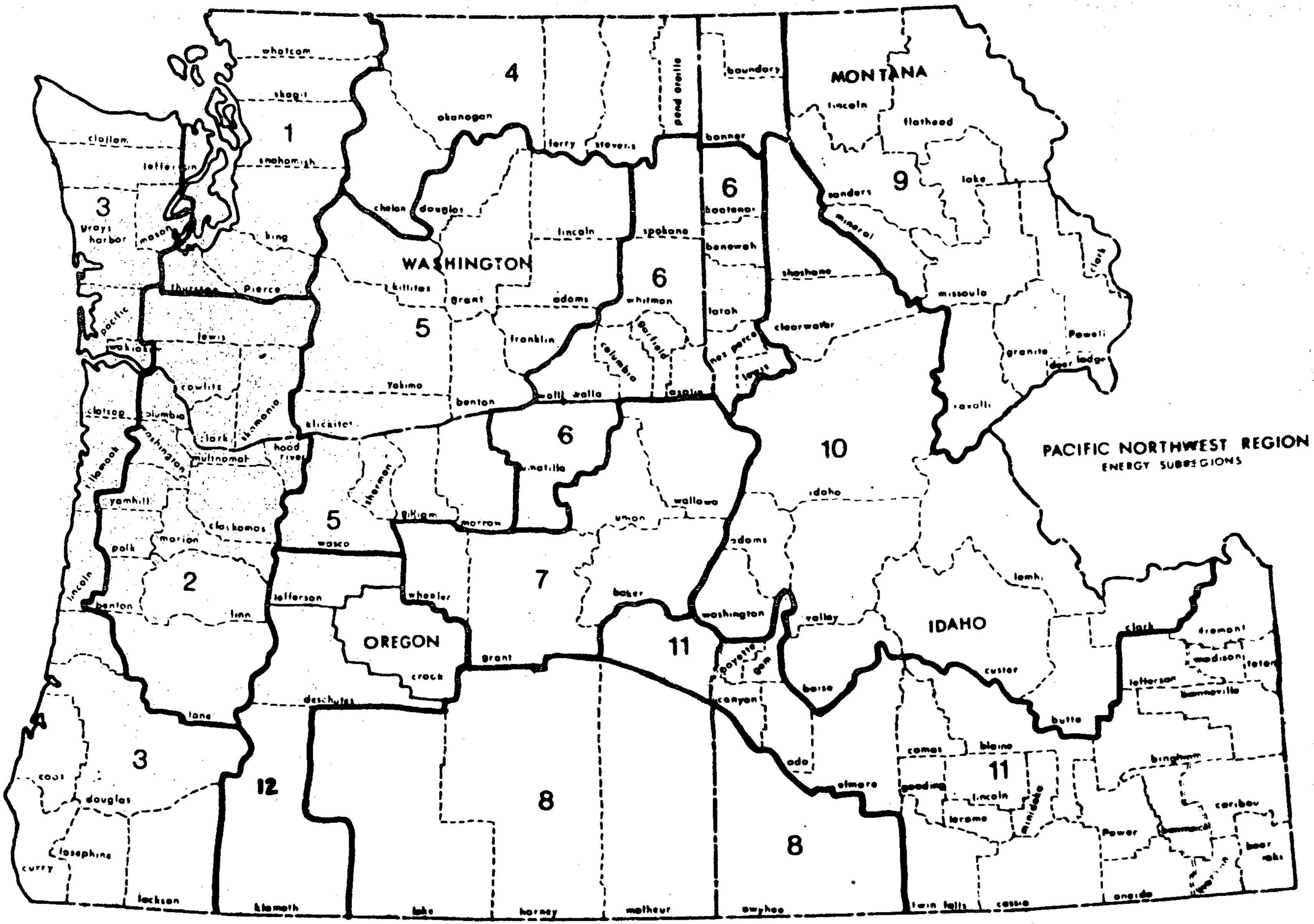
PACIFIC NORTHWEST REGION
ENERGY SUBREGIONS
WASHINGTON
OREGON
IDAHO
MONTANA
whatcom
skagit
snohomish
clallam
jefferson
grays harbor
mason
king
thurston
pierce
pacific
lewis
wahkiakum
cowlitz
clark
skamania
okanogan
chelan
douglas
ferry
stevens
pend oreille
lincoln
spokane
kittitas
grant
adams
whitman
franklin
garfield
columbia
yakima
benton
walla walla
asotin
klickitat
boundary
bonner
kootenai
benewah
shoshone
latah
clearwater
nez perce
lewis
idaho
flathead
lake
sanders
mineral
missoula
powell
granite
deer lodge
ravalli
clatsop
columbia
tillamook
washington
multnomah
hood river
yamhill
clackamas
polk
marion
lincoln
benton
linn
lane
coos
douglas
curry
josephine
jackson
klamath
lake
harney
malheur
sherman
gilliam
morrow
umatilla
union
wallowa
wasco
jefferson
wheeler
crook
grant
baker
deschutes
adams
washington
valley
payette
gem
canyon
boise
ada
elmore
owyhee
lemhi
custer
clark
fremont
madison
teton
jefferson
bonneville
butte
camas
blaine
gooding
lincoln
jerome
minidoka
bingham
power
caribou
bannock
bear lake
oneida
franklin
twin falls
cassia
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Figure 23.

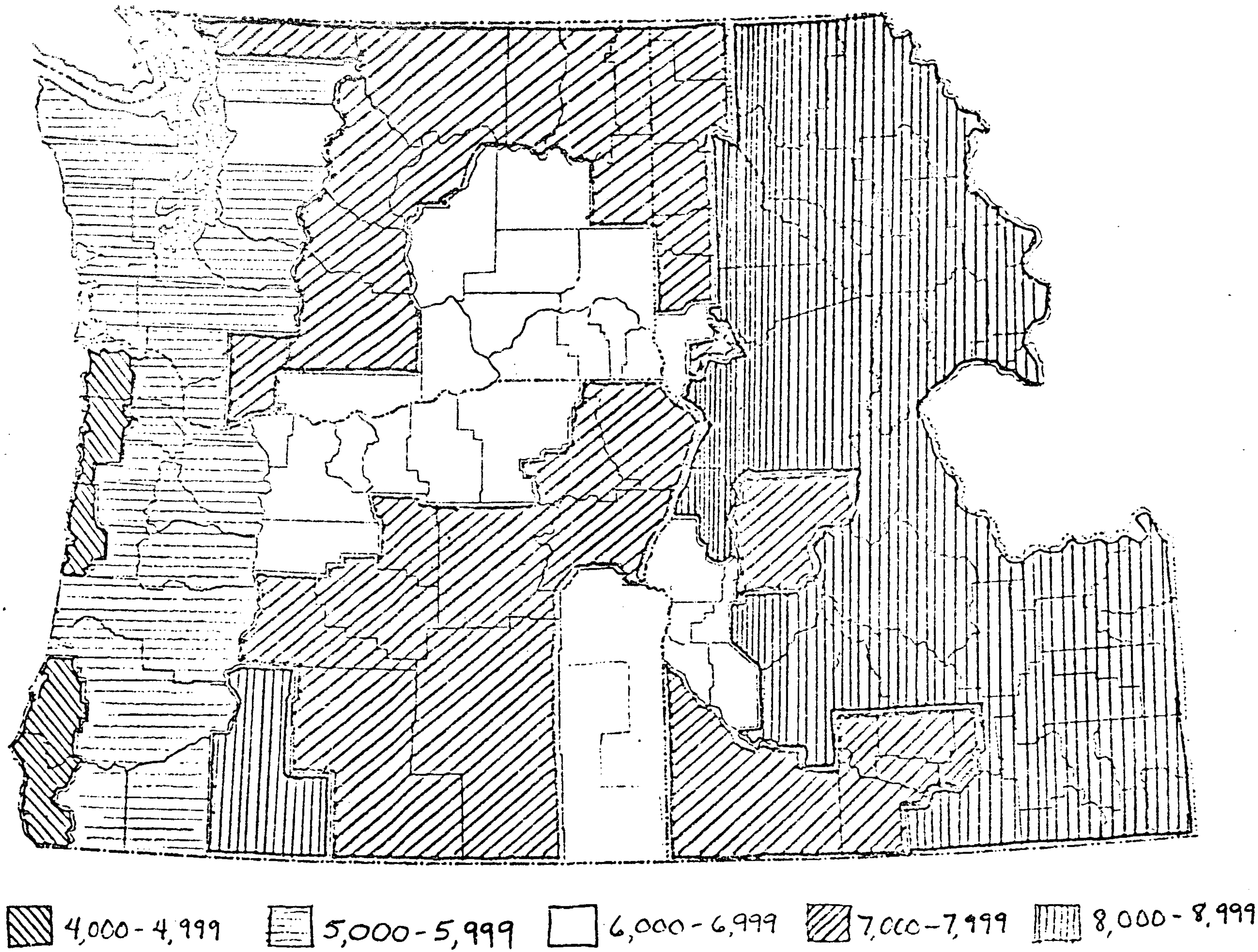

Figure 24. Heating plus cooling degree days.

Using the foregoing information, the following calculations can be made for a geothermal resource area:

1. Electric space heating load:

$$SHL_1 = \frac{(13.2 - 0.203 \times T)}{65 - T} \times 24 \times DD \times C_D \times \frac{P}{2.8} \times C_h$$

$$= \frac{(113 - 1.74 \times T)}{65 - T} \times DD \times C_D \times P \times C_h \text{ (in kwhr/yr)}$$

$$= \frac{(385.7 - 5.94 \times T \times 10^3)}{65 - T} \times DD \times C_D \times P \times C_h \text{ (in Btu/yr)}$$

where:

DD = degree days of heating for the area (°F),

T = outside residential design temperature (°F),

C_D = outside residential design temperature correction factor for the area,*

C_h = saturation rate for electrical space heating, and

P = population of area.

2. Fossil fuel space heating load:

$$SHL_2 = SHL_1 \times \frac{1 - C_h}{C_h}$$

3. Electric water heating load:

$$WHL_1 = 4{,}068 \times \frac{P}{2.8} \times C_w$$

$$= 1{,}453 \times P \times C_w \text{ (in kwhr/yr)}$$

$$= 4.959 \times 10^6 \times P \times C_w \text{ (in Btu/yr)}$$

where:

C_w = saturation rate for electrical water heating.

*See Table 8 from Reference 12 and use the values under column 5 at 99 percent.

4. Fossil fuel water heat load:

$$WHL_2 = WHL_1 \times \frac{1 - C_w}{C_w}$$

Summary:

Total space heating load:

$$SHL_R = SHL_1 + SHL_2$$

Total water heating load:

$$WHL_R = WHL_1 + WHL_2$$

Total residential heating load:

$$RHL = SHL_R + WHL_R$$

Commercial Use

The commercial load for space heating and domestic water heating was difficult to determine as very little data are available. The 1979 Rocket report found that 62 to 68 percent of the energy consumed by the commercial section was used for space heating and domestic water heating. The architectural firm Skidmore, Owings, and Merrill found in a BPA study that 245,000 Btu/yr per unit was an average for the total energy consumed. A 1979 study by LLC Geothermal Consultants** for a typical commercial block in downtown Klamath Falls calculated a space heating consumption of 4.34 Btu/ft^3/hr of peak load, or 34.7 Btu/ft^2/hr using 8-foot ceilings.

Based on this local experience and Figure 21, a value of 33 Btu/ft^2/hr peak heating load was assumed for Klamath Falls using an outside design temperature of 0°F. Using the current commercial outside design temperature of 9°F (-13°C), a corrected peak heating load of 28.4 Btu/ft^2/hr is obtained for Klamath Falls. This gives an annual use of (C_{DC} = 0.78 for an outside commercial design temperature of 9°F).*

*See Table 8 from Reference 12 and use the values under column 5 at 97.5 percent.
**Klamath Falls Geothermal District Heating, The Commercial District Design Interim Report, City of Klamath Falls, February, 1979.

$$SHL = \frac{28.4 \text{ Btu} \times 24 \text{ hr} \times 6{,}516°F \times \text{day} \times 0.78}{ft^2 \times \text{hr} \times \text{day} \times (65 - 9°F) \times \text{yr}}$$

$$= 61{,}861 \text{ Btu/ft}^2\text{/yr}$$

$$= 18.12 \text{ kwhr/ft}^2\text{/yr}$$

From this peak heating load, an expression can be developed to determine the peak commercial heating load for any other area based on the commercial outside design temperature, T_c. This relationship is:

$$PHL = 33 - 0.508\ T_c \text{ (in Btu/hr/ft}^2\text{)}$$

Thus, the annual heating load relationship can be written as follows:

$$SHL = \frac{(33.0 - 0.508\ T_c) \times 24 \times DD \times C_{DC}}{65 - T_c} \quad \text{(in Btu/ft}^2\text{/hr)}$$

Based on 1970 data, BPA found the various saturation or capture rates to be:

	Electric	Gas	Fuel Oil
Percent space heating	23*	27.3	39.7
Percent space cooling	72	1.0	0
Percent water heating	33*	27.3	39.7
Percent others	100	0	0

*These rates are assumed to have increased to 25 and 35 percent respectively in 1980.

The Urban Land Institute estimates that in United States communities with less than 4,000 persons the area devoted to commercial land use is 1 acre per 1,000 persons and for communities greater than 4,000 persons, 0.75 acres per 1,000 persons. By allowing 20 percent of a commercial site for parking and common areas (nonheated area), and reducing the site area by another 20 percent for regional correction below national averages, the heated space becomes:

$1.00 \times 0.80 \times 0.80 \simeq 0.65$ acres/1,000 population $< 4{,}000$;

$0.75 \times 0.80 \times 0.80 \simeq 0.50$ acres/1,000 population $> 4{,}000$;

or 28.31 ft^2/person and 21.78 ft^2/person, respectively.

The water heating load calculations make the following assumptions:

2 gals/employee/day,

2 employees/1,000 ft^2,

= 4 gals/1,000 ft^2/day.

Comparing to known residential use of:

4,068 kwhr/yr/residence,

30 x 2.8 = 84 gals/residence/day;

therefore, commercial water heating:

$$= \frac{4{,}068 \text{ kwhr x res x day x gals}}{\text{yr x res x 84 gals x 1,000 ft}^2 \text{ x day}}$$

= 0.1937 kwhr/ft^2/yr

= 661 Btu/ft^2/yr.

Based upon the previous calculations, the following commercial heating loads can be determined for a geothermal area:

1. Electric space heating load (saturation rate of 25 percent):

$$SHL_3 = 0.25 \times \frac{(33.0 - 0.508 \times T_c)}{65 - T_c} \times 24 \times P \times A \times DD \times C_{DC}$$

$$= \frac{(198 - 3.05 \times T_c)}{65 - T_c} \times P \times A \times DD \times C_{DC} \text{ (in Btu/yr)}$$

$$= \frac{(5.80 - 0.0894 \times T_c)}{65 - T_c} \times 10^{-2} \times P \times A \times DD \times C_{DC} \text{ (in kwhr/yr)}$$

where:

P = population of the area,

A = 28.31 for $P < 4{,}000$

21.78 for $P > 4{,}000$,

DD = degree days of heating (°F),

T_c = commercial outside design temperature (°F), and

C_{DC} = commercial correction factor for outside design temperature.

2. Fossil fuel space heating load:

$$SHL_4 = 3.00 \times SHL_3$$

3. Electric water heating load (saturation rate of 35 percent):

$$WHL_3 = 0.35 \times 661 \times P \times A$$
$$= 231.4 \times P \times A \text{ (in Btu/yr)}$$
$$= 0.0678 \times P \times A \text{ (in kwhr/yr)}$$

4. Fossil fuel water heating load:

$$WHL_4 = 1.857 \times WHL_3$$

Summary:

Total space heating load:

$$SHL_C = SHL_3 + SHL_4$$

Total water heating load:

$$WHL_C = WHL_3 + WHL_4$$

Total commercial heating load:

$$CHL = SHL_C + WHL_C$$

Public and Institutional Use

This use includes municipal, county, state, and federal buildings, schools, churches, and fraternal organizations. To our knowledge, no separate estimates for these facilities have been made by BPA or contractors such as Rocket. More than likely they are included in the commercial load figures. Based on local experience, the following estimates were made for a community:

Public buildings	3 ft^2/person
Schools	22 ft^2/person
Churches and fraternal	5 ft^2/person
Total	30 ft^2/person

Using the Klamath Falls' commercial heating rate of 28.4 Btu/ft^2/hr peak load:

$$30 \times 28.4 = 852 \text{ Btu/person/hr.}$$

For Klamath Falls, the annual rate would be:

$$\frac{852 \times 24 \times 6{,}516 \times 0.78}{65 - 9}$$

$$= 1.856 \times 10^6 \text{ Btu/person/yr}$$

The peak heating load expression for the public and institutional load for any other area based on the commercial outside design temperature, T_c, would be:

$$PHL = 30(33 - 0.508\ T_C)$$

$$= 990 - 15.2\ T_C \text{ (in Btu/person/hr)}$$

Thus the annual heating load relationship can be written as follows:

$$SHL = \frac{(990 - 15.2 \times T_c) \times 24 \times DD \times C_{DC}}{65 - T_C} \text{ (in Btu/person/yr).}$$

The corresponding water heating rate based on the commercial usage of 661 Btu/ft^2/yr would be:

$$661 \times 30 = 0.0198 \times 10^6 \text{ Btu/person/yr}$$

Based on these calculations, the public and institutional heating loads for an area are as follows:

1. Electric space heating load (using the commercial saturation rate of 25 percent):

$$SHL_5 = 0.25 \times \frac{(990 - 15.2 \times T_c)}{65 - T_c} \times 24 \times P \times DD \times C_{DC}$$

$$= \frac{(5{,}940 - 91.2 \times T_c)}{65 - T_c} \times P \times DD \times C_{DC} \text{ (in Btu/yr)}$$

$$= \frac{(1.74 - 0.0267 \times T_c)}{65 - T_c} \times P \times DD \times C_{DC} \text{ (in kwhr/hr)}$$

2. Fossil fuel space heating load:

$$SHL_6 = 3.00 \times SHL_5$$

3. Electric water heating load (using the commercial saturation rate of 35 percent):

$$WHL_5 = 0.35 \times 0.0198 \times 10^6 \times P$$

$$= 6.930 \times 10^3 \times P \text{ (in Btu/yr)}$$

$$= 20.30 \times P \text{ (in kwhr/yr)}$$

4. Fossil fuel water heating load:

$$WHL_6 = 1.857 \times WHL_5$$

Summary:

Total space heating load:

$$SHL_p = SHL_5 + SHL_6$$

Total water heating load:

$$WHL_p = SHL_5 + SHL_6$$

Total public and institutional heating load:

$$PHL = SHL_p + WHL_p$$

At this point several approximations can be made to simplify the calculations:

a. The commercial space and water heating load ranges from approximately 4.1 percent of the residential space and water heating load ($A > 4{,}000$) to 5.3 percent ($A < 4{,}000$), or:

$$CHL = 0.041 \times RHL \; (A > 4{,}000)$$

$$= 0.053 \times RHL \; (A < 4{,}000)$$

b. The public and institutional space and water heating load is approximately 5.6 percent of the residential space and water heating, or:

$$PHR = 0.056 \times RHL$$

c. The sum of the commercial and public institutional heating load varies from 9.7 to 10.9 percent of the space heating load, with a weighted average around 10 percent, or:

$$CHL + PHL \simeq 0.1 \times RHL$$

Industrial Load

The industrial process load was difficult to determine accurately, since each industry is unique in size and energy use. The space heating and water heating load was not determined as this energy demand is probably met by internal waste heat, and is also insignificant when compared to other uses determined in this report.

The directories of manufacturers published by each state government and the Dunn and Bradstreet Million Dollar Directory were used as the basic references. Each town near one of the composite geothermal resources was searched in the references, and industrial plants grouped by Standard Industrial Classification (SIC) codes were identified. These SIC codes were then compared with a list prepared by G. Reistad at OSU (Table 11) that described SIC groups with geothermal potential. The total United States energy use by each SIC code was available from ASHRAE and the total number of industries in each category was available from United States Department of Commerce SIC data. This information then gave an average energy consumption per plant in the United States (also in Table 11). Where possible, these energy consumptions were revised for specific locations based upon Rocket Research data and Montana and Idaho state data. Finally, the process temperature range of each SIC code industry was determined and compared with the adjacent geothermal resource temperature. Using this temperature relationship, the percentage of the energy demand at each plant that could be satisfied by geothermal fluid was estimated. These estimates were refined by information from the Idaho and Montana State Hydrothermal Commercialization Baseline reports (see Table 12) and by personal experience (see Agribusiness Study, Reference 4). The use of water-to-air heat pumps was considered for the low-temperature geothermal resources. No generalized formula was used to calculate the industrial load as each site was evaluated separately.

TABLE 11.

SIC GROUPS WITH GEOTHERMAL POTENTIAL

Standard Industrial Classification (SIC) Number	SIC Product Group	Product Group Temperature Requirement (°F)	Number of U.S. Companies in Group*	Total U.S. Process Heat Use by Group ($x10^{12}$ Btu/yr)	Average Process Heat Use by Company ($x10^{12}$ Btu/yr)
1012	Cooper ores	250	45	1.7	0.04
1211	Bituminous coal and lignite	150-250	1001	18.0	0.02
1474	Potash, soda & Borate minerals	250	26	1.03	0.04
2011	Meat packing plants	140-200	1110	45.38	0.04
2016	Poultry dressing plants	140	315	3.16	0.01
2032	Canned specialties	170-250	99	1.22	0.01
2023	Condensed & evaporated milk	160-250	169	8.67	0.05
2026	Fluid milk	162-170	1003	1.44	0.001
2033	Canned fruits & vegetables	180-250	684	5.16	0.007
2C34	Dehydrated fruits & vegetables & soups	160-212	113	7.11	0.06
2037	Frozen fruits & vegetables	170-212	261	5.27	0.02
2046	Wet corn milling	120-270	54	8.59	0.16
2048	Prepared feeds	180-190	953	2.28	0.002
2051	Bread, cake, & related products	100	1413	0.84	0.0006
2062	Canesugar refining	110-265	28	31.16	1.11
2063	Beet sugar	140-280	57	61.84	1.08
2075	Soybean oil milling	160-300	75	16.41	0.22
2079	Shortening & cooking oils	160-300	74	2.13	0.03
2082	Malt beverages	170-300	94	15.82	0.17
2085	Distilled liquor	212-300	81	21.38	0.26
2086	Bottled & canned soft drinks	75-170	1535	2.43	0.002
2421	General sawmills & planing mills	200	1929	63.4	0.03
2435	Hardwood veneer & plywood	250	277	50.6	0.18
2511	Wood household furniture	70-150	905	9.5	0.01
2512	Upholstered household furniture	70-150	851	2.3	0.002
2611	Pulp mills	150-290	59	722.0	12.23
2621	Paper mills	150-290	339	722.0	2.13
2631	Paperboard mills	150-290	214	722.0	3.37

*Includes only companies with gross income exceeding $1 million annually.

