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DOE/RA/50261--T1

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DE84 015348

MARKET PENETRATION ANALYSIS
FOR DIRECT HEAT
GEOTHERMAL ENERGY APPLICATIONS

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DIVISION OF GEOTHERMAL ENERGY
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UNDER CONTRACT NUMBER
DE-AC01-80-RA50261

JUNE, 1981

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I.

EXECUTIVE SUMMARY

1.1 Introduction

Known and anticipated geothermal resources exist all across the United States in resource pockets and larger zones. The potential contribution of these natural geothermal resources to overall U.S. domestic energy supplies depends upon the location and availability of the resource, resource temperatures, the requirements of potential users, and the cost of delivered geothermal energy. The major uses of geothermal energy are for the generation of electricity and direct heat applications. This study is concerned with the estimation of the National geothermal market potential and penetration in direct heat applications for residences and certain industry segments. Direct heat applications include residential space and hot water heating, and industrial low-temperature (< 350°F) process heat. An important aspect of this study is that the analysis considers both known and anticipated geothermal resources. This allows for an estimation of the longer-range potential for geothermal applications. Thus the approach and results of this study provide new insights and valuable information not obtained from more limited, site-specific types of analyses. Estimates made in this study track geothermal market potential and projected penetration from the present to the year 2020. Private sector commercialization of geothermal energy over this period requires assistance in the identification of markets and market sizes, potential users, and appropriate technical applications.

1.2 Market Size

Before market penetration potential can be estimated, it is necessary to define the relevant size of the potential market. Through the use of resource and data studies undertaken by the U.S. Geological Survey and the Interagency Geothermal Coordinating Council, 31 States are identified as having known or anticipated geothermal resources. These States, listed in Exhibit 1, provide a geographic boundary for geothermal energy applications. Those portions of the States located in or near geothermal resource areas further define the markets into which geothermal may penetrate. The total market available to geothermal is also shown in Exhibit 1.

**EXHIBIT 1: BASELINE POTENTIAL GEOTHERMAL
ENERGY MARKET
(IN QUADS)**

STATE	RESIDENCES	INDUSTRY	TOTAL
ALABAMA	0.030	-	0.030
ALASKA	0.011	0.004	0.015
ARIZONA	0.039	0.024	0.063
ARKANSAS	0.049	-	0.049
CALIFORNIA	0.528	0.203	0.731
COLORADO	0.102	0.029	0.131
DELAWARE	0.001	0.002	0.003
HAWAII	0.001	0.003	0.004
IDAHO	0.020	0.026	0.046
ILLINOIS	0.068	-	0.068
INDIANA	0.109	-	0.109
LOUISIANA	0.083	0.330	0.413
MARYLAND	0.002	0.001	0.003
MICHIGAN	0.005	-	0.005
MISSISSIPPI	0.036	-	0.036
MISSOURI	0.045	-	0.045
MONTANA	0.014	0.007	0.021
NEVADA	0.016	0.009	0.025
NEW JERSEY	0.020	0.012	0.032
NEW MEXICO	0.018	0.007	0.025
NEW YORK	0.017	-	0.017
NORTH CAROLINA	0.002	0.002	0.004
OHIO	0.068	-	0.068
OREGON	0.019	0.018	0.037
PENNSYLVANIA	0.086	-	0.086
TEXAS	0.294	0.319	0.613
UTAH	0.040	0.013	0.053
VIRGINIA	0.022	0.017	0.039
WASHINGTON	0.046	0.046	0.092
WEST VIRGINIA	0.002	-	0.002
WYOMING	0.016	0.005	0.021
TOTAL:	1.81	1.07	2.88

The determination of the market available for geothermal penetration is based on State residential and industrial energy consumption patterns and the locations of industry and population within each State. The future size of the available market is obtained by allowing the current available market to grow at a moderate rate of 2% per year for residences and 1.5% per year for industry. The sizes of the current (1978) and future available markets are shown below in Exhibit 2.

**EXHIBIT 2: POTENTIAL MARKET
AVAILABLE TO GEOTHERMAL ENERGY
(QUADS)**

<u>SECTOR</u>	<u>1978</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Residences	1.8	2.3	2.75	3.35	4.2
Industry	<u>1.1</u>	<u>1.3</u>	<u>1.5</u>	<u>1.74</u>	<u>2.1</u>
TOTAL:	2.9	3.6	4.25	5.09	6.3

These values represent the maximum possible contribution of geothermal direct heat applications in the sectors considered. To facilitate the examination of geothermal potential for urban as well as small community residential applications, the residential sector is divided into two components:

- "Cities" - areas showing population greater than 25,000 persons; and
- "Towns" - areas showing population between 2,500 and 25,000 persons.