SIC GROUPS WITH GEOTHERMAL POTENTIAL (continued)

Standard Industrial Classification (SIC) Number	SIC Product Group	Product Group Temperature Requirement (°F)	Number of U.S. Companies in Group*	Total U.S. Process Heat Use by Group ($x10^{12}$ Btu/yr)	Average Process Heat Use by Company ($x10^{12}$ Btu/yr)
2865	Cyclic crudes & intermediates	250-300	194	35.45	0.18
2819	Industrial inorganic chemicals	280	517	113.2	0.22
2821	Plastic materials & resins	190-215	463	0.17	0.0004
2823	Cellulosic man-made fibers	<250	22	23.5	1.07
2824	Non-cellulosic organic fibers	<212	67	75.4	1.13
2834	Pharmaceutical preparations	150-250	445	19.9	0.04
2841	Soap & other detergents	180	250	0.86	0.003
2869	Industrial organic chemicals	200-300	449	27.0	0.06
2873	Nitrogenous fertilizers	290	213	0.89	0.004
2951	Paving mixtures & blocks	275-300	544	88.1	0.16
3111	Leather tanning & finishing	90-140	232	2.52	0.01
3241	Hydraulic cement	275-300	189	8.0	0.04
3271	Concrete block & brick	165	677	12.29	0.02
3273	Ready-mixed concrete	120-190	1391	0.34	0.0002
3275	Gypsum products	300	93	11.18	0.12
3295	Ground & treated minerals	160-230	503	13.26	0.03
3479	Metal coating & allied services	130-190	497	0.01	
3621	Motors and generators	150-300	402	0.18	0.0004
3711	Motor vehicles & car bodies	250-300	156	0.29	0.002

*Includes only companies with gross income exceeding $1 million annually.

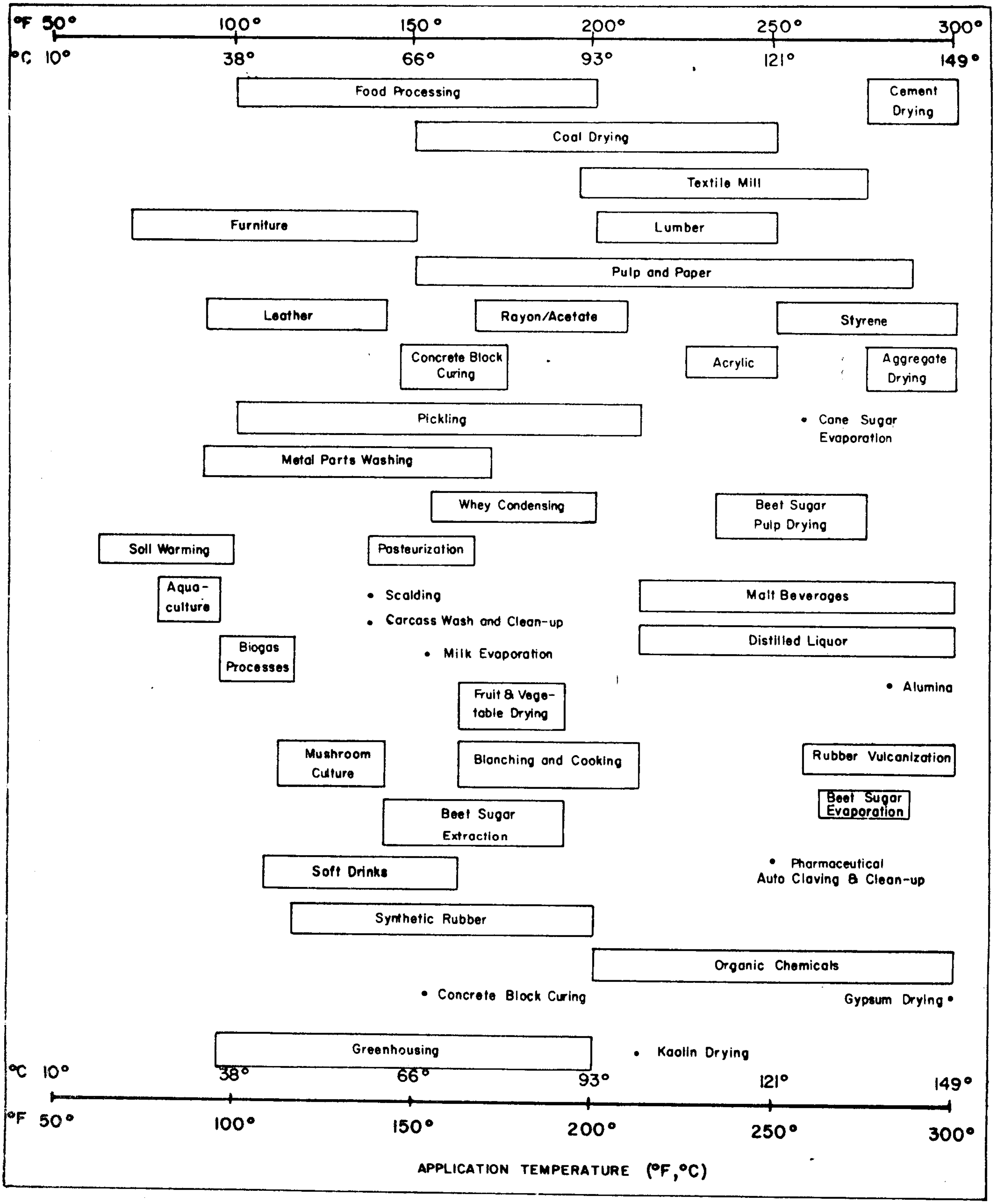

TABLE 11. Application temperature ranges for some industrial processes and agricultural applications.

TABLE 12.

INDUSTRIAL PROCESS HEAT REQUIREMENTS

		104°F-140°F	140°F-176°F	176°F-212°F	212°F-248°F	248°F-284°F	284°F-320°F	320°F-356°F	356°F-392°F	392°F	482°F
INDUSTRY	SIC Number	40°C-60°C	60°C-80°C	80°C-100°C	100°C-120°C	120°C-140°C	140°C-160°C	160°C-180°C	180°C-200°C	200°C	250°C
Meat packing	2011	NA	99%	100%							
Prepared meats	2013	NA	46.2%	61.5%	100%						
Natural cheese	2022	23%	100%								
Fluid milk	2026	NA	NA	100%							
Canned fruits and vegetables	2033	NA	NA	22.7%	67.6%	100%					
Dehydrated fruits and vegetables	2034	NA	100%								
Potato dehydration	2034										
granules		NA	19.9%	40%	53%					100%	
flakes		NA	19.9%	40%	53%				100%		
Frozen fruits and vegetables	2037	NA	NA	30%	100%						
Wet corn milling	2046	21.5%			36.4%	46.6%		84.1%		100%	
Prepared feeds	2048										
pellet conditioning		NA	NA	100%							
alfalfa drying		NA	NA	NA	NA	NA	NA	NA	NA	100%	
Beet sugar	2063	NA	7.4%	22.4%		95.4%					100%
Soft drinks	2086	60.9%	100%								
Sawmills and planing mills	2421	NA	NA	NA	NA	NA	100%				
Alumina	2819	NA	NA	NA	NA	76.2%					100%
Soaps	2841	NA	NA	0.6%						100%	
Detergents	2841	NA	NA	52.2%				99.9%		100%	
Concrete block	3271										
low pressure		NA	100%								
autoclaving		NA	NA	NA	NA	NA	NA	NA	100%		
Ready mix	3273	100%									

According to the 1979 Rocket Research report, energy saturation or capture rates for industrial processing varied as follows:

State	Purchased Electricity Capture %	Purchased Fossil Fuel Capture %	Other* Capture %
Oregon	23.0	24.0	52.0
Washington	30.5	34.7	34.8
Idaho	24.8	41.1	34.1

*Other fuel types generally involve the use of waste material generated in the plant, such as "hog fuel," and thus economically could not be replaced by geothermal energy.

Since no other information is available, these capture rates are assumed to have remained constant, and thus are used for this study.

The following is a summary of the number of industries considered in each state and their geothermal energy replacement potential:

State	No. of Industries	Geothermal Replacement Electric Load x 10^9 Btu/yr	Geothermal Replacement Total Load x 10^9 Btu/yr
Oregon	73	692.4	3,010.5
Washington	17	273.2	895.7
Idaho	30	757.1	3,052.9
Montana*	16	42.9	114.0
TOTAL	136	1,765.6	7,073.1

*No data available on capture rates for Montana, thus values for Idaho were used.

The industrial process heating loads replaceable by geothermal can thus be calculated for each site using the following relationship:

1. Electric process heating load:

$$IPL_1 = C_e \times TPL$$

where:

C_e = capture rate for electricity by state in decimal form,

TPL = total process load corrected for geothermal resource temperature replacement.

2. Fossil fuel process heating load:

$$IPL_2 = C_f \times TPL$$

where:

C_f = capture rate for fossil fuel by state in decimal form.

3. Total process heating load:

$$IPL = IPL_1 + IPL_2.$$

Sample Direct Heat Load Calculation

Using the composite resource site of Little Valley/Neal/Vale/W. Snake River in eastern Oregon for our sample calculation, the input data are as follows:

Population = 20,000 (primarily Ontario, Vale and Nyssa)

$DD = 5{,}726$

$T = -1°F$

$C_D = 0.70$

$C_w = 0.910$

$C_h = 0.551$

$A = 21.78$

$T_c = 6°F$

$C_{DC} = 0.76$

1. Residential Loads:

a. Electric space heating:

$$SHL_1 = \frac{(385.7 - 5.94 \times T)}{65 - T} \times 10^3 \times DD \times C_D \times P \times C_h$$

$$= \frac{[385.7 - 5.94 \times (-1)]}{65 - (-1)} \times 10^3 \times 5{,}726 \times 0.70 \times 20{,}000 \times 0.551$$

$$= 262.1 \times 10^9 \text{ Btu/yr}$$

b. Fossil fuel space heating:

$$SHL_2 = SHL_1 \times \frac{1 - C_h}{C_h}$$

$$= 262.1 \times 10^9 \times \frac{1 - 0.551}{0.551}$$

$$= 213.6 \times 10^9 \text{ Btu/yr}$$

c. Electric water heating:

$$WHL_1 = 4.959 \times 10^6 \times P \times C_w$$

$$= 4.959 \times 10^6 \times 20{,}000 \times 0.910$$

$$= 90.3 \times 10^9 \text{ Btu/yr}$$

d. Fossil fuel water heating:

$$WHL_2 = WHL_1 \times \frac{1 - C_w}{C_w}$$

$$= 90.3 \times \frac{1 - 0.910}{0.910}$$

$$= 8.9 \times 10^9 \text{ Btu/yr}$$

e. Residential Summary:

Total space heating:

$$SHL_R = 262.1 \times 10^9 + 213.6 \times 10^9$$

$$= 475.7 \times 10^9 \text{ Btu/yr}$$

Total water heating:

$$WHL_R = 90.3 \times 10^9 + 8.9 \times 10^9$$

$$= 99.2 \times 10^9 \text{ Btu/yr}$$

Total residential heating:

$$RHL = 475.7 \times 10^9 + 99.2 \times 10^9$$

$$= 574.9 \times 10^9 \text{ Btu/yr}$$

2. Commercial Loads:

a. Electric space heating:

$$SHL_3 = \frac{(198 - 3.05 \times T_c)}{65 - T_c} \times P \times A \times DD \times C_{DC}$$

$$= \frac{(198 - 3.05 \times 6)}{65 - 6} \times 20{,}000 \times 21.78 \times 5{,}726 \times 0.76$$

$$= 5.8 \times 10^9 \text{ Btu/yr}$$

b. Fossil fuel space heating:

$$SHL_4 = 3.00 \times SHL_3$$

$$= 3.00 \times 5.8 \times 10^9$$

$$= 17.3 \times 10^9 \text{ Btu/yr}$$

c. Electric water heating:

$$WHL_3 = 231.4 \times P \times A$$

$$= 231.4 \times 20{,}000 \times 21.78$$

$$= 0.1 \times 10^9 \text{ Btu/yr}$$

d. Fossil fuel water heating:

$$WHL_4 = 1.857 \times WHL_3$$

$$= 1.857 \times 0.1 \times 10^9$$

$$= 0.2 \times 10^9 \text{ Btu/yr}$$

e. Commercial summary:

Total space heating:

$$SHL_C = 5.8 \times 10^9 + 17.3 \times 10^9$$

$$= 23.1 \times 10^9 \text{ Btu/yr}$$

Total water heating:

$$WHL_C = 0.1 \times 10^9 + 0.2 \times 10^9$$

$$= 0.3 \times 10^9 \text{ Btu/yr}$$

Total commercial heating:

$$CHL = 23.1 \times 10^9 + 0.3 \times 10^9$$

$$= 23.4 \times 10^9 \text{ Btu/yr}$$

3. Public and Institutional Loads:

a. Electric space heating:

$$SHL_5 = \frac{(5{,}940 - 91.2 \times T_c)}{65 - T_c} \times P \times DD \times C_{DC}$$

$$= \frac{(5{,}940 - 91.2 \times 6)}{65 - 6} \times 20{,}000 \times 5{,}726 \times 0.76$$

$$= 8.0 \times 10^9 \text{ Btu/yr}$$

b. Fossil fuel space heating:

$$SHL_6 = 3.00 \times SHL_5$$

$$= 3.00 \times 8.0 \times 10^9$$

$$= 23.9 \times 10^9 \text{ Btu/yr}$$

c. Electric water heating:

$$WHL_5 = 6.930 \times 10^3 \times P$$

$$= 6.930 \times 10^3 \times 20{,}000$$

$$= 0.1 \times 10^9 \text{ Btu/yr}$$

d. Fossil fuel water heating:

$$WHL_6 = 1.857 \times WHL_5$$

$$= 0.3 \times 10^9 \text{ Btu/yr}$$

e. Public and institutional summary:

Total space heating:

$$SHL_p = 8.0 \times 10^9 + 23.9 \times 10^9$$

$$= 31.9 \times 10^9 \text{ Btu/yr}$$

Total water heating:

$$WHL_p = 0.1 \times 10^9 + 0.3 \times 10^9$$

$$= 0.4 \times 10^9 \text{ Btu/yr}$$

Total public and institutional heating:

$$PHL = 31.9 \times 10^9 + 0.4 \times 10^9$$

$$= 32.3 \times 10^9 \text{ Btu/yr}$$

Industrial Process Load (Source: Oregon Directory of Manufacturers list for Ontario-Nyssa):

SIC Code (No. of Industries)	Energy Consumption $\times 10^{12}$ Btu/yr	Process Temperature °F
2011 (2)	0.08	140-200
2026 (1)	0.001	162-170
2033 (1)	0.007	180-250
2048 (2)	0.004	180-190
2051 (1)	0.0006	100
2063 (1)	1.08	140-280
2075 (1)	0.22	160-300
2421 (2)	0.06	200
2951 (1)	0.16	275-300
3273 (3)	0.0006	120-190
3295 (2)	0.06	160-230
Total: 17 industries	$1.6732 = 1{,}673.2 \times 10^9$ Btu/yr	

Since the resource temperature is estimated to vary from 315° to 370°F (Table 7), all of the industrial process energy requirements have the potential of being satisfied by the geothermal resource, and thus the energy consumption total will not be adjusted as indicated in Table 12. The economics of conversion are not a consideration at this point. Recent drilling experience in Ontario, at the Ore-Ida potato plant, resulted in a nonproductive geothermal well, with adequate temperature, but inadequate fluid flow. However, there is a possiblity of the energy needs for this plant could be satisfied from a well drilled near Vale by piping the fluid to Ontario through a 15-mile pipeline.

The industrial energy load calculations are as follows:

1. Electric process load:

$$IPL_1 = C_e \times TPL$$
$$= 0.230 \times 1{,}673.2 \times 10^9$$
$$= 384.8 \times 10^9 \text{ Btu/yr}$$

2. Fossil fuel process load:

$$IPL_2 = C_f \times TPL$$
$$= 0.240 \times 1{,}673.2 \times 10^9$$
$$= 401.6 \times 10^9 \text{ Btu/yr}$$

3. Total process heating load:

$$IPL = IPL_1 + IPL_2$$
$$= 384.8 \times 10^9 + 401.6 \times 10^9$$
$$= 786.4 \times 10^9 \text{ Btu/yr}$$

Summary of Sample Site Energy Conversion Loads

Residential	574.9 x 10^9 Btu/yr
Commercial	23.4 x 10^9 Btu/yr
Public and Institutional	32.3 x 10^9 Btu/yr
Industrial	786.4 x 10^9 Btu/yr
Total	1,417.0 x 10^9 Btu/yr

This is the total energy use (in 1980) within approximately 25 miles of the resource that can be replaced by geothermal energy. This includes 751.2 x 10^9 Btu/yr of present electrical load and 665.8 x 10^9 Btu/yr of present fossil fuel load.

All that remains is to project the development schedule through the year 2000. This will include an estimated 6 percent growth over the 20-year period. This projection will be addressed in a subsequent section and is shown in Table 13.

Obviously, not all of the potentially replaceable energy will be converted to geothermal by the year 2000. Retrofit cost, load concentration, ease of supply, community support, and other legal, institutional, and environmental factors will affect conversion. The geothermal resource itself is not a limitation since 164.1 x 10^{12} Btu/yr are available as indicated in Table 7 . In addition, a potential of 906 MW_e can be developed, with 250 MW_e estimated to be developed by the year 2000.

One comment that should be made at this point is the relationship between annual load and peak load. The peak space heating load will vary from three to six times of the annual load (using the same time reference) for most sites in the Pacific Northwest. The high rate will apply to low degree-day sites (Eugene)* and the lower number to high degree-day sites (Stanley-Challis),* for comparison, Klamath Falls* has a factor of 5. Thus, for our eastern Oregon sample site, the annual space heating rate is 532.7 x 10^9 Btu/yr or 60.6 x 10^6 Btu/hr, whereas the peak rate is approximately

*The corresponding degree days of heating for each site is 4,739, 10,700, and 6,516, respectively.

365 x 10^6 Btu/hr or 6.0 times the average (see formula on page 95). The resource can still meet this load; however, the feasibility of designing a geothermal system to meet the peak vs. only a portion of the peak will have to be evaluated. The space heating portion accounts for about 37.5 percent of the total load in example. The remaining load, water heating and industrial use, would have a peak and average energy load of approximately the same. Sites with less or no industrial load would have a higher percentage of space heating and thus a higher ratio of peak to average load.

Similar calculations of the 1980 direct-use load are made for each of the 52 composite sites in the BPA market area. These figures are given in Table 13 and are presented as electrical load and total load (electrical plus fossil). These loads, summarized here by state, are the loads that are colocated with a geothermal resource and could be replaced by geothermal energy. The loads located in areas where the resource is of heat pump potential are reduced to 3/4 of the original to allow for the electrical energy necessary to run the compressors. The state summaries are as follows:

State	No. of Sites	1980 Direct-Use Load x 10^9 Btu/yr Electrical	Fossil	Total
Northern California	2	106	78	184
Idaho	19	8,333	7,948	16,281
Western Montana	8	856	3,842	4,698
Northern Nevada	3	37	37	74
Oregon	12	2,968	2,670	5,638
Washington	9	3,521	3,122	6,643
Total	53*	15,821	17,697	33,518

*Two sites split along state boundaries.

TABLE 13.
GEOTHERMAL LOAD AND DEVELOPMENT SCHEDULE

Resource No.	1980 Load Area Population	% Pop. Growth 1980-2000	1980 Direct Use Load x 10^9 Btu/yr (electric)	total	Direct Use Development Schedule x 10^9 Btu/yr 1985	1990	1995	2000	Elec. Power Development Sched.* MWe 1985	1990	1995	2000
OREGON												
177-179	9,300	30	(175)	359	40	80	150	200	0	0	(50)	(100)
180	1,500	19	(30)	51	25	45	50	55	--	--	--	--
181-183/OR1-2	6,150	40	(127)	256	10	100	150	200	0	0	(50)	(100)
186/187/OR9	45,000	17	(1063)	1889	280	450	750	1200	--	--	--	--
189/OR8	3,500	(-5)	(111)	228	50	100	150	200	0	0	50	50
190/191	125	(-5)	(2)	5	0	5	5	5	0	0	50	50
193/194/OR5-6	6,000	1	(145)	290	10	40	75	100	--	--	--	--
196-199/OR7	40	1	--	--	--	--	--	--	0	50	100	150
201/OR3	20,000	20	(455)	929	10	50	125	250	--	--	--	--
202-204/ID9a	20,000	6	(751)	1417	100	200	500	1000	0	50	150	250
GB KGRA/OR4	15	(-5)	--	--	--	--	--	--	0	0	(50)	(50)
OSR1	10,000	29	(109)	214	10	50	125	200	--	--	--	--
TOTAL	121, 630		(2968)	5638	535	1120	2080	3410	0	100	500	750
NEVADA												
130-132/NV2,5	40		--	--	--	--	--	--	0	50	100	100
167/NV4	700		(13)	26	0	5	10	15	--	--	--	--
168/NV7	1,300		(24)	48	10	25	40	50	--	--	--	--
TOTAL	2,040		(37)	74	10	30	50	65	0	50	100	100
CALIFORNIA												
034/035/CA1	1,200		(25)	43	5	10	15	20	0	50	100	100
036/038/CA2	3,700		(81)	141	10	20	30	50	--	--	--	--
TOTAL	4,900		(106)	184	15	30	45	70	0	50	100	100

TABLE 13.
GEOTHERMAL LOAD AND DEVELOPMENT SCHEDULE

Resource No.	1980 Load Area Population	% Pop. Growth 1980-2000	1980 Direct Use Load x 10^9 Btu/yr		Direct Use Development Schedule x 10^9 Btu/yr				Elec. Power Development Sched. MWe			
			(electric)	total	1985	1990	1995	2000	1985	1990	1995	2000
IDAHO												
ID8	7,500	45	(96)	369	10	50	120	200	--	--	--	--
ID9b	150,000	59	(2907)	5033	250	600	1500	2500	--	--	--	--
ID9c	50,000	38	(1110)	2053	50	200	350	750	--	--	--	--
114/ID9e,9f	56,000	23	(1244)	2305	50	100	300	600	--	--	--	--
ID12/GL KGRA	6,000	36	(126)	270	10	50	100	150	0	0	(50)	(50)
ID13	68,000	37	(1236)	2541	50	200	400	600	--	--	--	--
087	800	7	(22)	44	5	10	20	40	--	--	--	--
091	1,500	25	(29)	50	0	5	10	20	--	--	--	--
093/094	7,000	21	(136)	235	100	150	200	220	0	50	100	150
095	5,500	21	(107)	184	0	5	10	15	--	--	--	--
099-102/ID9d	10,000	28	(209)	370	50	100	175	250	--	--	--	--
104/105	4,000	12	(43)	161	10	40	60	80	0	0	20	20
107/108/ID3	2,700	92	(36)	141	50	100	150	180	--	--	--	--
109-112/ID10	1,500	(-17)	(30)	53	0	10	20	30	0	50	50	50
115	300	24	(5)	11	20	35	50	80	5	5	5	5
116/117/ID11	15,000	21	(227)	788	25	75	150	300	--	--	--	--
118-121	4,500	31	(78)	159	10	30	50	100	0	0	(50)	(50)
IP KGRA	--	--	--	--	0	0	0	0	0	0	0	(100)
WSR1	26,000	24	(692)	1514	10	100	200	350	--	--	--	--
TOTAL	416,300		(8333)	16281	700	1860	3865	6465	5	105	275	425
WASHINGTON												
WA2	70,000	21	(1204)	2165	100	250	500	800	--	--	--	--
WA3	20,000	27	(330)	590	100	150	250	350	--	--	--	--
WA4	45,000	12	(482)	948	50	100	250	400	--	--	--	--
WSR1	12,000	10	(162)	279	30	50	100	150	--	--	--	--
WRS2	110,000	21	(1223)	2418	50	200	400	700	--	--	--	--
WSR3-4	8,000	10	(104)	210	50	100	200	300	--	--	--	--
WSR5	1,000	25	(16)	33	0	20	25	25	0	0	(50)	(100)
212/MB KGRA	0	38	--	--	--	--	--	--	0	0	(50)	(100)
MS KGRA	0	27	--	--	--	--	--	--	0	0	(50)	(100)
TOTAL	266,000		(3521)	6643	380	870	1725	2725	0	0	150	300

TABLE 13.
GEOTHERMAL LOAD AND DEVELOPMENT SCHEDULE

Resource No.	1980 Load Area Population	% Pop. Growth 1980-2000	1980 Direct Use Load x 10^9 Btu/yr (electric)	1980 Direct Use Load x 10^9 Btu/yr total	Direct Use Development Schedule x 10^9 Btu/yr 1985	1990	1995	2000	Elec. Power Development Sched. MWe 1985	1990	1995	2000
MONTANA												
126/MT4/MSR10	18,000	(-11)	(128)	722	10	50	100	150	--	--	--	--
MT5/128	30,000	0	(209)	1193	10	50	100	150	--	--	--	--
MT7	25,000		(172)	926	50	100	250	400	--	--	--	--
123/124	35,000		(243)	1294	100	300	500	800	--	--	--	--
125	2,000		(16)	86	10	25	40	50	--	--	--	--
129/MT10	2,000		(13)	72	5	10	15	20	--	--	--	--
MSR46	2,000		(13)	71	20	35	50	60	--	--	--	--
MSR50	9,000		(62)	334	5	15	25	50	--	--	--	--
TOTAL	123,000		(856)	4698	210	585	1080	1680	0	0	0	0
			(15821)	33518								

*Number in parentheses are sites with reservoir data indicating temperatures less than 302°F (150°C). However, based on positive interest (leasing and/or drilling) by development companies; positive estimates by EPRI, B. Greider, and state energy offices; and potential low temperature power generations equipment development, these sites are felt to have a feasible development potential. More detailed reservoir data are needed to determine the resource potential.

These loads are annual loads; the peak space heating load's component would vary from three to six times the average based on the earlier discussion.

The direct-use loads are summarized by utility in Table 14. The utilities are grouped by "preference" and "nonpreference" (investor-owned). The number of sites within each utility jurisdiction is estimated to the nearest quarter (see Table 7). Within each utility, the direct-use load is summarized as to electrical load and fossil fuel load that can be replaced by geothermal energy under residential, commercial, public, and industrial categories. The total indicates that 80 percent of the load is due to residential use, 3 percent to commercial, 4 percent to public, and 13 percent to industrial (26,676 x 10^9, 1,086 x 10^9, 1,484 x 10^9, and 4,270 x 10^9 Btu/yr respectively). Detailed load figures for each site are tabulated in the appendix.

Electrical Loads

As mentioned earlier in this section, electrical power generated from geothermal energy can be transmitted great distances, thus eliminating the need for the producer and consumer to be colocated. This is especially important in the northwest, as many of the potential high-temperature geothermal resources are located in isolated and relatively unpopulated areas.

USGS Circular 790 lists 16 hydrothermal sites above 302°F (150°C) that are located within the BPA marketing area. In addition, 17 igneous systems are listed that have potential for thermal energy. State geothermal personnel in turn have identified six more potential sites not shown in the USGS tabulation. The total of 39 sites all have potential for geothermal electric power generation.* Due to environmental constraints (locations in national parks or scenic areas) only

*The hydrothermal sites are generally considered having a better possibility for development, especially in the near term.

TABLE 14.
DIRECT-USE LOAD SUMMARY BY UTILITY
Electrical (Fossil Fuel)*

Utility	No. of Sites	Residential ($x10^9$ Btu/yr)	Commercial ($x10^9$ Btu/yr)	Public ($x10^9$ Btu/yr)	Industrial ($x10^9$ Btu/yr)	Total ($x10^9$ Btu/yr)
BPA Preference Customers						
Benton Co. PUD	3/4	876 (778)	16 (49)	23 (67)	2 (3)	917 (897) = 1,814
Clearwater Power Co.	1/2	121 (76)	2 (6)	3 (8)	88 (145)	214 (235) = 449
Columbia REA	1/2	228 (199)	4 (13)	6 (17)	3 (3)	241 (232) = 473
Consumers Power	1/4	42 (40)	1 (2)	1 (3)	0	44 (45) = 89
Fall River REC	1	151 (416)	6 (18)	8 (24)	62 (103)	227 (561) = 788
Grant Co. PUD	1	266 (168)	4 (13)	6 (18)	54 (62)	330 (261) = 591
Harney Elec. Coop	1	107 (102)	2 (7)	3 (9)	32 (28)	144 (146) = 290
Lane Co. Elec. Coop	1	95 (87)	2 (6)	2 (8)	28 (29)	127 (130) = 257
Milton-Freewater City	3/4	76 (66)	1 (4)	2 (1)	3 (3)	82 (74) = 156
Prairie Power Coop	1/2	15 (10)	0 (1)	0 (1)	0	15 (12) = 27
Raft River REC	1	5 (5)	0	0	0	5 (5) = 10
Richland City & Light	1/4	292 (259)	5 (16)	8 (22)	1 (1)	306 (298) = 604
Salmon River E.C.	1	33 (95)	1 (4)	2 (6)	0	36 (105) = 141
Skamania Co. PUD	1	99 (99)	2 (6)	3 (8)	0	104 (113) = 217
Surprise Valley E.C.	3	104 (69)	2 (5)	2 (7)	0	108 (81) = 189
Vigilante Elec. Coop	1 1/4	127 (622)	8 (24)	11 (32)	7 (11)	153 (689) = 842
Wells REC	2	35 (33)	1 (2)	1 (3)	0	37 (38) = 75
Subtotals	16 3/4	2,672 (3,124)	57 (176)	81 (234)	280 (388)	3,090 (3,922) = 7,012

TABLE 14.
(continued)

Utility	No. of Sites	Residential ($x10^9$ Btu/yr)	Commercial ($x10^9$ Btu/yr)	Public ($x10^9$ Btu/yr)	Industrial ($x10^9$ Btu/yr)	Total ($x10^9$ Btu/yr)
BPA Non-Preference Customers						
California PUC	1	346 (327)	7 (21)	10 (29)	92 (97)	455 (474) = 929
Idaho Power Co.	11 3/4	6,756 (4,937)	119 (356)	164 (490)	762 (1,027)	7,801 (6,810)=14,611
Montana Power Co.	6 3/4	582 (2,838)	36 (106)	49 (146)	36 (60)	703 (3,150)= 3,853
Pacific Power & Light	4 3/4	2,217 (1,512)	38 (113)	52 (154)	369 (404)	2,676 (2,183)= 4,859
Portland G.E.	3/4	125 (120)	3 (8)	3 (10)	0	131 (138) = 269
Puget Sound P & L	1	16 (14)	0 (1)	0 (1)	0	16 (16) = 32
Utah Power & Light	2	175 (163)	4 (10)	5 (14)	22 (36)	206 (223) = 429
Washington Water & Power	1 1/2	364 (227)	6 (18)	8 (25)	263 (434)	641 (704) = 1,345
Weiser City	3/4	98 (63)	2 (5)	2 (7)	0	102 (75) = 177
Subtotals	30 1/4	10,679 (10,201)	215 (638)	293 (876)	1,544 (2,058)	12,731 (13,773) = 26,504
TOTALS	47**	13,351 (13,325)	272 (814)	374 (1,110)	1,824 (2,446)	15,821 (17,695)
		26,676	1,086	1,484	4,270	33,516

*Each column is divided into electrical replacement potential and fossil fuel replacement potential (in parentheses).

**Six additional sites are not included in these figures as they have only electrical potential.

10-23-80

a total of 19 sites was selected for evaluation. A summary by state is as follows:

State	USGS >302°F	USGS Igneous	Number of Sites State Identified	Total Potential	Sites Evaluated
Northern California	1	1	0	2	1
Idaho	2	4	3	9	7
Western Montana	0	0	0	0	0
Northern Nevada	3	0	0	3	1
Oregon	8	9	1	18	7
Northern Utah	0	0	0	0	0
Washington	1	2	2	5	3
Western Wyoming	1	1	0	2	0
Total	16	17	6	39	19

Each site was then evaluated as to total potential and the estimated on-line development by the year 2000. These figures were arrived at based on conversations with state geothermal representatives, Bureau of Land Management personnel, and our own experience. Several site estimates were verified by independent estimates made by R. Greider (Reference 21) and EPRI (Reference 22). A summary of the potential and year 2000 development estimates are summarized by state; the details are given in Tables 7 and 13.

State	No. of Sites	USGS or State Estimates of Potential MW_e		Year 2000 Estimated Development MW_e
		Probable	Possible*	
Northern California	1	1,490	(0)	100
Idaho	7	376	(1,700)	425
Western Montana	0	0	(0)	0
Northern Nevada	1	136	(0)	100
Oregon	7	1,291	(750)	750
Northern Utah	0	0	(0)	0
Washington	3	0	(600)	300
Western Wyoming	0	0	(0)	0
Total	19	3,293	(3,050)	1,675

*"Possible" figures do not include "probable" figures.

Thus, a total of 51 percent of the probable electrical potential and 26 percent of the possible and probable electrical potential (including the igneous systems) is estimated to be developed by the year 2000.

Development Schedule

1. Direct Use.

The data developed earlier in this section on the potential for converting existing electrical and fossil fuel to geothermal are presented in Table 13. Based on population growth, community interest, legal and environmental constraints, and development costs, a development schedule was estimated over the next 20 years at 5-year increments and is tabulated in Table 13. Population growth was based on BPA county growth data. If geothermal development already existed at a site or was presently under active consideration, the development schedule would obviously be accelerated. Areas estimated to experience large growth increases would probably develop geothermal faster than those of low growth rate as it is easier to design new facilities for geothermal use than retrofit existing facilities. Areas having a high percentage of electrical space heating use would be converted to geothermal at a slower rate than those with high fossil fuel use. This is caused by the difficulty of converting electrical resistance heating to a geothermal system (forced air or hot water). As mentioned earlier only 26 percent of electric heating is by electric furnace, the remainder being resistance heating. The electric furnace can be converted to geothermal similar to fossil fuel furnaces.

A graphical presentation of the development schedule for each state is shown in Figure 25. The rate of growth starts low and increases faster near the year 2000. Beyond the year 2000, the rate of increase will probably slow, as the market becomes saturated, creating a S-shaped curve. The more favorable the development atmosphere, based on the variables mentioned, the closer the development schedule curve will approach the direct-use load value (allowing for population changes). These development trends are shown in Figure 26, illustrating both a hypothetical favorable and poor development schedule.

In many cases, specific site reports were available from state agencies. These detailed analyses of the geothermal resource, community and possible development restrictions, were incorporated into our development schedule estimates. Older reports were updated based on recent changes to initial assumptions. Finally, state and local people working on geothermal development were contacted to confirm projection assumptions and trends.

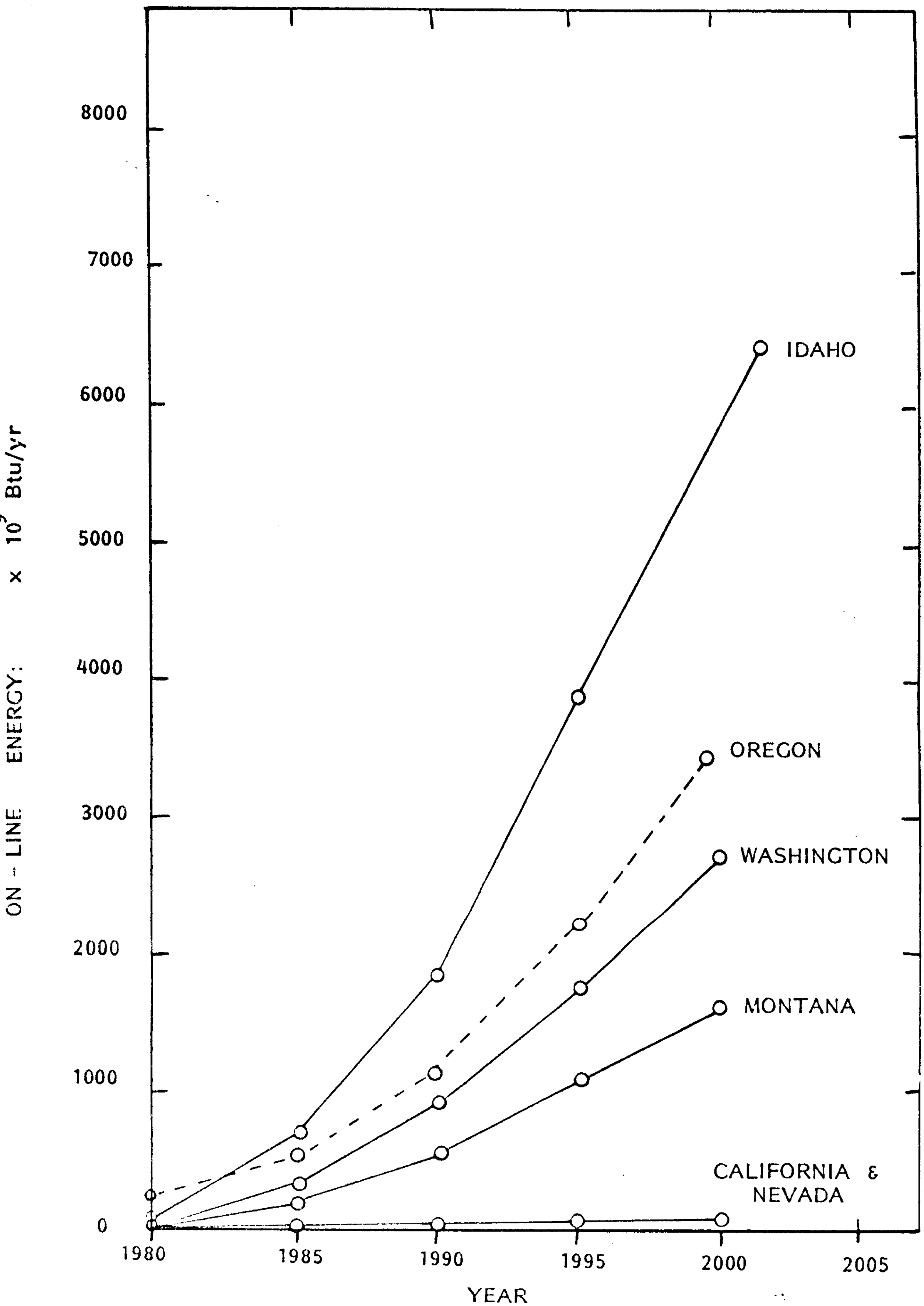

Figure 25. Direct use development schedule.

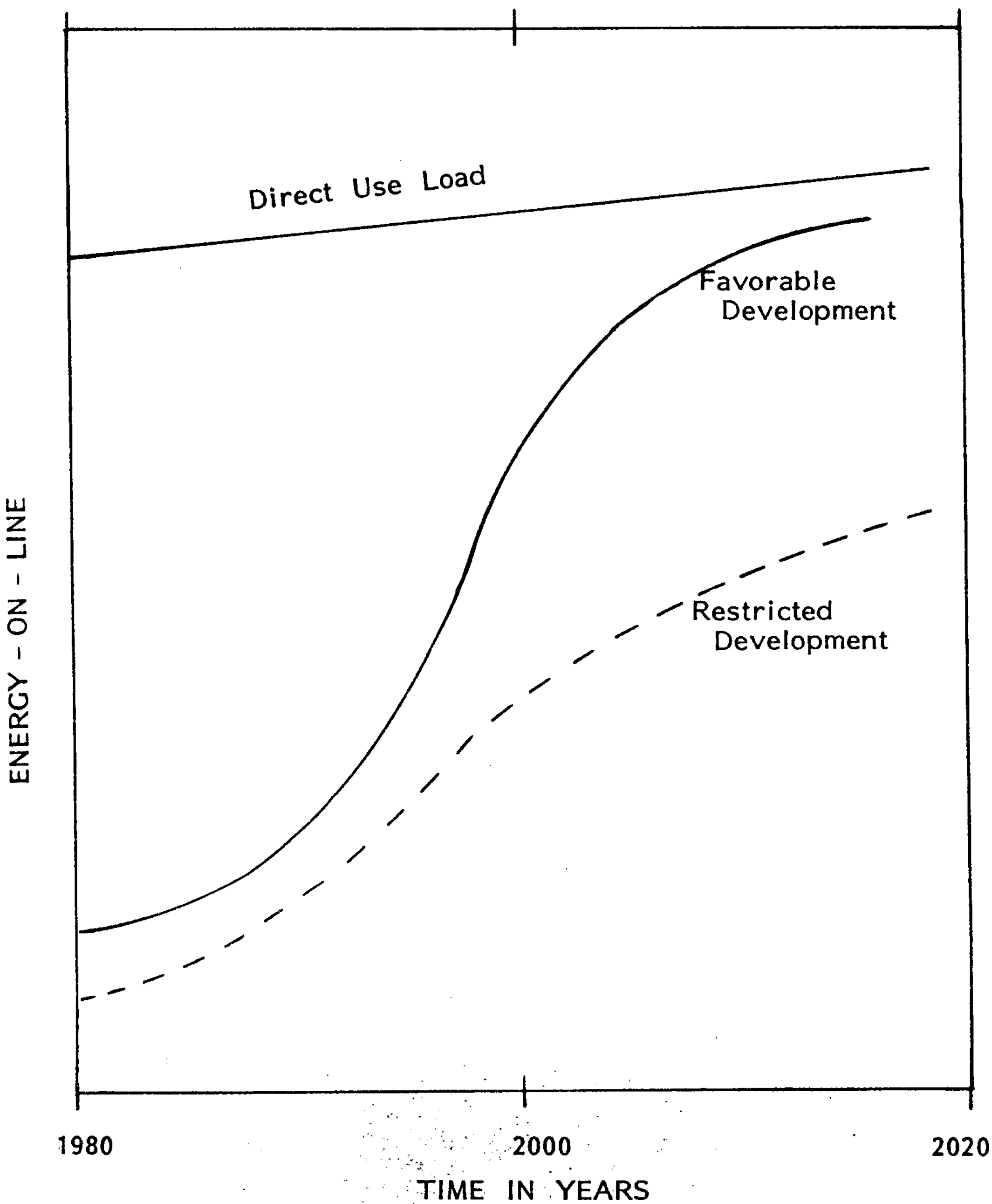

Figure 26. Generalized development schedule.

Since no formal or hard-and-fast rule could be developed for these projections, the specific numbers are subject to variations. To verify trends, these figures should be updated periodically--at least every five years.

The present nonelectric geothermal use and projected use for each state is summarized below:

State	Development x 10^9 Btu/yr				
	1980*	1985	1990	1995	2000
Northern California	0.1	15	30	45	70
Idaho	79.7	700	1,860	3,865	6,465
Western Montana	11.1	210	585	1,080	1,680
Northern Nevada	0	10	30	50	65
Oregon	257.2	535	1,120	2,080	3,410
Northern Utah	0	0	0	0	0
Washington	13.5	380	870	1,725	2,725
Western Wyoming	1.6	0	0	0	0
Total	363.2	1,850	4,495	8,845	14,415

*Reference: Geothermal Progress Monitor, USDOE (DOG/RA-0051/4)

2. Electrical Power.

The electrical power potential and estimated development schedule are shown in Tables 7 and 13 for each composite site. The only geothermal electrical generating site coming on line in the Pacific Northwest is at Raft River in southern Idaho where a 5-MW_e pilot plant is under construction. No other site in the BPA marketing area is under design or construction, thus at least a lead time of eight years will pass before any additional power will be generated (except for possible small-scale wellhead generators). For this reason, no new power on line is shown until 1990.* In general, power plants are constructed in 50- to 55-MW_e and 100-MW_e increments, with a total of from 200 to 400 MW_e being the minimum that will economically justify interest in a site.** Some sites may start with 20 MW_e in order to shorten the time to begin a return on the investment and to give investors a completed project. This idea is being proposed at the Roosevelt site in Utah and by NORNEV at the Dixie Valley site in Nevada (wellhead generator).