The market sizes (in quads) for these two sectors are shown below in Exhibit 3.

**EXHIBIT 3: RESIDENTIAL POTENTIAL MARKETS
(QUADS)**

	<u>1978</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Residences - Total	1.8	2.3	2.75	3.35	4.2
Cities	1.2	1.5	1.85	2.25	2.8
Towns	0.6	0.8	0.9	1.10	1.4

1.3 Market Model Approach

The procedure used to generate penetration estimates is the familiar logistic model. The modeling format is used successfully in similar studies to account for consumer uncertainty and the diffusion of innovations or new technologies into the marketplace. The key elements incorporated into the logistic model include an equilibrium market share equation and a market lag or market adjustment equation. These functional expressions are designed to account for the relative attractiveness of geothermal energy compared to conventional energy sources and measure the degree of adjustment of the market to the introduction of cost-competitive geothermal energy. A detailed discussion of the quantitative approach is presented in Chapter III. The system of equations used to generate State-specific geothermal and conventional energy costs are presented in Chapter IV.

1.4 Market Penetration Analysis

A representative Base Case is constructed incorporating actual historical data, calculated inputs, and conservative values for basic financial, growth, and similar variables. Thus, the Base Case results reflect a conservative "most-likely" course for geothermal market penetration under current and foreseeable conditions. Key parameter values for the Base Case include:

- An annual conventional fuel escalation factor 3% greater than the corresponding geothermal factor;
- An Investment Tax Credit (ITC) reflecting current tax laws having a value of 15% through 1985 and at 10% thereafter;
- A system life of 30 years; and
- A market adjustment factor (MAF) which constrains geothermal market penetration to approximately 60% of the total available market.

An important feature of this market penetration approach is that it provides an opportunity to gain insight into how geothermal market potential can be expected to behave under differing conditions. This allows the results to be tested for sensitivity to changes in key policy and exogenous variables. Sensitivity analyses are conducted with respect to the following parameters:

- Investment Tax Credits (ITC). Two values (15% and 20%) are used to assess the impact of current ITC allowances, possible future legislation, and policy on geothermal energy;

- High Prices. This analysis includes an annual conventional fuel cost escalation factor that is 5% greater than the corresponding geothermal factor;
- Market Adjustment Factor (MAF). To test results against different market adjustment constraints, an MAF analysis that limits penetration to approximately 50% of the total relevant market is conducted;
- Increased Response. The response parameter is increased for comparison of results associated with an increased consumer response to geothermal energy; and
- System Life. System lifetimes are changed from 30 to 10 years to provide insight into market penetration of geothermal energy under restricted time periods.

1.5 Market Penetration Results

Aggregate geothermal market penetration results for the Base Case and selected sensitivity cases are summarized in Exhibit 4. The following two Exhibits (5 and 6) illustrate the penetration potential over time by market sector (Cities, Towns, and Industry). Exhibit 5 displays results for the Base, ITC, and High Prices Cases. Two other scenarios (MAF at 50%, Increased Response) are illustrated Exhibit 6.

EXHIBIT 4: COMPARISON OF TOTAL
GEOTHERMAL MARKET PENETRATION
(IN QUADS)

<u>SCENARIO</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
BASE CASE	0.02	0.08	0.42	0.74
ITC AT 15%	0.025	0.14	0.46	1.35
ITC AT 20%	0.029	0.18	0.60	1.64
HIGH CASE	0.06	0.74	1.39	2.60
MAF AT 50%	0.004	0.02	0.034	0.192
RESPONSE CASE	0.025	0.081	0.455	0.862

**EXHIBIT 5: MARKET SHARE RESULTS
BY SECTOR
(IN QUADS)**

<u>SCENARIO</u>	<u>CITIES</u>	<u>TOWNS</u>	<u>INDUSTRY</u>
BASE CASE			
1990	0.015	0.005	0.001
2000	0.046	0.018	0.019
2010	0.219	0.028	0.172
2020	0.410	0.036	0.289
ITC AT 15%			
1990	0.017	0.007	0.001
2000	0.090	0.021	0.029
2010	0.244	0.028	0.192
2020	0.922	0.044	0.385
ITC AT 20%			
1990	0.018	0.009	0.001
2000	0.114	0.022	0.045
2010	0.363	0.029	0.207
2020	0.988	0.091	0.561
HIGH PRICES CASE			
1990	0.039	0.018	0.005
2000	0.552	0.028	0.156
2010	0.844	0.212	0.334
2020	1.193	0.371	1.042