Other sites such as those near environmentally sensitive areas or areas of limited resource information, will be developed slower, and thus not come on line until 1995 or 2000.

Almost all sites will be developed beyond the year 2000, the upper limit depending upon the resource potential and energy uses.

In general, state and federal geothermal people agreed fairly closely with the proposed development schedule, especially at the year 2000. Some of these figures were in agreement with those proposed by R. Greider in Reference 21 and EPRI in Reference 22.

Two other developments that may accelerate the use of geothermal energy for electrical power generation should be mentioned. These are units designed to use resource temperatures lower than 300°F (149°C) and hybrid units designed to use a secondary fuel such as wood waste to boost low-temperature geothermal resources. The low-temperature units will probably be of a binary cycle design of low capacity (less than 50 MW_e); however, they

*Reference: See EPRI letter in Appendix.
**Reference: Geothermal Investment and Policy Analysis with Evaluation of California and Utah Resource Areas, DOE/RA/4713-1, October, 1979 (Reference 23).

will allow some sites that have previously been rejected due to low-temperature and/or estimated capacity, to be reevaluated for development. This is especially true of remote sites that could provide power to irrigation pumping districts, small ranching communities, isolated industrial sites, etc. The interest in this type of unit appears to be presently based on inquiries for technical assistance at the OIT Geo-Heat Center. Units of this type (less than 1 MW_e) are presently in use in China, using resources as low as 150°F (66°C). The hybrid system, using wood or agricultural waste as the booster fuel, is already on the design board. For example, Geo Products of Oakland, California, is presently considering a plant for the Wendel/Amadee area near Susanville, California, and Magma Power Company is considering a plant using wood chips for the Surprise Valley area of northeastern California.

These two developments will certainly enhance the production of electrical energy from lower-temperature geothermal fluids. Thus, marginal sites (based on temperature) should not be completely eliminated from future considerations for development.

Detailed Description of Geothermal Resource Sites

Referring to Tables 7 and 13, the following is a brief description of the potential for geothermal development at each site.

1. Oregon

   a. Hood/Carey/Breitenbush: The northern portion of the Oregon Cascades appears to have excellent potential, both for electric power generation and nonelectric use. Unfortunately, only limited information on the resource is available, due to lack of access and masking by cold ground water. Some exploration is taking place on Mt. Hood, with a proposed project to pipe hot water to Portland for space heating and one to heat

Timberline Lodge. Deep drilling is likely to discover high-temperature resources; however, exploration and access will be difficult. Future potential could include space heating for the Willamette Valley from Salem to Portland.

b. Kahneetah: A limited resource located on the Warm Springs Indian Reservation. It has the potential to supply the Kahneetah Lodge complex and the nearby town of Warm Springs.

c. Belknap/Foley/McCredie: The center portion of the Oregon Cascades appears to have the same general potential as the northern portion. Both electrical power production and direct use appear possible. Active interest is presently being shown at Oakridge for district heating, and there is a future potential to heat the Eugene area.

d. Klamath Falls/Klamath Hills: Approximately 500 wells already exist in the area which are being used for space heating and some industrial processing. A large commercial greenhouse operation and aquaculture project is located south of town. In the immediate future a district heating project and an ethanol plant will be constructed. There appears to be little potential for electric power generation.

e. Lakeview: Some use is presently being made of geothermal energy for space heating and greenhouse heating. A district heating project is presently being considered. Recent interest appears to point towards electric power potential north of town, where a gradient of 64°-85°F/100 ft has been measured.

f. Crump's/Fisher: Very little potential for direct use due to lack of population. A limited potential for electrical power generation.

g. Crane/Harney: Direct-use potential only, with the communities of Burns and Hines being candidates for space heating. A large lumber operation is located at Hines. Oregon Department of Geology and Mineral Industries are presently drilling four temperature gradient holes in the area.

h. Alvord/Mickey/Borax/Trout: One of the best prospects for electric power generation. Little potential for direct use due to lack of population. May be a problem with development due to strong environmental opposition. R. Greider estimates 200-MW_e on-line by the year 2000.

i. Medical/Craig-Cove: Historical use of several locations in this area including resorts for medical purposes and a recently constructed alcohol plant. Low-temperature use at Cove for greenhouses, a swimming pool, and hog farm. An interest has been expressed for space heating in La Grande. If a resource does not exist under the city, it probably can be piped from Hot Lake located to the south.

j. Little Valley/Neal/Vale/W. Snake: Probably the best geothermal prospect in the state. Historical use at Vale for space heating and active exploration and drilling in the surrounding area. A recent low-producing well was drilled at Ontario for the Ore-Ida potato processing plant. Extensive industrial application potential in agriculture as well as space heating load. It is also an excellent potential for electric power generation. R. Greider estimates 300-MW_e on-line by the year 2000.

k. Glass Butte: An extensive igneous system, related to the Brothers Fault zone, that appears to have electrical power potential; however, knowledge of the resource is limited. No direct-use load potential. Phillips Petroleum Company has done some exploration in the area; however, interest does not appear as strong today.

1. Milton-Freewater: A low-temperature resource as indicated by shallow, warm wells in the area. Also related to the Walla Walla resource in Washington. It has potential for heat pump applications for space heating and some industrial processing.

Note: Newberry-Caldera area appears to have excellent potential for electric power generation (up to 740 MW_e); however, it is presently not being considered due to environmental limitations and restrictions by the state. USGS is, however, carrying on an active drilling program in the area.

2. Nevada

   a. Baltazor/Dyke/Pinto: An isolated location with potential for electric power generation. Limited leasing activity; however, subsurface temperature estimates appear good.

   b. Mineral/Jackpot: A moderate- to low-temperature resource with potential for space heating of several small communities.

   c. Hot Sulfur/Wells: A moderate temperature resource with potential to space heat the community of Wells. Several active projects are underway to evaluate the direct-use potential, including one to use the existing water distribution lines for transporting geothermal fluids.

Note: Potential for space heating exists just outside of the BPA market area at Winnemucca and Elko.

3. California

   a. Surprise/Ft. Bidwell: An excellent potential for electric power production and direct use in the Surprise Valley. Interest has been expressed for ethanol production and district heating at Ft. Bidwell. A good chance of near-term development of a hybrid electric power plant using wood chips (Magma Power Company) with a large future potential (up to 1,490 MW_e).

b. Kelly/W. Valley: Two major areas for direct use are at Kelly Hot Springs and the city of Alturas. Several projects have been proposed for the large output at Kelly Hot Springs, the most active one being greenhouse heating.

4. Idaho

a. Ketchum: A low-temperature resource with excellent potential for space heating of this growing resort area. Some difficulty has been encountered in obtaining access to the resource under private ownership. Excellent near-term development possibilities, with numerous (65) condominiums, homes, and businesses presently being heated.

b. Boise Front: One of the oldest direct uses of geothermal for space heating in the country is located on Warm Springs Avenue in Boise. Recent developments include the heating of several state buildings and a proposed large-scale district heating project in downtown Boise. There appear to be excellent prospects for continuation of the space heating developments in the area, especially in the near term.

c. Nampa-Caldwell: A low-temperature resource as part of the extensive Snake River Plain system. Little is known of the resource; however, several wells in the area indicate the potential for space heating and for use in the area's numerous food processing plants.

d. Banbury/Hollister/Artesian: A low- to moderate-temperature resource located near Twin Falls. Active interest and use of geothermal presently has been developed at Buhl (aquaculture) and at the College of Southern Idaho in Twin Falls. Limited use for space heat in the future.

e. Blackfoot/Grays Lake: Located in the overthrust or intermountain seismic belt of eastern Idaho, it is probably one of the more favorable prospects in the state. Based on a dry oil and gas well, a temperature of 400°F (204°C) has been measured. Cold water does mask the site; however, exploration data suggests a large heat source. A potential electric site as well as some direct use for space heating at Soda Springs.

f. Pocatello: The low-temperature resource is located north of the town and has some potential for space heating. There appears to be limited potential to meet some of the industrial processing needs of the area. Energy Services Company is, however, under contract to Great Western for a barley malting project using geothermal.

g. Riggins: A resource located about six miles from town. Limited space heating potential.

h. Cabarton: Located near Cascade, the resource has limited space heating potential.

i. Crane-Cove/Weiser: Two separate locations having potential for electric power generation. Site space and marginal temperatures may limit development; however, both are considered the leading candidates for development in the state. Direct use was made at Weiser for greenhouses and a swimming pool (now closed). The town of Weiser has the potential for a district heating project and Crane-Cove Creek is being considered for an ethanol plant site.

j. Roystone: Located near Emmett, it is a good site for industrial development as well as satisfying space heating needs of Emmett. Recent work indicates there may be a potential for electric power generation similar to Raft River. An ethanol plant project is slated to start production in 1981.

k. Latty/Radio/Gravel/Bruneau-Grand View/Mt. Home: Very little information is available on the first three sites; however, the Bruneau-Grand View area is the largest moderate-temperature resource in the country. Excellent potential for space heating such as at Grand View where a site has been selected for a 3,000-foot deep well. Interest has been expressed for several industrial process projects near Mt. Home, as well as at the Mt. Home Air Force base.

l. Owl Creek/Big Creek: Located in a national forest area, it is an environmentally sensitive area. The site does have the potential for electric power generation and to supply heat to a nearby new cobalt and molybdenum mine. The town of Salmon is about 25 miles away, but could be considered for geothermal space heating. Salmon does have a local low-temperature resource.

m. Sunbeam/Slate/Stanley-Challis: An area adjacent to and partially in the Sawtooth National Recreation Area. The two towns that are not limited by environmental consideration for using the resource for space heating are Stanley and Challis. Stanley has a high resort growth potential and Challis will house the workers for a new molybdenum mine. Stanley has completed a district heating study, but lacks funds to drill a well.

n. Magic/Worswick/Wardrop/Barron's/Camas: This area has a potential for industrial development including an industrial park and ethanol project. Magic Reservoir is considered for electrical power generation, but has marginal temperature indications.

o. Raft River: Geothermal research is being conducted at this site using five wells up to 6,000 feet deep. Numerous experiments dealing with agriculture, aquaculture, industrial and electrical applications are being conducted at the site. A 5-MW_e binary pilot power plant is under construction on line. There is future potential for industrial and agricultural development in the area, including an ethanol plant.

p. Ashton/Newdale: Located near Rexburg and Sugar City in the eastern part of the state. It has potential to be used for space heating and process use; however, there is a large, shallow, cold water aquifer making the geothermal resource hard to find. Current drilling near Rexburg has produced temperatures less than expected. Ashton may have electrical potential.

q. Maple/Riverdale/Wayland (Battle Creek)/Squaw: Recent drilling (Sun Oil Company) in the Preston area of southeastern Idaho indicates potential for a high-temperature resource. The area also has industrial processing potential and limited space heating use.

r. Island Park: This area has good potential for electric power development, but the resource is masked by shallow, cold water. The site is the recharge area for the Snake River Plain aquifer, and thus will have less heat than Yellowstone. Development may be limited due to environmental constraints--the proximity to Yellowstone National Park. For this reason, power-on-line will probably be delayed.

s. Lewiston: The low-temperature resource is probably located across the Snake River in Clarkston, Washington. If the resource can be developed by the use of heat pumps, there is a large space heating and industrial process load that can be satisfied. Unfortunately, little is known of the extent and character of the resource.

Note: The Snake River Plain is a major geothermal resource area making a crescent-shaped sweep across southern Idaho from Yellowstone Park to Vale, Oregon. The high-temperature areas are located along the margin of the plain. At these points, such as at Vale, Oregon; Weiser, Idaho; and Yellowstone, the structure is fault-controlled, allowing high temperatures (300°-350°F = 149°-177°C) to be reached at shallow depths. In the center of the plain the high-temperature resource is estimated to be around 10,000 feet in depth. In this area temperature is not a problem; however, a fault or flow contact is needed to provide water (the problem with the Ore-Ida and INEL wells). At shallow depth, if a fracture or aquifer is present, temperatures up to 110°-150°F (43°-66°C) can be expected.

5. Washington

   a. Yakima: Part of the Columbia Basin where above-normal ground water temperatures and geothermal gradients are common. Although the resource is not hot enough to be used directly for space heating or industrial processing, it can be economically utilized by boosting the temperature through the use of heat pumps. It has excellent potential for near-term development. Studies are presently being undertaken to develop the resource.

   b. Ephrata: Part of the Columbia Basin with potential and characteristics similar to Yakima. Use of the city's domestic water and heat pumps for space heating is also being considered.

   c. Walla Walla: Similar in nature to Yakima and Ephrata. Related to the resource in Milton-Freewater, Oregon.

   d. Clarkston: A low-temperature resource located along the Snake River. Very little is known about the characteristics and extent, except for some information from a few shallow wells. It has the potential to supply heat to Lewiston, Idaho, across the river. The temperatures appear to be within the heat pump application range.

e. Prosser: Similar in nature to Yakima, Ephrata, and Walla Walla.

f. N. Bonneville/Carson: Two separate hot spring locations have the potential of providing energy for space heating of these communities along the Columbia River. North Bonneville is presently being relocated, thus geothermal heating systems can be incorporated into the new buildings. There is some question as to whether the resource will finally prove to be above or below 100°F (38°C). Above 100°F (38°C) it can be used directly for heating and be more economical to use. Below 100°F (38°C) would require heat pumps.

g. King County: A resource located on the Green River to the east of Seattle. Little is known of the resource; however, Burlington Northern Company is actively investigating the area for electric power use. If the resource proves to be large, it could provide space heat for the Seattle area in the future.

h. Baker H.S./Mt. Baker: A high-temperature resource in the Cascades. It has an excellent potential for electric power generation; however, environmental constraints may delay development.

i. Mt. St. Helens: Another high-temperature resource in the Cascades that has excellent electric power potential. The recent volcanic activity will delay development--however, the resource is obviously present.

Note: The Columbia Plateau low-temperature ground water is probably the best geothermal resource in the state, especially for near-term development. There is evidence that it may extend as far north as Spokane.

6. Montana

a. Gregson/Warm/Anaconda: Three separate resources, all having good potential for development. Presently Gregson Hot Springs has a resort using geothermal, and Warm Springs has a state hospital being redeveloped for geothermal space heating. At Anaconda, the temperature of the resource limits applications in the smelting operation; however, it might be used to thaw ore in railroad cars during the winter (natural gas is presently being used). Unfortunately, a recent news release indicated the plant may be closing.

b. Pipestone/Barkel's (Silver Star): Barkel's Hot Spring is an isolated site which may limit development. Pipestone is a lower-temperature resource with a potential to supply heat to space heat portions of Butte.

c. Bozeman: A good resource for space heating use in the town of Bozeman. Even though the resource is four miles from town, the development is expanding towards the hot springs which will reduce transmission costs.

d. Broadwater/Alhambra: Alhambra Hot Springs is the more isolated of the two sites, and thus has less potential for development. Information on the resource is also limited. Broadwater Hot Springs is about three miles from Helena, thus it has excellent potential for space heating that city. Presently the hot spring heats several houses and a health club, and plans to heat a new subdivision are being discussed.

e. Boulder: A good potential for this resource is to provide heat for the town of Boulder about two miles away or to supply an adjacent industrial park. USDOE is presently involved in a resource assessment program in the area.

f. Ennis (Thexton): The hottest known resource in Montana with excellent direct-use potential. The adjacent town of Ennis can be developed for geothermal space heat. Virginia City, about 15 miles away, has a potential for long-term development. Some USGS work has been done at the resource.

g. White Sulfur: The local community of White Sulfur Springs has encouraged the development of this resource for space heating. At present the local bank and motel are being heated. The aquifer appears to be fairly large.

h. Hunters: One of the hottest resources in the state with direct-use potential in Springdale. Future use may provide heat to Livingston and Big Timbers located at greater distances from the resource.

Note: Most of the resource in Montana is located in the eastern part of the state. The western portion has no large-point source loads, thus most of the end-use projects will be small and spread out. The majority of the resources are located on private land, with none at present having electric power generation potential.

V. GEOTHERMAL INCENTIVES

In order to accelerate the identification and utilization of geothermal resources, various development strategies have been implemented by federal and state governments. The intent of these efforts is summarized as follows:

1. To identify and quantify resources not yet located and confirmed, and to reduce the uncertainties associated with resource energy estimates;
2. To assist in the research and development of new technology which may expand the usable resource base while reducing costs, and therefore lead to more rapid commercialization;
3. To streamline regulatory processes, such as leasing and permitting, in order to speed project implementation;
4. To increase site specific outreach and planning, in order to create awareness of the resource and assist in near-term project implementation;
5. To assess the environmental impacts of geothermal energy that may impede resource development, in order to establish appropriate regulations and monitoring procedures, and to develop control technology; and
6. To encourage capital investment, through public and private risk-sharing, reducing front-end costs, and other economic incentives designed to accelerate geothermal utilization.

The federal government sponsors a variety of research, demonstration, and cost-sharing programs intended to achieve the foregoing objectives. Current levels of U.S. DOE funding for these programs is reproduced in Table 15.

Direct economic incentives administered federally include a personal income tax credit of 40 percent of geothermal equipment cost, up to a maximum credit of $4,000, for residential installations; a 15 percent business investment energy tax

TABLE 15.
Funding Levels for Geothermal Energy Programs
FY 1979 through FY 1981

	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
	ACTUAL FY 1979	ESTIMATE FY 1980	ESTIMATE FY 1981	INCREASE (DECREASE)
GEOTHERMAL ENERGY				
HYDROTHERMAL RESOURCES				
Resource Definition	26,163	13,406	19,398	5,992
Non-Electric Applications	10,238	12,200	16,000	3,800
Environmental Control	1,859	1,300	2,600	1,300
Facilities	22,968	33,694	15,002	(18,692)
Capital Equipment	1,232	800	0	(800)
Total Hydrothermal Resources	62,460	61,400	53,000	(8,400)
HYDROTHERMAL COMMERCIALIZATION				
Planning and Analysis	5,239	5,000	5,040	40
Private Sector Development	4,410	4,860	4,960	100
Total Hydrothermal Commercialization	9,649	9,860	10,000	140
GEOPRESSURED RESOURCES				
Program Coordination	1,192	882	2,200	1,318
Resource Definition	24,455	32,329	31,000	(1329)
Engineering Applications	72	839	900	61
Environmental Control	551	1,650	1,700	50
Facilities	0	0	0	0
Capital Equipment	111	300	200	(100)
Total Geopressured Resources	26,381	36,000	36,000	0
GEOTHERMAL TECHNOLOGY DEVELOPMENT				
Component Technology Development				
Drilling and Completion	5,432	7,000	8,250	1,250
Energy Conversion	9,344	7,100	12,800	5,700
Reservoir Stimulation	4,442	3,000	4,500	1,500
Geochemical Engineering and Materials	7,071	3,600	5,005	1,405
Geosciences	8,477	4,200	7,835	3,635
Subtotal Component Development	34,766	24,900	38,390	13,490
Hot Dry Rock	15,077	14,000	13,500	(500)
Capital Equipment	1,479	2,100	1,110	(990)
Total Geothermal Technology Development	51,322	41,000	53,000	12,000
TOTAL GEOTHERMAL ENERGY	149,812	148,260	152,000	3,740

credit for geothermal equipment, in addition to the regular 10 percent investment credit; and a well depletion allowance and allowable intangible drilling cost deductions. DOE's User-Coupled Drilling and Geothermal Loan Guarantee Programs are also major federal incentives, acting to reduce the risks associated with major geothermal projects by cost-sharing drilling and insuring up to 70 percent of project costs. In addition to DOE, several other federal agencies also offer grant and loan programs which may be used to fund geothermal projects.

A summary of federal grant and loan programs follows:

1. DOE:
   - Program Research & Development Announcement (PRDA)
   - Program Opportunity Notice (PON)
   - User-Coupled Drilling Program (SCA)
   - Appropriate Technology Grant Program
   - Institutional Buildings Grant Program
2. FmHA:
   - Business and Industrial Loans & Grants
   - Community Facility Loans
3. EDA:
   - Public Works and Development Facilities Grants
   - Business Development Loans
4. HUD:
   - Community Development Block Grants
   - Urban Development Action Grants
5. SBA:
   - Business Development Loans

State governments are also implementing various incentives. For example, in Oregon the following measures have been established:

1. Income tax credits are available to homeowners, renters, landlords, contract purchasers, and builders, for 25 percent of the cost of geothermal systems up to $1,000 per dwelling; this credit can also be claimed for connection to a geothermal district heating service;

2. Geothermal systems are exempted from property tax values; and
3. Business income tax credits are available, for 35 percent of the cost of geothermal equipment, claimed over a five-year period.

In addition, the Oregon Energy Department has sponsored its own small grants program, in order to assist local communities with feasibility studies and implementation measures. The states of Montana, Idaho, and Washington have undertaken similar programs to assist localities.

In addition to these existing incentives, several states are considering new measures for even greater resource enhancement. For example, Oregon's recent Geothermal Task Force has proposed the following incentives:

1. An additional 20 percent business tax credit for geothermal industries locating in remote geothermal areas;
2. Establishment of a state-level depletion allowance and intangible drilling cost deductions;
3. Establishment of a dedicated geothermal development fund for aiding exploration and utilization through low-interest loans, to be capitalized with the state's share of federal geothermal leasing revenues;
4. Inclusion of geothermal research and development, and construction work in progress, in public utility rate bases;
5. Inclusion of ground water heat pumps as eligible systems for residential and business tax credits;
6. Exemption of certain small-scale, nonelectric geothermal projects from PUC jurisdiction; and
7. Deferment of property taxes on a geothermal project until power or Btu's are on-line.

Nevada and other states are considering similar provisions for increasing geothermal's economic attractiveness.