**EXHIBIT 6: MARKET SHARE RESULTS
BY SECTOR
(IN QUADS)**

<u>SCENARIO</u>	<u>CITIES</u>	<u>INDUSTRY</u>
MAF at 50%		
1990	0.004	-
2000	0.016	-
2010	0.033	0.001
2020	0.188	0.004
RESPONSE CASE		
1990	0.019	0.006
2000	0.067	0.014
2010	0.239	0.216
2020	0.347	0.515

1.5.1 The Base Case

Initial Base Case geothermal penetration in both the residential sectors and the industrial sector as defined for this study is dominated by the contributions of three Western States -- Idaho, Montana, and Oregon. These States also continue to dominate the results for Towns through the course of the analysis. Other States (including several Eastern States), however, add to the penetration in the Cities and Industry sectors over the analysis period. By the year 2000, penetration appears in all regions of the country in the Cities and Industry sectors.

Geothermal's contribution in all residential applications in 2000 is 0.064 quads rising to 0.446 quads by 2020. Industry use of geothermal energy is almost 0.02 quads in 2000, increasing to almost 0.29 quads by 2020. Base Case output implies that geothermal resources can be developed on a National basis for both residential and industrial direct heat applications.

1.5.2 Investment Tax Credit Cases

The Investment Tax Credit (ITC) is an important policy tool available to the government which can be used effectively to assist and target private sector geothermal development and production. This study includes two ITC cases featuring increased (to 15% and 20%) and extended (2020) ITC allowances. The ITC cases show that the higher ITC values improve the economics of geothermal earlier in several States (notably California and Pennsylvania) thus causing a larger portion of the potential market to be captured in the long-term. In addition, the larger ITC values enable several States not penetrating under Base Case parameters to show penetration in the higher ITC case.

The total market potential for the 15% ITC case (1.35 quads) is nearly double the Base Case value of 0.74 quads. For the 20% ITC case, results are significantly improved over time for all market sectors increasing from 0.029 quads in 1990 to 1.64 quads by 2020.

1.5.3 High Prices Case

The future movement of energy prices will play a significant role in affecting geothermal energy use in both the residential and industrial sectors. The High Prices Case output shows the impact of higher conventional costs on geothermal penetration. As expected, all three sectors record large penetration gains over the Base Case. Penetration in the small community sector (Towns) increases from 0.028 quads in 2000 to 0.371 by 2020. This result is especially revealing for this

sector because recent data from the Rural Electric Association indicates that conventional energy prices for rural localities are rising faster than urban areas. For industry in the High Prices Case, geothermal penetration rises from 0.005 in 1990 to 1.04 quads in the year 2020. This compares to an increase from 0.001 to 0.289 quads in the Base Case.

1.5.4 Other Selected Cases

Results generated from the remaining sensitivity analyses (MAF at 50%, increased response and restricted life scenarios) all move in anticipated directions as a result of an increase or decrease in the specific Base Case parameter. As geothermal is allowed to capture only a smaller part of the potential market (e.g., penetration is limited to 50%), the penetration outlook for geothermal is dampened. The MAF at 50% yielded a 1990 market of 0.004 quads increasing to 0.188 quads by 2020. The Base Case values were 0.015 and 0.410 quads. An increase in the factor that helps determine the slope of the logistic curve (e.g., consumer responsiveness) generates a quicker response to the use of geothermal systems. Finally, the 10-year restricted life scenario details the depressed market that occurs if the allocation of geothermal system costs are limited to a 10-year life cycle.

1.6 Conclusions

The market penetration results estimated during the course of this study provide some interesting insights with respect to the development of geothermal energy applications. These include the following:

- Base Case results suggest that geothermal energy can be developed on a National basis for residential and industrial applications;
- A significant potential National market exists for small community (rural) applications;
- Increased investment tax credit measures aid mid- to long-term geothermal penetration; and
- Geothermal penetration is very sensitive to price factors.

From a technical viewpoint, these conclusions suggest that geothermal planning efforts would be extremely effective when directed toward identifying and matching high price fuel consumers who happen to be located in or near geothermal resource areas with reliable geothermal delivery systems. Research and development efforts

directed at small community geothermal systems and applications may also prove beneficial to geothermal developers. The private sector experience obtained from knowledge about useable geothermal energy systems in competitive resource and fuel cost regions will directly aid the overall development of geothermal energy as a viable and valuable National energy resource.

II. GEOTHERMAL DIRECT HEAT MARKET POTENTIAL

2.1 Market Potential Overview

This project report presents the methodology and results of one approach to the assessment of the U.S. market penetration potential of geothermal direct heat applications. Geothermal direct heat applications can contribute to certain types of energy demands found in both the residential and industrial sectors. For example, geothermal energy can be used to satisfy space heating and hot water needs in residences and can also be used in industrial low temperature process heat applications. These applications form the relevant potential geothermal markets for the purposes of this study. While potential geothermal direct heat applications are thus constrained, these potential markets are of significant size and importance in overall U.S. energy demands.

In 1978, U.S. residences accounted for approximately 21% of total national energy use.¹ In the same year, industrial demands for low temperature (less than 350°F) process heat comprised about 38% of all U.S. industrial process heat requirements.² Only a portion of these markets, however, are available to geothermal energy because of regional characteristics, resource characteristics, and the proximity of potential users to known and anticipated geothermal resource areas. The above conditions were considered in estimating the relevant potential end-use market share available for capture by geothermal energy.

Estimates of the potential market for geothermal energy in direct heat applications are based on the identification of known and anticipated geothermal resource areas. Data from the Interagency Geothermal Coordinating Committee was used to detail geothermal market locations for different States (See Exhibit 7). Because necessary resource related data is not available for all States listed, Exhibit 8 is provided to show those States selected for inclusion in this study. A discussion

1 U.S. Department of Energy, Energy Information Administration, State Energy Data Report, p. 4.

2 Solar Energy Research Institute, Industrial Applications and Policy Branch, unpublished data released to TRAC.

EXHIBIT 7: KNOWN AND POTENTIAL GEOTHERMAL RESOURCES

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EXHIBIT 8: STATES CONSIDERED FOR THE MARKET
PENETRATION ANALYSIS

of the estimated size of potential geothermal residential and industrial direct heat markets is presented below. Estimates of the total national residential and industrial markets (in BTU terms) available for capture by geothermal direct heat applications are shown in Exhibit 9 below. These values represent the maximum energy contribution possible for geothermal low temperature, direct heat applications.

**EXHIBIT 9: MARKET SIZE AVAILABLE TO GEOTHERMAL
(IN QUADS)**

SECTOR/YEAR	1978	1990	2000	2010	2020
RESIDENCES					
Cities (> 25,000 persons)	1.2	1.5	1.85	2.25	2.8
Towns (2500 - 25,000 persons)	0.6	0.8	0.9	1.10	1.4
INDUSTRY	1.1	1.3	1.5	1.74	2.1
	—	—	—	—	—
TOTAL:	2.9	3.6	4.25	5.09	6.3

2.2 The Residential Market

The residential sector uses three main types of fuels to provide space heating and hot water -- fuel oil, natural gas, and electricity. Residential consumption of natural gas and fuel oil is largely attributable to hot water and space heating. Residential consumption of electricity, however, can be attributed to a number of heating, cooling, lighting and major appliance uses. Data on residential energy consumption for all these fuels is available on a State-by-State basis.³

It is assumed that household consumption of natural gas and fuel oil is used for space and hot water heating. Electricity used in space and water heating must be estimated. For the purposes of this study, residential electricity use for space

³ Ibid., State Energy Data Report.

and water heating was calculated based on a survey report of residential electric appliance usage.⁴ This percentage was applied to State residential electricity consumption to obtain an applicable State electricity value for residential direct heat consumption. State totals for fuel oil, natural gas, and electricity are summed to obtain the potential market available to geothermal in that State.

For those States in which only a portion of the residential consumers could physically utilize geothermal resources (because of the economic requirement of reasonable proximity to the resource) potential State markets must appropriately be limited in the analysis to the energy consumed in the resource area as an upper bound. These constrained State consumption figures are determined as follows. Total relevant State residential energy use is weighted by population. Consumption in the geothermal resource area is derived by multiplying the total applicable State consumption figures by the percentage of the population located in or near the geothermal zone. This yields the maximum energy contribution geothermal applications could make if it were to capture 100 percent of the relevant market. It is important to note that the market penetration estimates resulting from this study are stated as percentages of this relevant market.

A further disaggregation of the relevant State markets was made to provide insight into the size and location of communities in which geothermal energy may prove economically attractive. For each State, potential markets are segregated for analysis according to population and population densities. State specific population density values are derived for population centers located in or near the geothermal resource area. These include:

- 1) Cities (population greater than 25,000 persons);
- 2) Towns (population between 2,500 and 25,000 persons).

This disaggregation of the residential market allows for the examination of geothermal penetration potential for urban as well as small community applications. It also excludes that portion of the State's population residing in areas with less than 2,500 persons. Estimates of the size of the State residential energy market available to geothermal energy for each of the thirty-one States included in this analysis is presented in Exhibit 10. The projected rate of growth for this

4 Richard D. Harper, et. al., Patterns of Energy Use by Electrical Appliances Study (Kansas City: Midwest Research Institute, [1978]), p. 54.

market sector has been examined in several energy studies.⁵ The growth values range from less than 1% to almost 4% per year. For this study a conservative intermediate growth rate of 2% per year is used for residential energy demand.