VI. RECOMMENDED PILOT PROJECTS

Five general projects are identified that should be considered by BPA to encourage geothermal development in their market area. These projects are generic and are not site specific. Where appropriate, a number of sites are recommended under each section that are within BPA's preference customer service area. Projects costs and energy savings are also determined where appropriate. The five project areas are:

A. Regional Resource Planning and Development

B. Wellhead Generators

C. Resource Exploration, Confirmation, and Evaluation

D. District Heating

E. Heat Pumps

The first project on the planning and development aspect, relates in part to the remaining projects. This recommendation suggests means of providing incentives or financing for the other projects. The wellhead generator project is the only one involving electrical power; however, rather than suggest large power plants, smaller versions are proposed to bring power on line sooner. The resource exploration, confirmation, and evaluation project is a basic need, as all other projects depend in part, if not entirely, on the outcome of this first phase of geothermal development. The last two projects are interrelated in that they both involve space heating and, more specifically, district heating. The district heating project deals with using resources above 100°F (38°C), whereas the heat pump project concerns the use of low-temperature resources or optimizing higher temperature fluids with fossil-fueled peaking or other hybrid systems.

A. REGIONAL RESOURCE PLANNING AND DEVELOPMENT

Given geothermal's significant regional energy potential coupled with the relative infancy of its development, one of the resource's major needs is a regionally coordinated institutional framework for planning and development. Although there is considerable planning work being performed through DOE's Region X and the individual state energy programs, there still remains a substantial need for additional resource management assistance, especially on a regional scale.

Specific examples of planning and development activities which should be considered include:

1. Project coordination: Within the BPA market area there are, and will continue to be, a variety of ongoing geothermal projects that would benefit significantly from an institutional coordination mechanism, which could establish regional priorities, facilitate information-sharing, and document regional progress.
2. Data collection: There is an urgent need to establish and implement uniform methods of regional data collection, such that the completeness and accuracy of regional geothermal data can be improved, and such that community heating load data can be uniformly collected by regional utilities.
3. Public education: A continuing barrier to geothermal development is the public's lack of awareness or understanding of the resource. An extensive regional information program is required to create such awareness, and most importantly, to stimulate interest in potential user groups throughout the region.
4. Environmental baseline studies: Much of the delay in achieving geothermal goals will be due to environmental requirements, including the necessity

of establishing environmental baselines in resource areas not previously documented. Such anomaly-wide assessments should be initiated as early on as possible, such that subsequent development proposals will not be deterred or unnecessarily delayed while environmental baselines are established.

5. Regional development fund: Despite existing and proposed federal and state financial incentives, geothermal continues to be severely handicapped by high front-end costs. The establishment of a regional development fund, which could make low-interest loans to states, municipalities, and certain utilities for geothermal projects, would add considerable momentum to regional progress.
6. Land-use planning for nonelectric uses: The development of nonelectric geothermal uses will be dependent in part upon supportive land-use practices in resource areas. The relationships between land-use planning and geothermal direct use should be investigated, and model geothermal land-use principles and practices developed and disseminated, such that local areas may soon implement policies and standards which will enhance the future, feasibility, and efficiency of geothermal direct use.

B. WELLHEAD GENERATORS

We recommend BPA either purchase for testing or design and construct a small wellhead power generator utilizing geothermal water from a single-production and injection well. Design and economic feasibility for these units needs to be investigated.

Wellhead generators range in size from small (~50-KW_e gross) Organic Rankine Cycle (binary) units extracting thermal energy from shallow low-temperature wells to over 5 MW_e using high-temperature deep wells.

Small Wellhead Generator for On-Site Power. A small wellhead co-generator could be used to supply power to well pumps by utilizing a 10° to 20°F (6° to 11°C) temperature differential from a district heating supply, or they could provide power to remote areas where powerlines do not exist. Estimated costs for these units range from $1,000 to $1,500 per kw;* however, the economics needs further investigation.

As an example, consider a small binary power generator utilizing a 20°F (11°C) temperature differential from a 192°F (89°C) well. Electricity generated would be used to supply power to the pump, since heating load and power requirements for the pump would match. Waste water could be used for nonelectric projects located nearby.

Figure 27 is a block flow diagram of the proposed system. Fluid for the cycle is trichlorotrifluorocthane (R-113). This fluid has the advantage of high molecular weight (187.4), low-boiling point (117.6°F = 47.6°C), and low-cycle pressure (41 psia vapor, 13 psia liquid). The pressure differential between expansion and condensing is 28 psia.

Geothermal water used would be about 500 gpm based on a supply temperature of 192°F (89°C) and a discharge temperature of 172°F (78°C) which can be used for space and domestic water heating demand of a district heating project. A cooling tower would be required.

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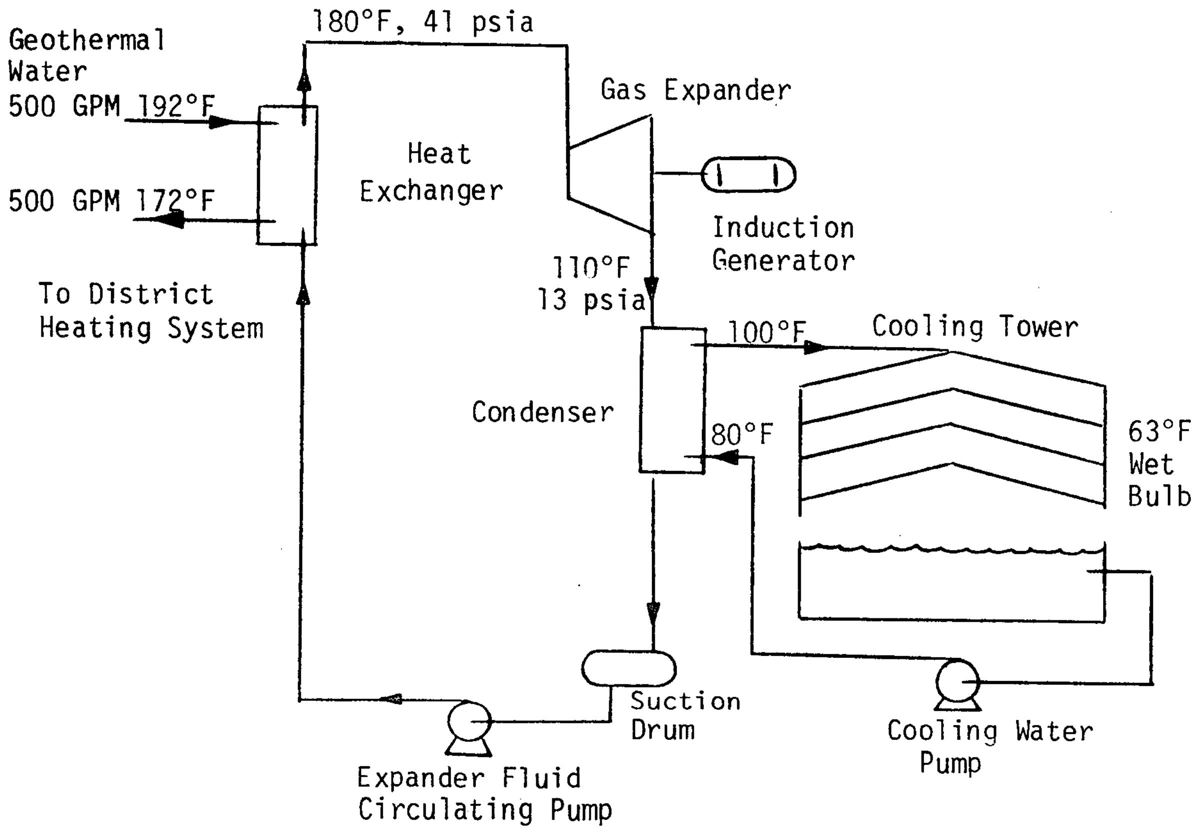
*SPS Inc., Miami, Florida and Mechanical Technology Inc., Latham, New York.

Figure 27.

DEMONSTRATION POWER GENERATOR

FOR PUMPS



Geothermal Fluids	192°F @ 450 GPM (89°C @ ℓ/s)
Cooling Tower	80°F Supply, 100°F Return (27° and 38°C)
Expander Efficiency	70%
Induction Gen. Efficiency	94%
Working Fluid	Trichlorotrifluoroethane (#113)

The following calculation gives a rough idea of the gross power output from a small wellhead co-generator plant:

$$\text{Gross Power} = \frac{105 - 98}{105 - 32} \times 500 \times 500 \times 20 \times .70 \times .94 \times \frac{1}{3,413} = 90 \text{ kw}$$

Low-Temperature Sites

1. Yakima Valley area - Grant County PUD or Columbia REA, (Washington).
2. Portions of western Montana within the Vigilante Coop., Service area.
3. Snake River Plains - Prairie Power Coop., or Fall River REC, (Idaho).
4. Klamath Falls - Co-generation with City District Heating Network.
5. Cascade Range (moderate temperature) - hybrid system using wood waste for peaking fuel.

Large High-Temperature Wellhead Generators. Separated system (flash), binary or shear torque turbines could be considered for the larger wellhead generators utilizing deeper and high-temperature (>300°F = 140°C) wells. Advantages of wellhead generators vs. conventional centralized power plants are:

1. A power plant module can be moved to a well site upon completion and testing of the well. See Figure 28.
2. Installation time to develop a field of 15 wells is estimated to be reduced by approximately one-half.
3. Earlier return on investment.
4. Reduced costs for collection mains that are necessary for centralized power plants.
5. Increased power output (estimated to be 39 percent)* in the case of shear torque turbines from a field of 15 wells (380°F = 193°C), each with a flow rate of 400,000 lb/hr.

A comparison of a conventional centralized geothermal field system and wellhead generator is shown on Figure 29.

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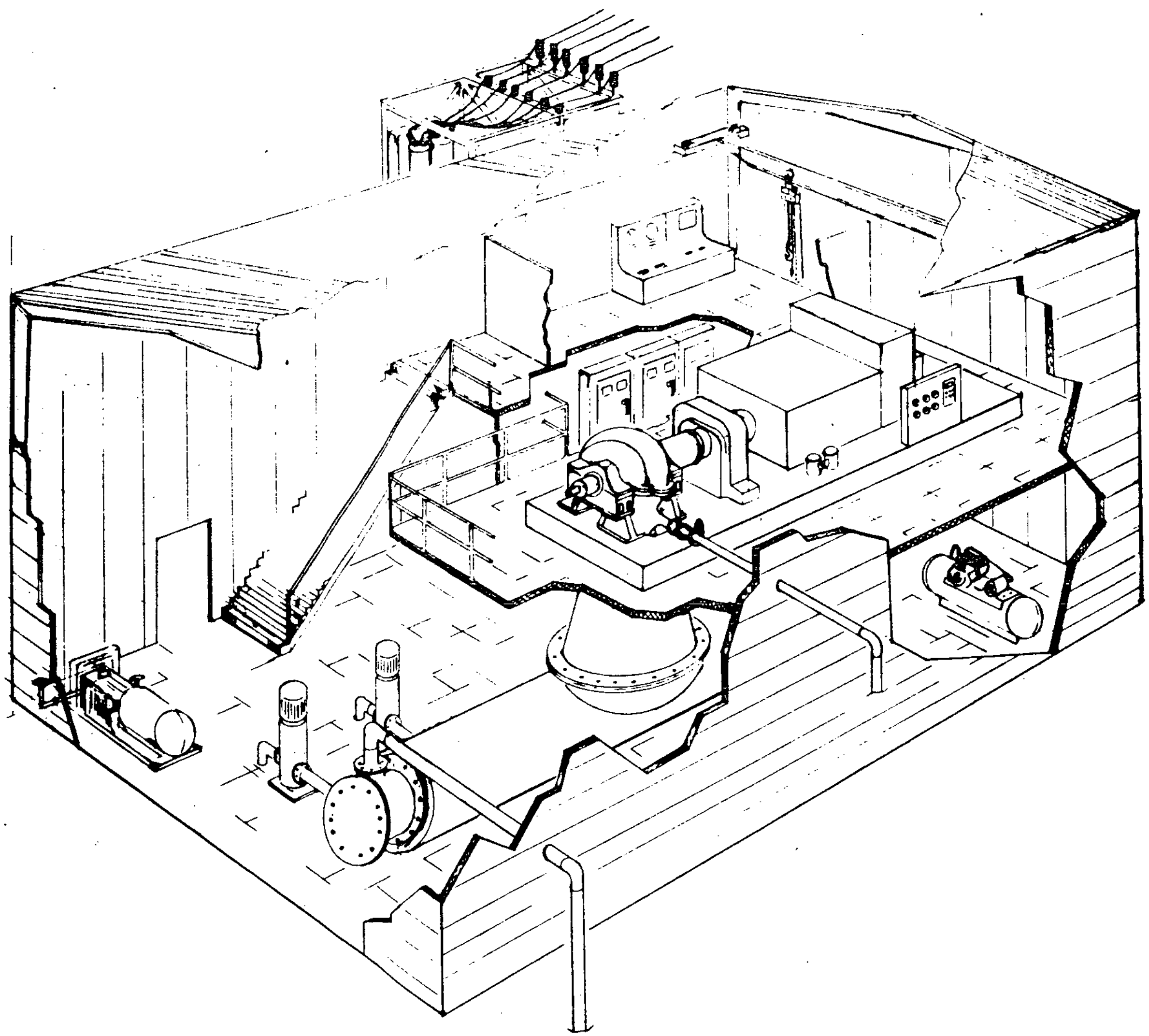
*American Thermal Resources, Inc., Orange, California.



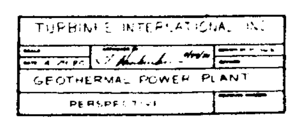


Figure 28. Wellhead generator.
(Source: American Thermal Resources, Inc.)

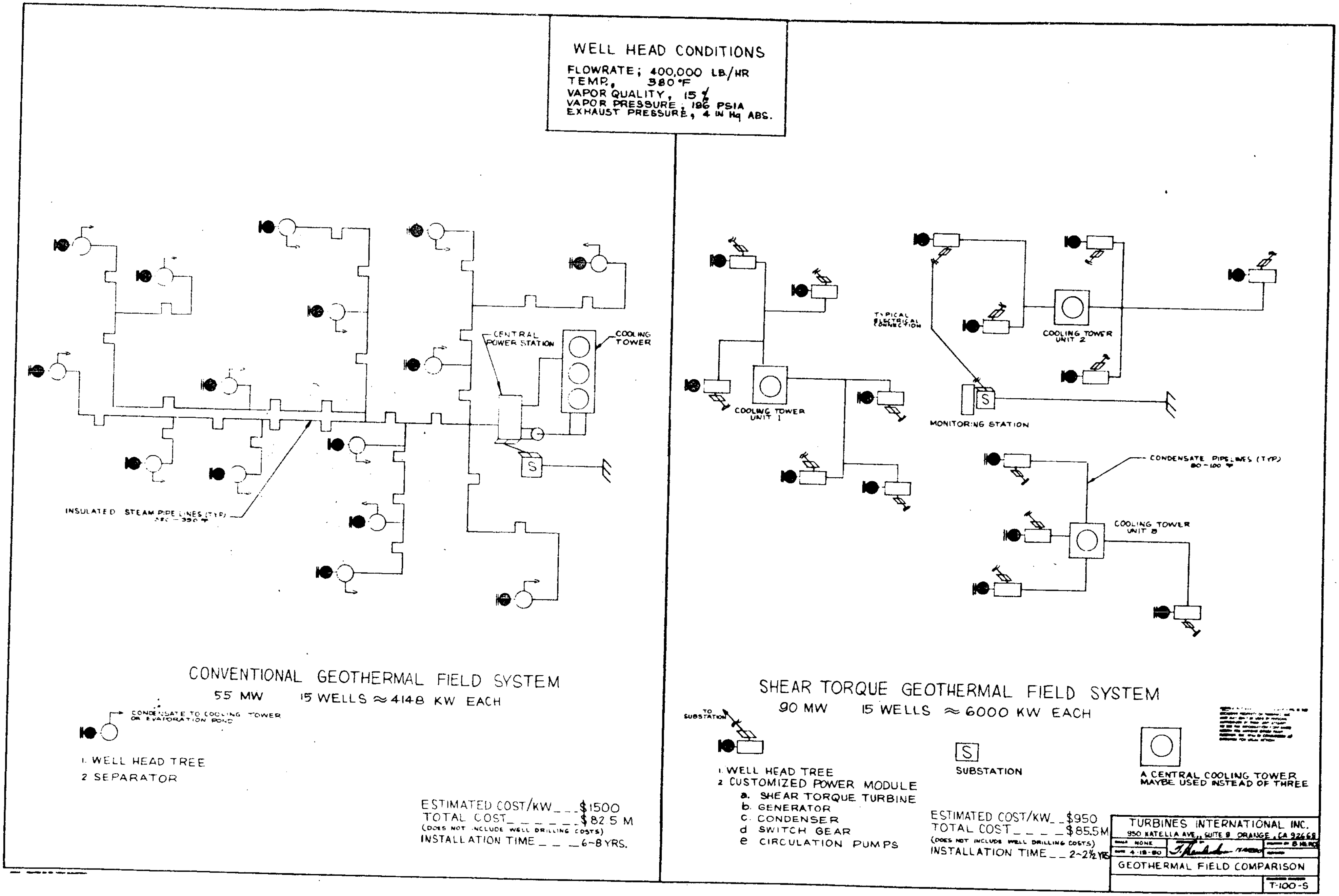


Figure 29. Comparison of conventional and wellhead generators.
(Source: American Thermal Resources, Inc.)

A separated steam wellhead generator is under construction at this time at Pahoa, Hawaii, and a prototype of the shear torque turbine is being tested at Imperial Valley, California.

Recommended sites for testing a wellhead generator would be:

High-temperature Sites

1. Alvord geothermal area (or Crump's or Mickey H.S.) - Harney Electric Corp., (Oregon).
2. Raft River test site - Raft River REC (Idaho).
3. Surprise Valley site - Surprise Valley Electric Coop., (California).

C. RESOURCES EXPLORATION, CONFIRMATION, AND EVALUATION

In the Pacific Northwest, the general areas of geothermal potential have been identified; however, the details on size, temperature, water quality, and heat content have not been determined for many sites. There is a pressing need to determine this information, to encourage development and utilization of the site. Investors and energy companies are reluctant to become involved in exploration, confirmation, and evaluation of reservoirs. They want this risk minimized or eliminated before they commit their finances. Thus, other agencies have to assume some of the risk (financial) if geothermal energy use is to be encouraged. These incentives are described in detail in Section V, and include forgivable loans, guaranteed loans, shared drilling program, purchase and publication of private exploration information, etc.

More specifically, three important questions that require answers in any geothermal utilization project are:

1. Where should a geothermal well be sited?
2. How deep must a well be drilled to obtain the required temperature for the specific need?

3. How much heat (thermal energy) can be extracted per unit time after drilling a well to the required depth?

The various geological, geochemical, and geophysical tools available to the geothermal explorationist are designed to produce specific information to answer the above questions. Because each geothermal prospect is unique, there is no one method or series of methods which will work in all circumstances. The costs of various methods must be considered in terms of the benefits received and the value of the particular resource. Nevertheless, the final verification of a geothermal resource must be based on drilling.

The various components of any exploration program include:

1. geological exploration
2. geochemical exploration
3. geophysical exploration
4. drilling
5. geophysical logging

Table 16 shows many of the exploration methods outlined. Approximate times for completion of the surveys and order-of-magnitude costs for the methods are also indicated. It should be stressed that the costs shown are approximate and will vary as a function of many factors including survey detail, accessibility, terrain and weather. Geothermal-gradient/heat-flow borehole costs include cost of drilling and completing holes as well as logging. The geochemical procedures include sample collection as well as analytical costs. The methods are also characterized as being principally of use in regional and/or detailed evaluations.

D. DISTRICT HEATING

A strong incentive for district heating is energy conservation and lower energy costs by using cheaper fuel and waste heat. Fuel economy is greater for district heating (for example, a home with an individual heating system operates at 50

TABLE 16.*

Summary of costs, time frames, and area covered with various geothermal exploration methods.

Method	Time	Expense	Area
Consulting geologist	< month	$200-$400/day	Regional/detailed
Airphoto interpretation	< month	$5/mi² ($2/km²)	Regional/detailed
Water analyses	month	$100-$200/sample	Regional/detailed
Surface geochemistry	month	$30/sample	Detailed
Volatile geochemistry	month	$20/sample	Detailed
Temperature gradient/heat flow boreholes	> month	$10-$100/ft ($30-$300/m)	Regional/detailed
Electromagnetic methods	month	$200-$1,500/line mi ($125-$930/line km)	Detailed
Resistivity	month	$200-$1,500/line mi ($125-$930/line km)	Detailed
Magnetics - airborne	< month	$25/line mi ($15/km)	Regional
- ground	< month	$200/line mi ($125/km)	Detailed
Seismic - refraction	< month	$5,000/line mi ($3,000/km)	Detailed
- reflection	< month	$5,000-$10,000/line mi ($3,000-$6,000/km)	Detailed
- microearthquakes	3-6 months	$1,200/day	Regional/detailed
Gravity	month	$30-$70 station	Regional/detailed
Magnetotellurics	month	$1,200-$2,000/line mi ($750-$1,250/km)	
Geophysical logging	< week	$2,000-$20,000/hole	Detailed

*From Reference 9--see additional data on page 71 and in the Appendix.

to 70 percent efficiency compared to 80 percent in the case of district heating). Other incentives are improved air quality through improved discharges of fossil-fuel fired centralized plants; the concentration of the facility, allowing efficient use of specialists; and fewer oil-transportating vehicles for fossil-fuel plants. Using geothermal energy as the energy source leads to a more efficient use of the resource.

Obstacles to district heating are: cost of distribution, distribution heat loss, the hight cost of supplying one-family houses on lots over 5,000 ft^2, high initial capital investments, and the many different types of heating systems in the United States. Natural gas is a severe competitor to district heating from an envionmental and economic view; however, geothermal energy has proven competitive (Klamath Falls) where the resource is near the heating load. Indications are that natural gas may increase substantially in the future, thus loosing its competitive position.

Iceland has experienced great success in using geothermal energy for district heating with a savings of approximately 30 percent over using heating oil. Approximately 65 percent of the buildings in the country and 97 percent of Reykjavik are on district heating systems. Other European countries, such as Sweden and Denmark, are expanding district heating systems because of fuel economy.