EXHIBIT 10: RESIDENTIAL MARKET
AVAILABLE TO GEOTHERMAL ENERGY - 1978

STATE	RESIDENCES		
	CITIES	TOWNS	TOTAL
ALABAMA	.017	.013	.030
ALASKA	.006	.005	.011
ARIZONA	.032	.007	.039
ARKANSAS	.023	.026	.049
CALIFORNIA	.399	.129	.528
COLORADO	.078	.024	.102
DELAWARE	-	.001	.001
HAWAII	.001	-	.001
IDAHO	.009	.011	.020
ILLINOIS	.030	.038	.068
INDIANA	.084	.025	.109
LOUISIANA	.051	.032	.083
MARYLAND	-	.002	.002
MICHIGAN	.003	.002	.005
MISSISSIPPI	.019	.017	.036
MISSOURI	.039	.006	.045
MONTANA	.006	.008	.014
NEVADA	.011	.005	.016
NEW JERSEY	.006	.014	.020
NEW MEXICO	.013	.005	.018
NEW YORK	.009	.008	.017
NORTH CAROLINA	-	.002	.002
OHIO	.031	.037	.068
OREGON	.012	.007	.019
PENNSYLVANIA	.033	.053	.086
TEXAS	.201	.093	.294
UTAH	.018	.022	.040
VIRGINIA	.014	.008	.022
WASHINGTON	.028	.018	.046
WEST VIRGINIA	-	.002	.002
WYOMING	.006	.010	.016
TOTAL:	1.179	.631	1.810

5 John C. Sawhill, ed., Energy Conservation and Public Policy (Englewood Cliffs, NJ: Prentice-Hall, 1979), p. 115, and Electric Power Research Institute, "Overview and Strategy: 1981-1985," EPRI Journal, Vol. 6, No. 1 (January/February 1981): 26-35.

2.3 Industrial Market

The potential relevant market for geothermal direct heat applications in industry must also be determined so that the penetration analysis can be performed. Low temperature (212°F - 350°F) industrial process heat (IPH) requirements differ greatly across industries and manufacturing processes. Industrial energy consumption data are available by Standard Industrial Classification (SIC) company categories on a national basis.⁶ A sample of this information for companies in seven SIC categories is shown in Exhibit 11 below. Other U.S. Department of Commerce data make it possible to compile fossil fuel consumption and cost estimates by fuel type for two-digit SIC industries in each of the States considered.⁷

**EXHIBIT 11: INDUSTRIAL PROCESS HEAT REQUIREMENTS
BY INDUSTRIAL GROUP AND TEMPERATURE RANGE (1978)**

INDUSTRIAL GROUP		ENERGY CONSUMPTION (10 ¹² BTU's)					
		212 - 350°F		350 - 2000°F		Total	
SIC		BTU's	%	BTU's	%	BTU's	%
20	Food	545	73	200	27	745	100
26	Paper	1376	74	500	26	1876	100
28	Chemicals	1119	50	1107	50	2226	100
29	Petroleum	190	7	2646	93	2836	100
32	Stone, Clay & Glass	45	4	1046	96	1090	100
33	Primary Metals	178	12	1280	88	1458	100
	Other Manufacturing	1052	68	500	32	1552	100
	TOTAL:	4505	38	7279	62	11784	100

Source: Solar Energy Research Institute, Industrial Applications and Policy Branch.

Combining these data with the percentages of low temperature IPH consumption for particular SIC industries yields estimates of the maximum industrial energy market available to geothermal in each State (See Exhibit 3). As was the case with the residential market, if only a portion of a State contained a geothermal resource area, the size of the low temperature IPH market available was determined by weighting the total State market by the percentage of population residing in or near a resource area. For purposes of this analysis, these potential IPH markets are allowed to grow at the rate of about 1.5 percent per year reflecting moderate industrial growth.

⁶ Ibid., SERI unpublished data.

⁷ U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufacturers: Fuels and Electric Energy Consumed.

III.

MARKET PENETRATION APPROACH

3.1 Technical Overview

The general approach presented in this report allows for the evaluation of the energy contribution and economic competitiveness of geothermal energy in direct heat residential and industrial applications both now and into the future. The commercialization of geothermal energy through private sector development requires technical information concerning end-use markets and geothermal resource base characteristics. Several government agencies are actively involved researching and providing important information to help identify the eventual locations of geothermal energy markets and spur geothermal resource development. The U.S. Department of Energy's Division of Geothermal Energy is responsible for many key efforts involving geothermal energy resources. Among them is the identification of geothermal market potential and the estimation of the penetration of geothermal applications into relevant markets over time. Under the guidance of the Division, analysts have recently conducted a number of studies which consider various aspects of the market potential for geothermal direct heat applications. Many of these efforts are referenced in the bibliography section of this report. The general emphasis of these studies is placed on careful, detailed examinations of the economic competitiveness and/or market potential of site-specific, identified geothermal resources.⁸ The identified portion of the total estimated geothermal resource constitutes only about 25 percent of the total.

These site-specific assessments yield reasonable near-term market estimates. But as geothermal well drilling and resource discoveries increase, and as operational experience is gained by users or potential users of geothermal systems, site-specific methodologies and variables will not produce reliable long-term estimates of overall national geothermal market potential or penetration.

8 Technicon Analytic Research Inc., Geothermal Investment and Policy Analysis With Evaluation of California and Utah Resource Areas (Philadelphia: Technicon, [1979]); Johns Hopkins University, Definition of Markets for Geothermal Energy in the Northern Atlantic Coastal Plain (Baltimore: Johns Hopkins, [1980]); and New Mexico Energy Institute, Geothermal Market Penetration Assessment for Colorado, New Mexico, Montana (Albuquerque: NMEI, [1979]).

This study is designed to complement the site-specific, near-term analyses by taking a much broader approach to geothermal market analysis through the inclusion of a broader resource base. The resource base is defined to be comprised of both discovered and unidentified geothermal resources. To ensure that the location of potential geothermal market areas accurately reflects the site of both identified and assumed or predicted geothermal resources, the areas of the undiscovered resources closely reflect the location of U.S. Geological Survey geologic provinces⁹ and Interagency Geothermal Coordinating Council data on the locations of undiscovered geothermal resources.¹⁰

The mathematical system used to generate penetration estimates is the familiar logistic model. This modeling format is used successfully in similar studies to account for consumer uncertainty and the diffusion of innovations or new technologies into the marketplace.

The market penetration of geothermal energy into the marketplace depends upon two factors:

- the relative attractiveness of geothermal energy compared to conventional energy sources (i.e., relative price, convenience, reliability); and
- the degree of adjustment of the market to existing market conditions (dependent upon the availability of the geothermal resource, the level of consumer awareness of geothermal characteristics, the age and condition of existing equipment, and others).

The quantitative analogue of the first factor included in the logit model of geothermal penetration is the relative price or cost. The logit model itself corresponds to a comparative static economic model and provides an asymptote for the dynamic model. Incorporating the second factor (the adjustment process) makes the system dynamic.

An "equilibrium market share" concept is used to obtain an expression for the first factor. Thus, the equilibrium level of market penetration depends upon the cost of geothermal energy relative to the cost of competing conventional sources in the particular application. This static approach incorporates the following concepts:

9 U.S. Geological Survey, Assessment of Geothermal Resources of the United States - 1978, 1979.

10 U.S. Department of Energy, Interagency Geothermal Coordinating Council, Fourth Annual Report: Geothermal Energy Research Development and Demonstration Program, p. 20.

- every potential user is fully informed about the relative costs of various alternatives for heating;
- the only heating characteristics of concern to potential users are the amount of heat available and the cost per unit of heat; and
- there are no market impediments to the instant and total conversion of every application to the lowest cost source of heating.

Were all these concepts to be universally valid at all times, then a comparative static model of geothermal demand would be appropriate. But, because some of these concepts or conditions apply only over time, a dynamic component must be added to account for changes over time -- the time "adjustment". It can reasonably be assumed that, given enough time, residential and industrial applications will use the lowest cost source (per unit of satisfaction of available heating) if free to do so. Therefore, the equilibrium market share is defined as the share of the market for which geothermal energy provides the lowest cost alternative.

Given the availability of geothermal energy at competitive rates, the adjustment path of the market can be expected to be described by an S-shaped curve. When geothermal first becomes available at competitive rates, there will remain a degree of reluctance in the market to try a new, unproven, technology. A large initial capital investment requirement will also slow the response rate. For example, most homeowners or industrial managers will hesitate before making a large investment in a heating system about which they know little or that might have to be replaced if geothermal heating proved to be unsafe or unreliable. After some homes or plants are fitted with geothermal systems and the systems are proven safe and reliable, the confidence of other users of geothermal heating will be increased. Furthermore, the greater the number of users who have had successful experiences with geothermal heating, the less risky the investment in geothermal heating will appear. This learning process will cause an accelerating rate of investment in geothermal heating among the users who are in the market for heating equipment.

Eventually, the geothermal market can be expected to approach a saturation point. As there are fewer and fewer customers left to convert to geothermal heating the rate of geothermal conversion will decrease. At this point, almost all of the market for geothermal heating will consist of new installations, with few remaining conversions. Thus, the accelerating rate of conversion, during the learning period, followed by the decelerating rate of conversion as the market nears saturation,

can be described by an S-shaped curve. The following section presents the model approach required to generate the market potential of geothermal energy for direct heat applications.