A very important economic factor is the heat density, i.e., the possible connected heat demand for district heating divided by the ground area. High heat density is required since the distribution network which transports the hot water to the buildings is expensive. Studies done in the United States and Sweden have categorized areas according to the economic prospects of district heating as shown on the following page (Swedish District Heating Manual, 1978).

Economy Prospects of Heat Density for District Heating

Peak Heat Density MBtu/hr acre	Area	Category
>0.97	Downtown--high rise	Very favorable
0.97-0.70	Downtown--multi-storied buildings	Favorable
0.70-0.28	City core--commercial bldg & multi-family apartment buildings	Possible
0.28-0.17	Residential--multi-family houses	Questionable
<0.17	One-family houses	Not possible

District heating is a matter of heat transportation which is accomplished by using low-temperature (250°F = 121°C), high-temperature (300°F = 149°C) hot water or steam as the medium.

Low-temperature hot water in the mains provides the possiblity of direct connection to the consumers. Direct connection means better efficiency, an increase in the permissible temperature differential at a given temperature, and a smaller amount of circulating hot water with smaller pipes and lower heat loss. System design is simplified, and without recirculation there is usually no need to incorporate internal pumps in space heating installations, which leads to lower installation and operating costs.

High-temperature hot-water systems usually require the addition of heat exchangers and recirculation pumps in the consumers' buildings. Higher heat losses also result in the distribution network. Steam systems generally have a lower efficiency and a limited transport distance when compared to hot-water systems.

The main emphasis in using low-temperature geothermal energy will be in space heating in the future. Large-scale district-heating projects will be undertaken (such as being developed in Boise and Klamath Falls). District heating will become more and more economical with further escalation in conventional fuels resulting in the development of resources farther from the heating load. Transmission distances of 30-60 miles are being considered and proven on paper (Akureyri, Iceland), with 13 miles presently a reality (Reykjavik, Iceland). Transmission temperature losses in the below 212°F (100°C) range are around 0.3°F/mi (0.1°C/km) for insulated pipe.

A geothermal district-heating system will generally have the same basic components as a conventional system. The production field, which includes wells, pumps, and collection mains, replaces the boiler in a conventional system. All other components, such as piping, valves, controls, and metering, etc., would be similar to a conventional system.

A single-pipe (open-ended) distribution network with heat exchangers installed in each building and disposal of the geothermal fluid at the end of the consumer connections would be the most desirable type system. This makes the distribution network cheaper, as the cost of single-pipe network is only about 70 percent of a two-pipe (closed-loop) system.

A two-pipe system involves a central heat exchanger, pumping, and control facility. Depending on the location and characteristics of the resource, i.e., the necessity to recharge by means of injection wells, this may be the most desirable approach.

It is practical to divide the construction of the geothermal district-heating system into three main parts, which break down as follows:

<u>Heat Production</u>

1. Exploration and Assessment
2. Drilling and Well Completion
3. Collecting Mains

Transportation

1. Main Pumping Station

2. Supply Mains

Distribution System

1. Distribution Pumping Station

2. Street Mains

3. Service Branches

4. Consumer Connections

The cost of each part is variable, as summarized in Section III.

At present-day prices, the geothermal application will cost about the same or less than the corresponding annual fossil-fuel cost. Due to expected escalation of fossil-fuel prices, the costs of the geothermal system will decline. Most geothermal direct-use systems will pay for themselves in 5 to 10 years from savings in conventional fuel.

BPA's involvement in district heating could be either to provide financial assistance to the particular community or to provide direct assistance in the form of consultants for design and construction. Relief could be provided to homeowners in the form of delayed payments on conversion and hookup or subsidizing the costs.

There are a number of smaller communities in the BPA preference customer area that could benefit from some sort of incentives. These are:

Location	1980 Population	Utility
Wells, Nevada	1,300	Wells REC
Ft. Bidewell/Cedarville, California	1,200	Surprise Valley EC
Stanley/Challis, Idaho	2,700	Salmon River EC
North Bonneville/Carson, Washington	8,000	Skamania Co., PUD

The cost details for each of these projects are as follows:

Location	1980 Capital Investment x 10^6 $	Maximum Energy Savings x 10^9 Btu/yr
Wells, Nevada	1.2-1.6	51
Ft. Bidewell/Cedarville, California	1.0-1.5	45
Stanley/Challis, Idaho	3.2-3.8	147
North Bonneville/Carson, Washington	9.0-11.0*	410

*There is some question as to the temperature of the resource. This figure assumes a temperature >100°F (38°C); if below 100°F (38°C), heat pumps will be required and the costs will increase.

The reason for the range in capital cost is that too many variables are only approximately known (i.e., well depth, flow rates, temperatures, injection well requirements, etc.)

The annual cost of the capital investment would vary between 9 and 10 percent, depending upon whether 30- or 20-year life is used. The annual maintenance and operation cost would vary from 4 to 5 percent. Thus, the total annual cost would vary from 13 to 15 percent of the capital investment. Using an average of 14 percent, the cost per million Btu of annual heat load would range from $3 to $5 MBtu.

E. HEAT PUMPS

We recommend BPA undertake a pilot district heating project involving a hybrid system. This type of project would have application in areas of a low-temperature geothermal resource that are marginal for normal space heating use. This type system consists of a combination simple heat exchange, centralized heat pump, and auxiliary boiler all matched to optimize the energy consumed. The heat load duration curve shown in Figure 30 illustrates how this is accomplished by the French systems. Geothermal energy is a natural energy source of growing interest for centralized heat pumps applied to district heating and cooling.

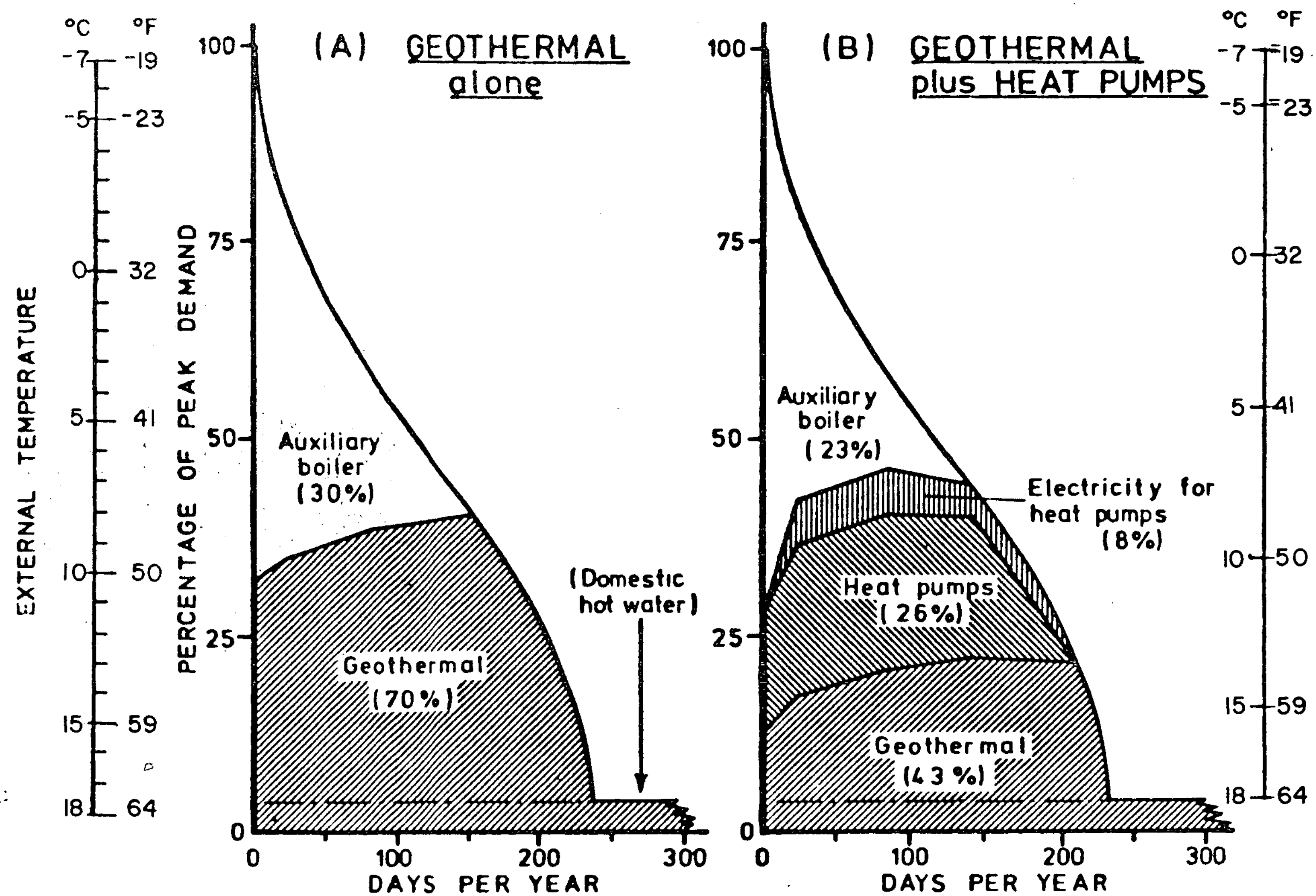


Figure 30. Meteorological conditions and corresponding contributions from different sources to total energy demand (Ryback, 1979).

Heat pumps may be employed to extract additional heat by further cooling the geothermal water to temperatures below that of the water returned from the consumers in order to achieve a better utilization of the geothermal resource. Likewise, geothermal temperatures below the heating net supply temperature may be upgraded by the utilization of heat pumps. The main problem with this source is not temperature fluctuation as with the other natural sources, but the difficulty of locating and extracting geothermal water since this may depend on rather expensive deep drilling. Another problem is the development of heat pump evaporators that can withstand the physical and chemical characteristics of geothermal water.

When the geothermal resource water is below 120°F (49°C), most conventional methods of extracting heat from geothermal water become impractical and uneconomical. The 120°F (49°C) geothermal water still contains a large amount of heat energy and is not the absolute lower limit but is based on typical conditions in which the heating air should be at least 100°F (38°C), and a driving force of 20°F (11°C) is needed to transfer heat across the heat exchanger.

A strong incentive to district heating is energy conservation, improved environmental quality, and lower energy costs. In Europe, there is a long history of district heating plants. Iceland and Hungary, of course, had extensive plants using geothermal energy a long time before any talk about an energy crisis. In the years after 1974, most countries in Northern Europe have made close examinations of the possibilities and potentials of using geothermal energy as a supplement to imported fuel.

Heat pumps lend themselves well to district heating concepts. As a matter of fact, France had a functional plant in Melun as early as 1971, and today some ten plants are in operation in France. In Denmark and Germany, demonstration projects are being planned as well as Sweden, Holland, Austria, and Switzerland where theories will be put into reality. The Danes are investigating a 10-MW heat pump using 50°F

(10°C) ground water which is more effective than air. However, the warmer the well water, the more efficient the system will be and the less electrical energy it will consume.

Three schemes: (1) simple exchange, (2) insertion of heat pump, and (3) hybrid, are possible to extract the energy from the geothermal fluid as illustrated in Figure 32 with the following description:

1. A simple heat exchange may be desirable if the resource temperature is greater than 180°F (82°C) and the cost of developing the resource is relatively low (i.e., shallow wells), thus justifying utilization of the resource 30 to 40 percent of the time during heating demand.
2. If the resource temperature is low (50° to 120°F = 10° to 49°C), supply temperatures to the consumer can be boosted with the insertion of a heat pump.
3. A hybrid system, Figure 31 and 32 , may be desirable in the case of a high-cost resource (deep wells) development. The plan would be to construct the plant so the wells could be fully utilized 24 hours per day, thus optimizing the most expensive part of the development, drilling wells. The geothermal heat exchanger represents only 25 percent of the maximum capacity; however, it will supply over half of the annual heat requirements. When heat requirements increase in the chilly spring and autumn months, the heat pump will further cool the geothermal water coming from the heat exchanger. Thus, it will be only necessary to couple in a boiler during the extreme cold winter periods in order to yield the maximum peak load performance.

The economic benefit derived from collectively supplying heat for numerous users can further be increased if the annual use factor is increased, that is, by increasing the amount of time the district operates

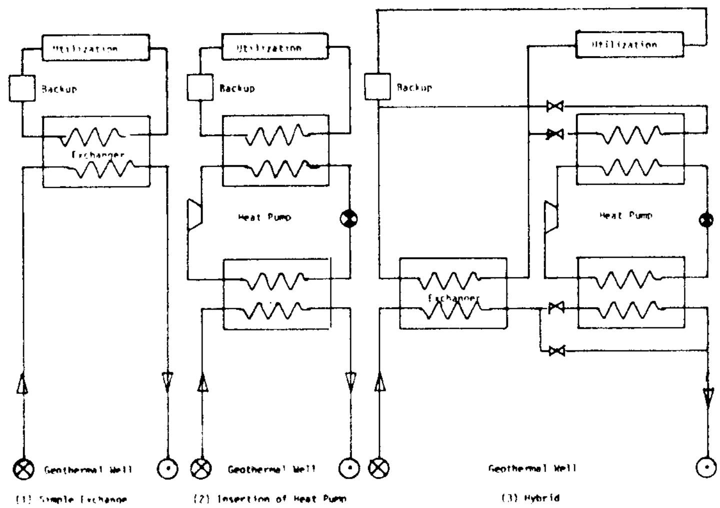
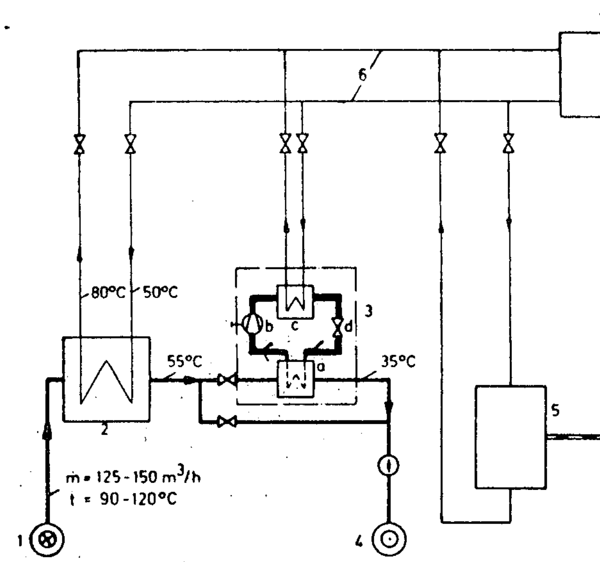


Figure 31. Examples of heat extraction schemes.



Primary circuit (geothermal)
Secondary circuit (district heating)
Circuit of the heat pump

1 Production well
2 Heat exchanger
3 Heat pump incl.
 a Evaporator
 b Compressor
 c Condenser
 d Reduction valve
4 Injection well
5 Conventional boiler plant
6 District heating system
7 End users (approx. 2000 houses)

Figure 32. Hybrid system.

at full capacity. Obviously, heating and cooling using heat pumps is not a continuous operation. The unused portion of time represents a waste of capital equipment.

If a commercial or process use can be found whose peak loads occur at different times than a residential load, a more beneficial use of the district system becomes possible. Most commercial and industrial food processing temperature requirements, however, are between 160° and 300°F (71° and 149°C). For process use, several heat pump models are capable of delivering up to 230°F (110°C) when operating on 140°F (60°C) water source temperature, and several firms are developing models capable of delivering temperatures as high as 350°F (177°C).

The effective use of heat pumps makes it possible to extend noticeably the cost-effectiveness of geothermal heating. Heat pumps also make it possible to connect a greater number of homes from a given well. The use of these machines provides an important asset when geothermal water temperature is low. The use of heat pumps should, of course, be adapted to the unique nature of each project. It is important to remember that these systems are sensitive to economic conditions relating to costs of geothermal systems themselves, wells, and backup systems.

Areas where this type of hybrid system would have applications are:

1. Yakima Valley area of Washington
2. Willamette Valley area of Oregon
3. Snake River Plain area of Idaho

Some cost information is presented in Section III for heat pump applications. A general idea of the types of savings that could be generated at each of the areas mentioned above are:

Area	Approx. 1980 Population	Approx. Maximum Potential Energy Savings
Yakima Valley	250,000	6×10^{12} Btu/yr
Willamette Valley	500,000	12×10^{12} Btu/yr
Snake River Plain	325,000	10×10^{12} Btu/yr

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APPENDIX

E L E C T R I C   P O W E R   R E S E A R C H   I N S T I T U T E

EPRI

September 23, 1980

Dr. John Lund
Professor & Energy Assoc.
Geothermal Program
Oregon Institute of Technology
Klamath Falls, OR 97601

Dear John:

As we discussed on the telephone, I am now of the opinion that the commercial availability dates for binary cycle geothermal power plants that we used in our Technical Assessment Guide may be conservative. There are two basic reasons for this. At the time we developed those dates the on-line date for the first commercial size binary cycle plant was uncertain. It now appears that a binary cycle demonstration power plant of commercial design and size will come on-line in mid 1984. Those dates also assumed that at least two years of demonstration would be needed to confirm commercial viability. The actual time will depend more on the early success of the project than on time.

With these factors in mind, it is possible that binary cycle commercial availability could come as early as 1985.

Sincerely yours,

Vasel Roberts

Vasel W. Roberts
Program Manager
Geothermal Power Systems

VR/jb

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Washington Office: 1800 Massachusetts Avenue, NW, Suite 700, Washington, DC 20036 (202) 872-9222

Example	10.		Site # (Oregon 202-203/ID 9a--see Table 13, pp. 125-127)	
See pp. 117-123	20000.		Population	
	0.91		C_w	
	0.551		C_h	
	5726.		DD	
	0.7		C_D	
	-1.		T	
	0.76		C_{DC}	
	6.		T_c	
residential (R) x 10^9 Btu/yr	262.1042	SHL1	Electric space heating	
	213.584	SHL2	Fossil fuel space heating	
	90.2537	WHL1	Electric water heating	
	8.9261	WHL2	Fossil fuel water heating	
	475.6883	SHLR	Total space heating	
	99.1799	WHLR	Total water heating	*Reduced to 3/4 in low temperature area--see p. 124.
	574.8683	RHL	Total residential heating	
commercial (C) x 10^9 Btu/yr	5.7736	SHL3		
	17.3208	SHL4		
	0.1007	WHL3		
	0.1871	WHL4		
	23.0945	SHLC		
	0.2879	WHLC		
	23.3824	CHL	Total commercial heating	
Public (P) x 10^9 Btu/yr	7.9553	SHL5		
	23.8659	SHL6		
	0.1385	WHL5		
	0.2573	WHL6		
	31.8212	SHLP		
	0.3959	WHLP		
	32.2172	PHL	Total public heating	
	630.468	THL	Total heating load x 10^9 Btu/yr (R+ C+P only)*	
	786.4		Total industrial process load x 10^9 Btu/yr	
	366.3264	TEL	Electric component of total heating load x 10^9 Btu/yr (R+C+P only)*	
	384.8		Electric component of industrial process load x 10^9 Btu/yr	
	107.3326	2	Electric component in x 10^6 kwhr/yr (R+C+P only)*	

OREGON						OREGON			
1.		2.		3.		4.		5.	
177-179		180		181-183/OR1-2		186/187/OR9		189/OR8	
9300.		1500.		6150.		45000.		3500.	
0.91		0.91		0.854		0.91		0.91	
0.445		0.551		0.456		0.551		0.445	
7500.		6411.		6026.		6516.		7069.	
0.68		0.69		0.69		0.74		0.74	
-4.		-3.		-3.		4.		4.	
0.71		0.74		0.74		0.78		0.78	
0.		4.		4.		9.		9.	
125.2493	SHL1	21.6957	SHL1	69.1949	SHL1	709.3877	SHL1	48.3419	SH
156.2098	SHL2	17.6794	SHL2	82.5483	SHL2	578.0672	SHL2	60.2916	SH
41.968	WHL1	6.769	WHL1	26.0451	WHL1	203.071	WHL1	15.7944	WH
4.1506	WHL2	0.6694	WHL2	4.4526	WHL2	20.0839	WHL2	1.562	WH
281.4592	SHLR	39.3751	SHLR	151.7432	SHLR	1287.4549	SHLR	108.6336	SH
46.1186	WHLR	7.4384	WHLR	30.4978	WHLR	223.1549	WHLR	17.3564	WH
327.5779	RHL	46.8136	RHL	182.2411	RHL	1510.6099	RHL	125.9901	RH
3.2855	SHL3	0.472	SHL3	1.8193	SHL3	15.1708	SHL3	1.28	SH
9.8567	SHL4	1.4162	SHL4	5.4579	SHL4	45.5125	SHL4	[illegible].8402	SH
0.0468	WHL3	0.0075	WHL3	0.0309	WHL3	0.2267	WHL3	0.0176	WH
0.087	WHL4	0.014	WHL4	0.0575	WHL4	0.4211	WHL4	0.0327	WH
13.1423	SHLC	1.8883	SHLC	7.2772	SHLC	60.6833	SHLC	5.1203	SH
0.1339	WHLC	0.0215	WHLC	0.0885	WHLC	0.6479	WHLC	0.0503	WH
13.2762	CHL	1.9099	CHL	7.3658	CHL	61.3313	CHL	5.1707	CH
4.5255	SHL5	0.6503	SHL5	2.5064	SHL5	20.9075	SHL5	1.7641	SH
13.5767	SHL6	1.9511	SHL6	7.5194	SHL6	62.7225	SHL6	5.2924	SH
0.0644	WHL5	0.0103	WHL5	0.0426	WHL5	0.3118	WHL5	0.0242	WH
0.1196	WHL6	0.0193	WHL6	0.0791	WHL6	0.5791	WHL6	0.045	WH
18.1023	SHLP	2.6015	SHLP	10.0259	SHLP	83.63	SHLP	7.8565	SH
0.1841	WHLP	0.0296	WHLP	0.1217	WHLP	0.8909	WHLP	0.0692	WH
18.2865	PHL	2.6312	PHL	10.1477	PHL	84.5209	PHL	7.1258	PH
359.1406	THL	51.3548	THL	199.7547	THL	1656.4623	THL	138.2868	TH
0		0		56.40		232.6		89.67	
175.1398	TEL	29.6051	TEL	99.6395	TEL	949.0757	TEL	67.2205	TE
0		0		27.60		113.8		43.88	
51.3155	2	8.6742	2	29.1941	2	278.0766	2	19.696	[illegible]