3.2 TRAC GEOTHERMAL MARKET PENETRATION MODEL

Direct heat uses of geothermal energy can be found for both residential and industrial applications. Space heating, water heating, and process heat requirements can all be satisfied through the use of geothermal energy, as described in this report in Section II on page 10. Both residential and industrial potential users can be expected to have different and distinct criteria by which they will evaluate product purchase decisions. In order to account for the differences of energy use and decision criteria, the modeling approach is designed to generate separate market estimates for each end-user group. This section of the report delineates the general model framework and equation specifications required to generate these market estimates.

3.2.1 Estimating Equilibrium Market Share

A key expression in the logistic model is that which describes the economic competitiveness and potential energy contribution of geothermal energy relative to competing conventional sources. This expression results in what is called the equilibrium market share. The equilibrium market share is expressed as a function of relative price indices with the following functional form:

$$(1) \quad \text{MSE} = \frac{1}{1 + (\text{ACG}_{j,t} / \text{ACC}_{j,t})^a}$$

where MSE = equilibrium market share

$\text{ACG}_{j,t}$ = annualized cost of geothermal energy (ACG) for a particular State (j) over a given time period (t)

$\text{ACC}_{j,t}$ = annualized cost of conventional energy (ACC) for a particular State (j) over a given time period (t)

a = market response parameter between geothermal and conventional energy sources

The annualized cost ratio (ACG/ACC) is the relative price ratio for geothermal and conventional energy in a given year. A detailed description for computing these values for residential and industrial costs is presented in Section IV. The market response parameter a is estimated by regression analysis after the generation of a

proxy estimate for MSE. Once the MSE proxy estimate is obtained, the equation is logged and α is estimated using least squares regression analysis. This procedure is illustrated in equations (2) and (3).

$$(2) \quad \text{Log} [(1/\text{MSE}) - 1] = \alpha \text{Log} (\text{ACG}/\text{ACC})$$

$$(3) \quad \text{MSE}^* = [(J'_m E^*_t / J'_m E_t)] , (t = 1, 2, \dots, T)$$

Where MSE^* = estimated equilibrium market (proxy value)

E^*_t = cost effective geothermal energy

E_t = amount of energy available for use

J'_m = m element vector of ones (1, 1, 1, ..., 1)

Values for MSE^* of Equation (3), are derived through the steps explained below.

3.2.2 Estimating Equilibrium Market Penetration Ratios

If a value for the geothermal energy available in each State can be estimated, and the total energy that has been consumed or will be consumed in a particular application is known for each State, then the maximum amount of geothermal energy which could be used in each State in each year would be less than or equal to the lesser of these two figures. In effect, the implication is that geothermal market penetration will be constrained by either of the following:

- amount of geothermal resource available in the area; or
- total energy consumption in a State for residential or industrial applications.

The sums of these values for each year gives the upper bound for geothermal energy use in each State for each year. For purposes of exposition, each State is referred to as a cell and each data element (prices or quantities) is defined at the cell level for each year. For example, each element in the matrix "E" in Equation (4) below is defined as the maximum amount of geothermal energy which could be used by cell i at time t.

$$(4) \quad E = [(e_{it})], (i = 1, 2, \dots, n; t = 1, 2, \dots, T)$$

Given the maximum amount of geothermal energy that will be available and the maximum amount of energy from all sources that will be used in cell i at time t , e_{it} is the lesser of the two values.

An $(n \times t)$ matrix of Kronecker deltas is defined such that each of its elements is equal to one if the cost of geothermal heating is less than the cost of alternative sources of heating for that cell at that time. Otherwise, the element is set equal to zero. The matrix of Kronecker deltas is used as a matrix operator or "switch" to include or to exclude elements of a matrix. The mathematical notation for this matrix appears below as Equation (5).

$$(5) \quad \Delta = (\delta_{it}) \quad (i = 1, 2, 3, \dots, n; \quad t = 1, 2, 3, \dots, T)$$

Where: $\delta_{it} = 1$ if $ACG_{it}/ACC_{it} < 1$; and

$\delta_{it} = 0$ if $ACG_{it}/ACC_{it} > 1$.