OREGON								OREGON	
6.		7.		9.		10		12.	
190/191		193/194/OR5-6		201/OR3		202-4/ID9a		OSR1	
125.		6000.		20000.		20000.		10000.	
0.91		0.91		0.91		0.91		0.854	
0.445		0.445		0.445		0.551		0.456	
7069.		7212.		6906.		5726.		4811.	
0.74		0.7		0.7		0.7		0.71	
4.		-1.		-1.		-1.		0.	
0.78		0.76		0.76		0.76		0.77	
9.		6.		6.		6.		7.	
1.7264	SHL1	79.9849	SHL1	255.304	SHL1	262.1042	SHL1	92.4261	(1)
2.1532	SHL2	99.7564	SHL2	318.4129	SHL2	213.584	SHL2	110.2627	(2)
0.564	WHL1	27.0761	WHL1	90.2537	WHL1	90.2537	WHL1	42.3498	(1)
0.0557	WHL2	2.6778	WHL2	8.9261	WHL2	8.9261	WHL2	7.2401	(2)
3.8797	SHLR	179.7413	SHLR	573.7169	SHLR	475.6883	SHLR	202.6889	(R)
0.6198	WHLR	29.7539	WHLR	99.1799	WHLR	99.1799	WHLR	49.5899	(R)
4.4996	RHL	209.4953	RHL	672.8969	RHL	574.8683	RHL	252.2789	
0.0457	SHL3	2.1815	SHL3	6.9634	SHL3	5.7736	SHL3	2.4573	(3)
0.1371	SHL4	6.5447	SHL4	20.8903	SHL4	17.3208	SHL4	7.372	(4)
0.0006	WHL3	0.0302	WHL3	0.1007	WHL3	0.1007	WHL3	0.0503	(3)
0.0011	WHL4	0.0561	WHL4	0.1871	WHL4	0.1871	WHL4	0.0935	(4)
0.1828	SHLC	8.7263	SHLC	27.8537	SHLC	23.0945	SHLC	9.8294	(C)
0.0017	WHLC	0.0863	WHLC	0.2879	WHLC	0.2879	WHLC	0.1439	(C)
0.1846	CHL	8.8127	CHL	28.1417	CHL	23.3824	CHL	9.9734	
0.063	SHL5	3.0059	SHL5	9.5947	SHL5	7.9553	SHL5	3.3861	(5)
0.189	SHL6	9.0178	SHL6	28.7841	SHL6	23.8659	SHL6	10.1584	(6)
0.0008	WHL5	0.0415	WHL5	0.1385	WHL5	0.1385	WHL5	0.0692	(5)
0.0016	WHL6	0.0772	WHL6	0.2573	WHL6	0.2573	WHL6	0.1286	(6)
0.252	SHLP	12.0238	SHLP	38.3788	SHLP	31.8212	SHLP	13.5445	(P)
0.0024	WHLP	0.1187	WHLP	0.3959	WHLP	0.3959	WHLP	0.1979	(P)
0.2544	PHL	12.1426	PHL	38.7748	PHL	32.2172	PHL	13.7425	
4.9388	THL	230.4508	THL	739.8136	THL	630.468	THL	275.9949 x 3/4	
0				188.86		786.4		7.10	
2.4008	TEL	112.3204	TEL	362.3554	TEL	366.3264	TEL	140.7392 x 3/4	
0		32.20		92.32		384.8		3.47	
0.7034	2	32.9095	2	106.1691	2	107.3326	2	41.2362	

NEVADA				CALIFORNIA			
14.		15.		16.		17.	
167/NV4		168/NV7		034/035/CA1		036/038/CA2	
700.		1300.		1200.		3700.	
0.91		0.91		0.91		0.91	
0.445		0.445		0.551		0.551	
7483.		7483.		6365.		6785.	
0.65		0.65		0.74		0.74	
-8.		-8.		4.		4.	
0.7		0.7		0.78		0.78	
-2.		-2.		9.		9.	
8.9915	SHL1	16.6985	SHL1	18.4786	SHL1	60.7353	SHL1
11.2141	SHL2	20.8262	SHL2	15.0579	SHL2	49.4921	SHL2
3.1588	WHL1	5.8664	WHL1	5.4152	WHL1	16.6969	WHL1
0.3124	WHL2	0.5802	WHL2	0.5355	WHL2	1.6513	WHL2
20.2056	SHLR	37.5247	SHLR	33.5365	SHLR	110.2275	SHLR
3.4712	WHLR	6.4466	WHLR	5.9507	WHLR	18.3482	WHLR
23.6769	RHL	43.9714	RHL	39.4873	RHL	128.5758	RHL
0.2432	SHL3	0.4517	SHL3	0.3951	SHL3	1.2988	SHL3
0.7298	SHL4	1.3553	SHL4	1.1855	SHL4	3.8966	SHL4
0.0035	WHL3	0.0065	WHL3	0.006	WHL3	0.0186	WHL3
0.0065	WHL4	0.0121	WHL4	0.0112	WHL4	0.0346	WHL4
0.9731	SHLC	1.8071	SHLC	1.5807	SHLC	5.1955	SHLC
0.01	WHLC	0.0187	WHLC	0.0172	WHLC	0.0532	WHLC
0.9831	CHL	1.8259	CHL	1.598	CHL	5.2487	CHL
0.335	SHL5	0.6222	SHL5	0.5446	SHL5	1.79	SHL5
1.0051	SHL6	1.8667	SHL6	1.6338	SHL6	5.37	SHL6
0.0048	WHL5	0.009	WHL5	0.0083	WHL5	0.0256	WHL5
0.009	WHL6	0.0167	WHL6	0.0154	WHL6	0.0476	WHL6
1.3402	SHLP	2.4889	SHLP	2.1784	SHLP	7.1601	SHLP
0.0138	WHLP	0.0257	WHLP	0.0237	WHLP	0.0732	WHLP
1.354	PHL	2.5147	PHL	2.2022	PHL	7.2333	PHL
26.0142	THL	48.3121	THL	43.2875	THL	141.0579	THL
0		0		0		0	
12.7371	TEL	23.6546	TEL	24.848	TEL	80.5655	TEL
0		0		0		0	
3.7319	2	6.9307	2	7.2804	2	23.6054	2

NEVADA				CALIFORNIA			
14.		15.		16.		17.	
167/NV4		168/NV7		034/035/CA1		036/038/CA2	
700.		1300.		1200.		3700.	
0.91		0.91		0.91		0.91	
0.445		0.445		0.551		0.551	
7483.		7483.		6365.		6785.	
0.65		0.65		0.74		0.74	
-8.		-8.		4.		4.	
0.7		0.7		0.78		0.78	
-2.		-2.		9.		9.	
8.9915	SHL1	16.6985	SHL1	18.4786	SHL1	60.7353	SHL1
11.2141	SHL2	20.8262	SHL2	15.0579	SHL2	49.4921	SHL2
3.1588	WHL1	5.8664	WHL1	5.4152	WHL1	16.6969	WHL1
0.3124	WHL2	0.5802	WHL2	0.5355	WHL2	1.6513	WHL2
20.2056	SHLR	37.5247	SHLR	33.5365	SHLR	110.2275	SHLR
3.4712	WHLR	6.4466	WHLR	5.9507	WHLR	18.3482	WHLR
23.6769	RHL	43.9714	RHL	39.4873	RHL	128.5759	RHL
0.2432	SHL3	0.4517	SHL3	0.3951	SHL3	1.2988	SHL3
0.7298	SHL4	1.3553	SHL4	1.1855	SHL4	3.8966	SHL4
0.0035	WHL3	0.0065	WHL3	0.006	WHL3	0.0186	WHL3
0.0065	WHL4	0.0121	WHL4	0.0112	WHL4	0.0346	WHL4
0.9731	SHLC	1.8071	SHLC	1.5807	SHLC	5.1955	SHLC
0.01	WHLC	0.0187	WHLC	0.0172	WHLC	0.0532	WHLC
0.9831	CHL	1.8259	CHL	1.598	CHL	5.2487	CHL
0.335	SHL5	0.6222	SHL5	0.5446	SHL5	1.79	SHL5
1.0051	SHL6	1.8667	SHL6	1.6338	SHL6	5.37	SHL6
0.0048	WHL5	0.009	WHL5	0.0083	WHL5	0.0256	WHL5
0.009	WHL6	0.0167	WHL6	0.0154	WHL6	0.0476	WHL6
1.3402	SHLP	2.4889	SHLP	2.1784	SHLP	7.1601	SHLP
0.0138	WHLP	0.0257	WHLP	0.0237	WHLP	0.0732	WHLP
1.354	PHL	2.5147	PHL	2.2022	PHL	7.2333	PHL
26.0142	THL	48.3121	THL	43.2875	THL	141.0579	THL
0		0		0		0	
12.7371	TEL	23.6546	TEL	24.848	TEL	80.5655	TEL
0		0		0		0	
3.7319	2	6.9307	2	7.2804	2	23.6054	2

IDAHO						IDAHO			
18.		19.		20.		21.		22.	
ID8		ID9b		ID9c		ID9e,9f/114		ID12/GL KGRA	
7500.		150000.		50000.		56000.		6000.	
0.526		0.91		0.91		0.91		0.91	
0.227		0.551		0.551		0.551		0.445	
9986.		5833.		5833.		6200.		7063.	
0.67		0.74		0.74		0.69		0.65	
-5.		3.		3.		-3.		-8.	
0.71		0.79		0.79		0.73		0.7	
0.		10.		10.		2.		-1.	
67.5961	SHL1	2116.8059	SHL1	705.6019	SHL1	783.3152	SHL1	72.7443	SH
230.1842	SHL2	1724.9471	SHL2	574.9823	SHL2	638.3094	SHL2	90.7261	SH
19.5632	WHL1	676.9034	WHL1	225.6344	WHL1	252.7106	WHL1	27.0761	WH
17.6292	WHL2	66.9464	WHL2	22.3154	WHL2	24.9933	WHL2	2.6778	WH
297.7803	SHLR	3841.753	SHLR	1280.5843	SHLR	1421.6246	SHLR	163.4705	SH
37.1924	WHLR	743.8499	WHLR	247.9499	WHLR	277.7039	WHLR	29.7539	WH
334.9728	RHL	4585.603	RHL	1528.5343	RHL	1699.3286	RHL	193.2245	RH
3.5279	SHL3	45.8479	SHL3	15.2826	SHL3	16.8149	SHL3	1.9681	SH
10.5838	SHL4	137.5439	SHL4	45.8479	SHL4	50.4447	SHL4	5.9044	SH
0.0377	WHL3	0.7559	WHL3	0.2519	WHL3	0.2822	WHL3	0.0302	WH
0.0701	WHL4	1.4038	WHL4	0.4679	WHL4	0.5241	WHL4	0.0561	WH
14.1117	SHLC	183.3919	SHLC	61.1306	SHLC	67.2596	SHLC	7.8725	SH
0.1079	WHLC	2.1598	WHLC	0.7199	WHLC	0.8063	WHLC	0.0863	WH
14.2197	CHL	185.5518	CHL	61.8506	CHL	68.066	CHL	7.9589	CH
4.8594	SHL5	63.1892	SHL5	21.063	SHL5	23.1634	SHL5	2.7108	SH
14.5782	SHL6	189.5676	SHL6	63.1892	SHL6	69.4903	SHL6	8.1324	SH
0.0519	WHL5	1.0394	WHL5	0.3464	WHL5	0.388	WHL5	0.0415	WH
0.0965	WHL6	1.9303	WHL6	0.6434	WHL6	0.7206	WHL6	0.0772	WH
19.4376	SHLP	252.7568	SHLP	84.2522	SHLP	92.6538	SHLP	10.7842	SH
0.1484	WHLP	2.9698	WHLP	0.9899	WHLP	1.1087	WHLP	0.1167	WH
19.5861	PHL	255.7266	PHL	85.2422	PHL	93.7626	PHL	10.952	PH
368.7787	THL	5026.8815	THL	1675.6271	THL	1861.1573	THL	212.1455	TH
0		5.93		377.4		443.6		57.99	
95.6365	TEL	2904.5421	TEL	968.1807	TEL	1076.6745	TEL	104.5712	TE
0		2.23		142.0		166.9		21.82	
28.0212	2	851.0231	2	283.6743	2	315.4628	2	30.6391	

23.	IDAHO	24.		25.		26.	IDAHO	27.	
ID13		087		091		093/094		095	
68000.		800.		1500.		7000.		5500.	
0.91		0.91		0.91		0.91		0.91	
0.445		0.551		0.551		0.551		0.551	
7063.		5464.		5839.		5839.		5839.	
0.65		0.7		0.74		0.74		0.74	
-8.		-1.		3.		3.		3.	
0.7		0.76		0.79		0.79		0.79	
-1.		6.		10.		10.		10.	
824.4363	SHL1	10.0044	SHL1	21.1898	SHL1	98.8858	SHL1	77.696	SHL
1028.2295	SHL2	8.1524	SHL2	17.2672	SHL2	80.5803	SHL2	63.3131	SHL
306.8629	WHL1	3.6101	WHL1	6.769	WHL1	31.5888	WHL1	24.8197	WHL
30.349	WHL2	0.357	WHL2	0.6694	WHL2	3.1241	WHL2	2.4547	WHL
1852.6659	SHLR	18.1569	SHLR	38.457	SHLR	179.4662	SHLR	141.0091	SHL
337.2119	WHLR	3.9671	WHLR	7.4384	WHLR	34.7129	WHLR	27.2744	WHL
2189.8779	RHL	22.1241	RHL	45.8955	RHL	214.1792	RHL	168.2836	RHL
22.3056	SHL3	0.2203	SHL3	0.4589	SHL3	2.1417	SHL3	1.6828	SHL
66.9168	SHL4	0.6611	SHL4	1.3768	SHL4	6.4253	SHL4	5.0484	SHL
0.3427	WHL3	0.004	WHL3	0.0075	WHL3	0.0352	WHL3	0.0277	WHL
0.6364	WHL4	0.0074	WHL4	0.014	WHL4	0.0655	WHL4	0.0514	WHL
89.2224	SHLC	0.8815	SHLC	1.8358	SHLC	8.567	SHLC	6.7312	SHL
0.9791	WHLC	0.0115	WHLC	0.0215	WHLC	0.1007	WHLC	0.0791	WHL
90.2015	CHL	0.893	CHL	1.8574	CHL	8.6678	CHL	6.8104	CHL
30.7224	SHL5	0.3036	SHL5	0.6325	SHL5	2.9518	SHL5	2.3193	SHL
92.1673	SHL6	0.9109	SHL6	1.8976	SHL6	8.8555	SHL6	6.9579	SHL
0.4712	WHL5	0.0055	WHL5	0.0103	WHL5	0.0485	WHL5	0.0381	WHL
0.875	WHL6	0.0102	WHL6	0.0193	WHL6	0.09	WHL6	0.0707	WHL
122.8898	SHLP	1.2146	SHLP	2.5301	SHLP	11.8074	SHLP	9.2772	SHL
1.3463	WHLP	0.0158	WHLP	0.0296	WHLP	0.1385	WHLP	0.1088	WHL
124.2361	PHL	1.2304	PHL	2.5598	PHL	11.946	PHL	9.3861	PHL
2404.3156	THL	24.2475	THL	50.3128	THL	234.7931	THL	184.4803	THL
136.42		19.77		0		0		0	
1185.1412	TEL	14.1482	TEL	29.0683	TEL	135.6521	TEL	106.5838	TEL
51.34		7.44		0		0		0	
347.2432	2	4.1453	2	8.5169	2	39.7457	2	31.2287	

28.	IDAHO	29.		30		31	IDAHO	32.	
099-102		104/105		107/108/ID3		109-112/ID10		115	
10000.		4000.		2700.		1500.		300.	
0.91		0.526		0.526		0.91		0.91	
0.551		0.227		0.227		0.551		0.445	
5979.		9719.		10700.		5979.		7061.	
0.76		0.55		0.67		0.76		0.65	
6.		-24.		-5.		6.		-8.	
0.81		0.59		0.71		0.81		0.7	
12.		-17.		0.		12.		-1.	
148.5539	SHL1	28.8089	SHL1	26.0745	SHL1	22.283	SHL1	3.6361	SHL
121.0539	SHL2	98.1028	SHL2	88.7912	SHL2	18.158	SHL2	4.535	SHL
45.1268	WHL1	10.4337	WHL1	7.0427	WHL1	6.769	WHL1	1.3538	WHL
4.463	WHL2	9.4022	WHL2	6.3465	WHL2	0.6694	WHL2	0.1338	WHL
269.6079	SHLR	126.9117	SHLR	114.8658	SHLR	40.4411	SHLR	8.1712	SHL
49.5899	WHLR	19.8359	WHLR	13.3892	WHLR	7.4384	WHLR	1.4875	WHL
319.1979	RHL	146.7477	RHL	128.2551	RHL	47.8796	RHL	9.6589	RHL
3.2121	SHL3	1.5221	SHL3	1.3608	SHL3	0.4818	SHL3	0.0983	SHL
9.6365	SHL4	4.5664	SHL4	4.0826	SHL4	1.4454	SHL4	0.2951	SHL
0.0503	WHL3	0.0201	WHL3	0.0136	WHL3	0.0075	WHL3	0.0015	WHL
0.0935	WHL4	0.0374	WHL4	0.0252	WHL4	0.014	WHL4	0.0028	WHL
12.8486	SHLC	6.0885	SHLC	5.4434	SHLC	1.9273	SHLC	0.3905	SHL
0.1439	WHLC	0.0575	WHLC	0.0388	WHLC	0.0215	WHLC	0.0043	WHL
12.9926	CHL	6.1461	CHL	5.4823	CHL	1.9489	CHL	0.3978	CHL
4.4277	SHL5	2.0951	SHL5	1.8744	SHL5	0.6641	SHL5	0.1355	SHL
13.2833	SHL6	6.2855	SHL6	5.6234	SHL6	1.9924	SHL6	0.4065	SHL
0.0692	WHL5	0.0277	WHL5	0.0187	WHL5	0.0103	WHL5	0.002	WHL
0.1286	WHL6	0.0514	WHL6	0.0347	WHL6	0.0193	WHL6	0.0038	WHL
17.711	SHLP	8.3807	SHLP	7.4978	SHLP	2.6566	SHLP	0.542	SHL
0.1979	WHLP	0.0791	WHLP	0.0534	WHLP	0.0296	WHLP	0.0059	WHL
17.909	PHL	8.4599	PHL	7.5513	PHL	2.6863	PHL	0.5479	PHL
350.0996	THL	161.3539	THL	141.2888	THL	52.5149	THL	10.8046	THL
19.77		0		0		0		0	
201.4405	TEL	42.9079	TEL	36.3849	TEL	30.216	TEL	5.2274	TEL
7.44		0		0		0		0	
59.0215	2	12.5719	2	10.6607	2	8.8532	2	1.5316	

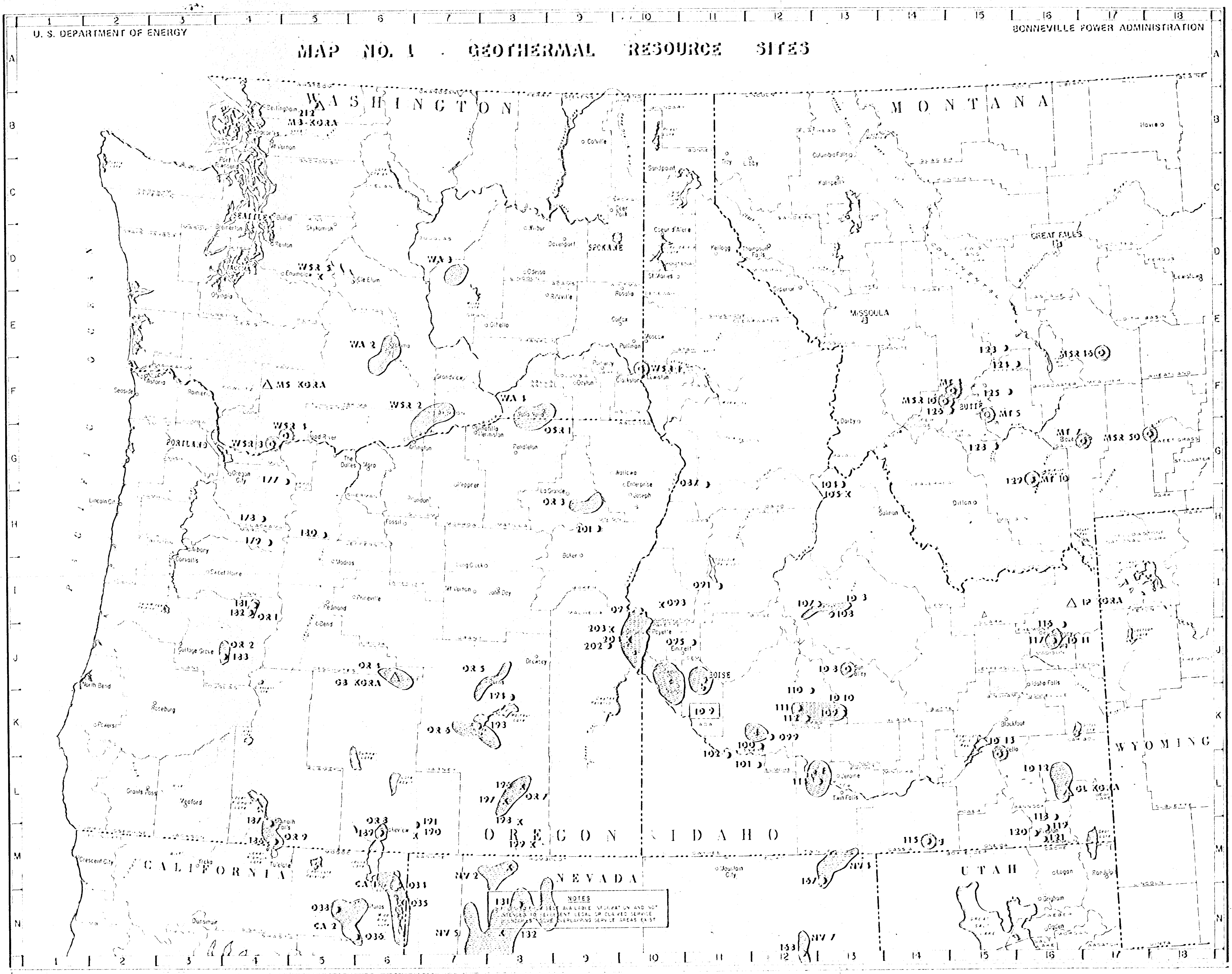
- 190 -

	33. IDAHO 116/117/ID11	34. IDAHO 118-121	36. IDAHO WSR1	37. WASHINGTON WA2
	15000.	4500.	26000.	70000.
	0.526	0.91	0.91	0.91
	0.227	0.445	0.551	0.551
	8793.	7061.	5464.	6009.
	0.63	0.65	0.7	0.7
	-11.	-8.	-1.	-2.
	0.67	0.7	0.76	0.75
	-6.	-1.	6.	5.
SHL1	111.9428	54.5428	325.1447	962.7191
SHL2	381.1973	68.0253	264.9546	784.5025
WHL1	39.1265	20.3071	117.3299	315.8882
WHL2	35.2584	2.0083	11.604	31.2416
SHLR	493.1401	122.5681	590.0994	1747.2216
WHLR	74.3849	22.3154	128.9339	347.1299
RHL	567.5251	144.8836	719.0334	2094.3516
SHL3	5.8635	1.4756	7.1622	20.9278
SHL4	17.5905	4.427	21.4868	62.7836
WHL3	0.0755	0.0226	0.131	0.3527
WHL4	0.1403	0.0421	0.2433	0.6551
SHLC	23.4541	5.9027	28.6491	83.7115
WHLC	0.2159	0.0647	0.3743	1.0079
CHL	23.6701	5.9675	29.0235	84.7195
SHL5	8.0742	2.0325	9.8686	28.8341
SHL6	24.2227	6.0975	29.606	86.5025
WHL5	0.1039	0.0311	0.1801	0.485
WHL6	0.193	0.0579	0.3345	0.9008
SHLP	32.2969	8.1301	39.4747	115.336[illegible]
WHLP	0.2969	0.089	0.5147	1.385[illegible]
PHL	32.5939	8.2192	39.9895	116.7226
THL	623.7892	159.0704	788.0465 x 3/4	2295.7938 x 3/4
	164.70	0	922.6	442.7
TEL	165.1866	78.412	459.8169 x 3/4	1329.2074 x 3/4
	62.00	0	347.2	207.1
2	48.3992	22.9745	134.7251	389.4542

	38. WASHINGTON WA3	39. WA4	40. WSR1	41. WASHINGTON WSR2	42. WSR3-4
	20000.	45000.	12000.	110000.	8000.
	0.91	0.854	0.91	0.854	0.854
	0.551	0.456	0.551	0.456	0.456
	5603.	4835.	5464.	4892.	5535.
	0.72	0.71	0.7	0.75	0.82
	1.	0.	-1.	5.	13.
	0.77	0.77	0.76	0.8	0.88
	7.	7.	6.	11.	19.
SHL1	263.7934	417.9924	150.0668	1091.9531	98.2222
SHL2	214.9605	498.6576	122.2867	1302.6808	117.1774
WHL1	90.2537	190.5743	54.1522	465.8484	33.8798
WHL2	8.9261	32.5806	5.3557	79.6415	5.7921
SHLR	478.7539	916.6501	272.3535	2394.6339	215.3997
WHLR	99.1799	223.1549	59.5079	545.4899	39.6719
RHL	577.9339	1139.8051	331.8615	2940.1239	255.0717
SHL3	5.7238	11.1133	3.3056	28.554	2.5838
SHL4	17.1714	33.3399	9.917	85.662	7.7516
WHL3	0.1007	0.2267	0.0604	0.5543	0.0403
WHL4	0.1871	0.4211	0.1123	1.0294	0.0748
SHLC	22.8952	44.4532	13.2226	114.216	10.3355
WHLC	0.2879	0.6479	0.1727	1.5838	0.1151
CHL	23.1832	45.1011	13.3954	115.7999	10.4507
SHL5	7.8871	15.3136	4.5547	39.3569	3.5639
SHL6	23.6614	45.9409	13.6643	118.0707	10.6917
WHL5	0.1385	0.3118	0.0831	0.7622	0.0554
WHL6	0.2573	0.5791	0.1544	1.4155	0.1029
SHLP	31.5486	61.2545	18.2191	157.4276	14.2556
WHLP	0.3959	0.8909	0.2375	2.1778	0.1583
PHL	31.9445	62.1455	18.4567	159.6054	14.4139
x 3/4 THL	633.0617	1247.0518	363.7137	3215.5294	279.[illegible]
	115.73	12.58	6.52	6.52	0
x 3/4 TEL	367.8975	635.5324	212.2231	1627.0291 (TEL)	138.[illegible] (TEL)
	54.14	5.89	3.05	3.05	0
	107.793 2	186.2093 2	62.1808 2	476.7152 2	40.5349 [illegible]

43. WASHINGTON		46. MONTANA		47.		48.	MONTANA	49.	
WSR5		MT4/126/MSR10		MT5/128		MT7		123/124	
1000.		18000.		30000.		25000.		35000.	
0.854		0.375		0.375		0.375		0.375	
0.456		0.135		0.135		0.135		0.135	
5761.		9719.		9719.		8165.		8190.	
0.74		0.54		0.54		0.57		0.56	
4.		-24.		-24.		-20.		-21.	
0.78		0.59		0.59		0.61		0.6	
9.		-17.		-17.		-14.		-16.	
11.5345	SHL1	75.6[illegible]	SHL1	126.1618	SHL1	93.2281	SHL1	128.6234	SHL
13.7605	SHL2	485.0222	SHL2	808.3704	SHL2	597.3507	SHL2	824.1425	SHL
4.2349	WHL1	33.4732	WHL1	55.7887	WHL1	46.4906	WHL1	65.0868	WHL
0.724	WHL2	55.7887	WHL2	92.9812	WHL2	77.4843	WHL2	108.4781	WHL
25.295	SHLR	560.7193	SHLR	934.5323	SHLR	690.5788	SHLR	952.7659	SHL
4.9589	WHLR	89.2619	WHLR	148.7699	WHLR	123.9749	WHLR	173.5649	WHL
30.254	RHL	649.9813	RHL	1083.3023	RHL	814.5538	RHL	1126.3309	RHL
0.298	SHL3	6.84[illegible]	SHL3	11.4161	SHL3	8.2629	SHL3	11.4135	SHL
0.8942	SHL4	20.[illegible]	SHL4	34.2483	SHL4	24.7887	SHL4	34.2406	SHL
0.005	WHL3	0.09[illegible]	WHL3	0.1511	WHL3	0.1259	WHL3	0.1763	WHL
0.0093	WHL4	0.168[illegible]	WHL4	0.2807	WHL4	0.2339	WHL4	0.3275	WHL
1.1922	SHLC	27.3986	SHLC	45.6644	SHLC	33.0516	SHLC	45.6542	SHL
0.0143	WHLC	0.2591	WHLC	0.4319	WHLC	0.3599	WHLC	0.5039	WHL
1.2066	CHL	27.6578	CHL	46.0964	CHL	33.4116	CHL	46.1582	CHL
0.4107	SHL5	9.4283	SHL5	15.7139	SHL5	11.3747	SHL5	15.7109	SHL
1.2323	SHL6	28.2851	SHL6	47.1419	SHL6	34.1243	SHL6	47.1329	SHL
0.0069	WHL5	0.1247	WHL5	0.2078	WHL5	0.1732	WHL5	0.2425	WHL
0.0128	WHL6	0.2316	WHL6	0.386	WHL6	0.3217	WHL6	0.4504	WHL
1.6431	SHLP	37.7135	SHLP	62.8558	SHLP	45.4991	SHLP	62.8438	SHL
0.0197	WHLP	0.3563	WHLP	0.5939	WHLP	0.4949	WHLP	0.6929	WHL
1.6629	PHL	38.0699	PHL	63.4498	PHL	45.9941	PHL	63.5368	PHL
33.1236	THL	715.7091	THL	1192.8485	THL	893.9596	THL	1236.0259	THL
0		5.93		0		31.63		57.99	
16.4903	TEL	125.6608	TEL	209.4397	TEL	159.6557	TEL	221.2537	TEL
0		2.23		0		11.90		21.82	
4.8316	2	36.8191	2	61.3653	2	46.7787	2	64.8267	2

50.	MONTANA	51.		52.		53.	MONTANA
125		129/MT10		MSR46		MSR50	
2000.		2000.		2000.		9000.	
0.375		0.375		0.375		0.375	
0.135		0.135		0.135		0.135	
9719.		8165.		8190.		8165.	
0.54		0.57		0.56		0.57	
-24.		-20.		-21.		-20.	
0.59		0.61		0.6		0.61	
-17.		-14.		-16.		-14.	
8.4107	SHL1	7.4582	SHL1	7.3499	SHL1	33.5621	SHL1
53.8913	SHL2	47.788	SHL2	47.0938	SHL2	215.0462	SHL2
3.7192	WHL1	3.7192	WHL1	3.7192	WHL1	16.7366	WHL1
6.1987	WHL2	6.1987	WHL2	6.1987	WHL2	27.8943	WHL2
62.3021	SHLR	55.2463	SHLR	54.4437	SHLR	248.6084	SHLR
9.9179	WHLR	9.9179	WHLR	9.9179	WHLR	44.6309	WHLR
72.2201	RHL	65.1643	RHL	64.3617	RHL	293.2394	RHL
0.761	SHL3	0.661	SHL3	0.6522	SHL3	2.9746	SHL3
2.2832	SHL4	1.983	SHL4	1.9566	SHL4	8.9239	SHL4
0.01	WHL3	0.01	WHL3	0.01	WHL3	0.0453	WHL3
0.0187	WHL4	0.0187	WHL4	0.0187	WHL4	0.0842	WHL4
3.0442	SHLC	2.6441	SHLC	2.6088	SHLC	11.8985	SHLC
0.0287	WHLC	0.0287	WHLC	0.0287	WHLC	0.1295	WHLC
3.073	CHL	2.6729	CHL	2.6376	CHL	12.0281	CHL
1.0475	SHL5	0.9099	SHL5	0.8977	SHL5	4.0949	SHL5
3.1427	SHL6	2.7299	SHL6	2.6933	SHL6	12.2847	SHL6
0.0138	WHL5	0.0138	WHL5	0.0138	WHL5	0.0623	WHL5
0.0257	WHL6	0.0257	WHL6	0.0257	WHL6	0.1158	WHL6
4.1903	SHLP	3.6399	SHLP	3.591	SHLP	16.3797	SHLP
0.0395	WHLP	0.0395	WHLP	0.0395	WHLP	0.1781	WHLP
4.2299	PHL	3.6795	PHL	3.6306	PHL	16.5578	PHL
79.5232	THL	71.5167	THL	70.63	THL	321.8254	THL
6.59		0		0		11.86	
13.9626	TEL	12.7724	TEL	12.643	TEL	57.476	TEL
2.48		0		0		4.46	
4.091	2	3.7422	2	3.7043	2	16.8403	2



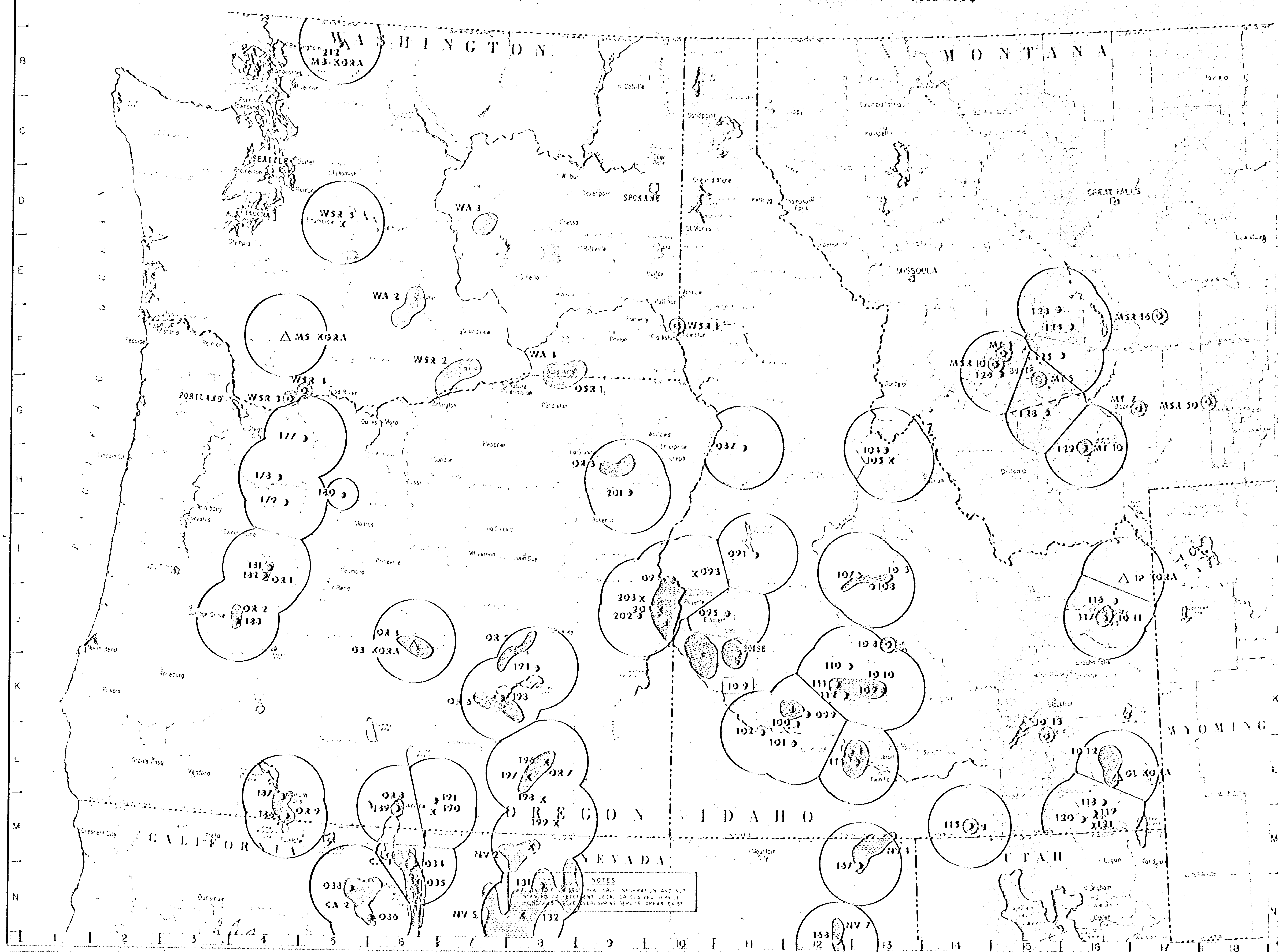
ASSESSMENT of the GEOTHERMAL POTENTIAL WITHIN the BPA MARKET AREA

SITE LEGEND	Prepared by		
(◉) below 90°C X above 150°C ❩ 90° - 150°C Δ Igneous KGRA	GEO-HEAT UTILIZATION CENTER OREGON INSTITUTE of TECHNOLOGY KLAMATH FALLS, OREGON	July, 1980	Sites are numbered by USGS Circ. 790 or State Report referenced in text SCALE: 1" = 50 miles

U. S. DEPARTMENT OF ENERGY

BONNEVILLE POWER ADMINISTRATION

MAP NO. 2 POTENTIAL LOAD DISPLACEMENT AREAS



ASSESSMENT of the GEOTHERMAL POTENTIAL WITHIN the BPA MARKET AREA

SITE LEGEND

(⊙) below 90°C   X above 150°C

) 90° - 150°C   △ Igneous KGRA

Outer 25 mile circle represents: Direct Use Load Displacement Area

Prepared by
GEO-HEAT UTILIZATION CENTER
OREGON INSTITUTE of TECHNOLOGY
KLAMATH FALLS, OREGON

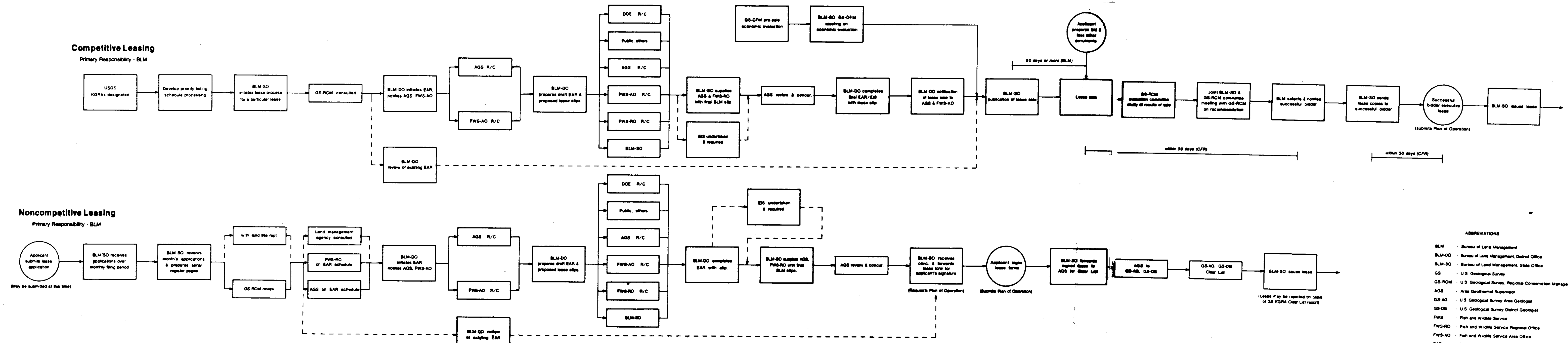
July, 1980

Sites are numbered by USGS Circ. 790 or State Report referenced in text

SCALE: 1" = 40 miles

GEOTHERMAL REGULATORY PROCESS

Pre-Lease Activities



(COMPILED FROM GEOTHERMAL STEAM ACT OF 1970, FEDERAL RULES AND REGULATIONS 43 CFR PART 3000 AND 30 CFR PARTS 270.& 271, AND MEMORANDUM OF UNDERSTANDING FOR THE GEOTHERMAL PROGRAM - USGS, BLM, FWS)

ABBREVIATIONS

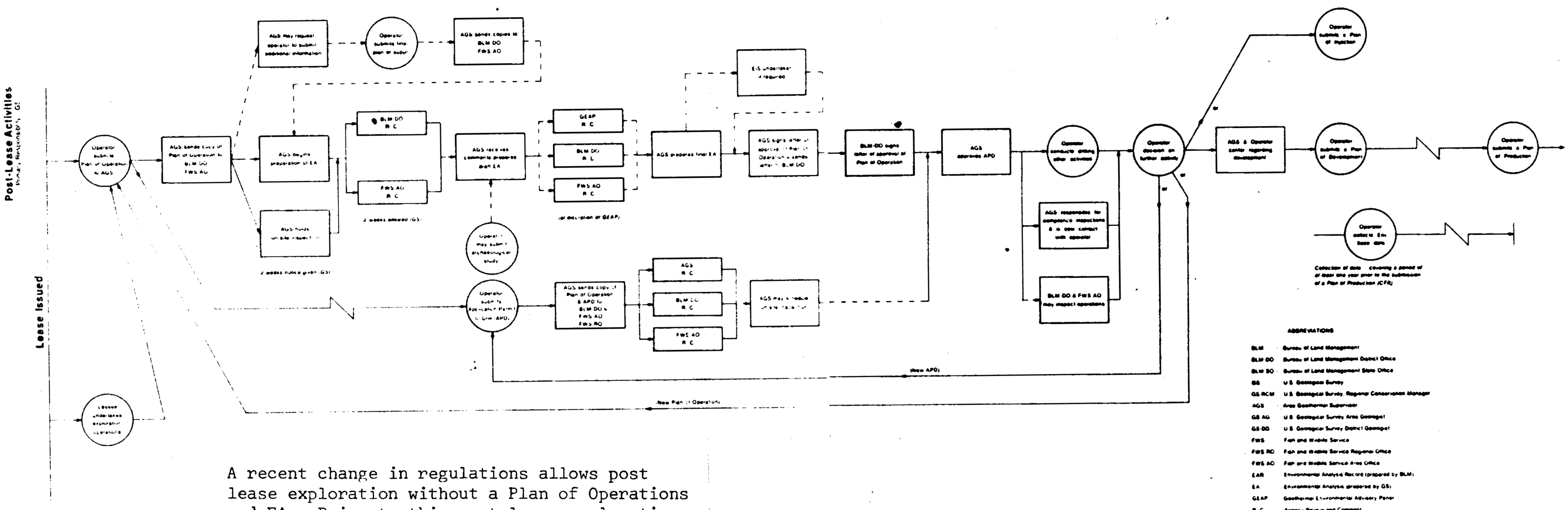
BLM	- Bureau of Land Management
BLM-DO	- Bureau of Land Management, District Office
BLM-SO	- Bureau of Land Management, State Office
GS	- U.S. Geological Survey
GS-RCM	- U.S. Geological Survey, Regional Conservation Manager
AGS	- Area Geothermal Supervisor
GS-AG	- U.S. Geological Survey Area Geologist
GS-DG	- U.S. Geological Survey District Geologist
FWS	- Fish and Wildlife Service
FWS-RO	- Fish and Wildlife Service Regional Office
FWS-AO	- Fish and Wildlife Service Area Office
EAR	- Environmental Analysis Record (prepared by BLM)
EA	- Environmental Analysis (prepared by GS)
GEAP	- Geothermal Environmental Advisory Panel
R/C	- Agency Review and Comment
DOE	- Department of Energy

To facilitate the EA process the AGS prepares a detailed EA when the first deep exploratory drilling is proposed on a lease (or unit) Environmental baseline information of the entire lease (or unit) is gathered for that EA and may be used again in the preparation of subsequent EA's.

GEOTHERMAL REGULATORY PROCESS (continued)

Post-Lease Activities

Proceedure for joint BLM-DO and AGS review of development and production plans is essentially same as review of Plan of Operation including preparation of Environmental Analysis.



A recent change in regulations allows post lease exploration without a Plan of Operations and EA. Prior to this post lease exploration required an EA to be completed on the Plan of Operation and notice of intent to conduct geothermal resource exploration operations before entry onto the lease land for any activity beyond casual use.