The estimated equilibrium market potential for geothermal heating in a given year is the sum of BTU's in those States where geothermal energy costs less than competing conventional fuels divided by the total BTU's available in all States in the same year.

$$(6) \quad E^* = \Delta E = [(\delta_{it} e_{it})], \quad (i = 1, 2, \dots, n; \quad t = 1, 2, \dots, T)$$

An $(n \times 1)$ matrix, $J'_n = (1, 1, 1, \dots, 1)$ (an n element vector of ones), is defined as a vector sum operator (i.e., if $x' = x_1, x_2, \dots, x_n$) such that $X'J'_n = \sum_{i=1}^n (x_i)$. Thus a proxy for the equilibrium market share at time t can be written concisely using matrix notation as Equation (3).

It should be noted that this method of estimating the equilibrium market share (or market penetration ratio) yields the maximum cost effective market divided (in millions of BTU's) by the maximum available market (in millions of BTU's) as a proxy for the actual cost effective divided by the actual available. It is assumed that each maximum overestimates the actual value by the same percent, or that the difference between the actual and upper bound for each cell is randomly distributed and (by the central limit theorem and given a large number of cells) the expected

value of the difference is nearly zero. It is clear that if the data are disaggregated (that is, if the cells are defined over smaller subgroups) the more reasonable this assumption becomes.

3.2.3 Market Adjustment Factor

The above steps complete the approach required to obtain the market share portion of the market penetration model. The next step in the modeling process requires the specification of the dynamic factor, or market adjustment factor, to account for the time required for geothermal to achieve market penetration. The diffusion of a new technology into the marketplace can be expressed in a well-known functional form (the S-shaped market response curve). For determining the market diffusion of geothermal technology, the following expression is used:

$$(7) \quad ML = A [Pt (1 - Pt)]$$

Where: ML = rate of change of penetration
 Pt = proportion of the market already converted
 to geothermal at time t
 A = market adjustment coefficient

When only a small number of consumers are using geothermal systems, there is little opportunity for others to obtain knowledge of or experience with the technology. Similarly, as geothermal technology approaches market saturation, there are few remaining opportunities for market expansion. In either case, and for very different reasons, the rate of penetration will be close to zero. In between these two extremes, the most rapid rate of geothermal market penetration will occur when there is a maximum exposure of the technology to the greatest number of potential users who have the opportunity to replace conventional energy systems with economically attractive geothermal systems. The cumulative consideration of the above factors results in a time path or diffusion path of geothermal energy which follows an S-shaped curve. In Equation (7) above, the Pt value is based on the amount of geothermal energy supplied in a given year divided by the total potential market available to geothermal energy. The adjustment coefficient "A" is set in the model at a value that will enable cost-competitive geothermal energy to capture a pre-determined, constrained amount of the total market share. The Base Case scenario sets the adjustment coefficient at 2.7 to allow competitive geothermal energy to capture approximately 60% of the long-run total market. Previous

studies have examined the length of time required for a new product to capture specific market shares.¹¹ One particular study examined the penetration time for sources of energy.¹² Historical trends suggest it takes between 50 - 60 years for a new energy source to penetrate 50% of the primary energy market. The Base Case value is set slightly higher because of the continual changing of the relative price ratio and because this project is considering an end-use market sector (i.e., direct heat residential and industrial markets) as opposed to the primary energy market. To test the sensitivity of geothermal penetration to the lower adjustment time, a special case was run where competitive geothermal was allowed to capture 50% of the market. The results of this analysis are presented in detail in Section 5.3 of this report.

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- 11 John G. Stover, "Use of Decision Modeling for Substitution Analysis: Application to Acceptance of New Electricity Generating Technologies." Technological Forecasting and Social Change (1978): 337-151; and Lloyd L. Phillipson, "Market Penetration Models for Energy Production Services and Conservation Techniques." Technological Forecasting and Social Change (1978): 223-36.
- 12 C. Marchetti, "Primary Energy Substitution Models: On the Interaction Between Energy and Society." Technological Forecasting and Social Change (1977): 345-56.

IV.

COMPILATION OF ENERGY COSTS

This section of the report presents the methods by which geothermal and conventional energy costs are calculated for each State for both residential and industrial applications. The cost methodologies are designed to produce annualized cost ratios (geothermal relative to conventional) for each State by sector. Whereas the calculation of conventional energy costs are relatively straightforward, the calculation of geothermal energy costs are much more intricate. The methodologies used to calculate geothermal costs are presented in detail below and the conventional fuel cost calculations later in the chapter.

4.1 Geothermal Energy Costs

An examination of geothermal literature and data sources did not reveal the existence of a consistent set of geothermal cost goals that could be used as a basis for deriving geothermal cost variables. To breach this information gap TRAC developed an approach for the estimation of State geothermal energy costs (residential and industrial) to be used in the market analysis. These costs are based on energy, economic, technical, and other relevant factors affecting the cost of geothermal energy development in a given State or region.

Previous studies cited earlier developed geothermal cost estimates for specific locations which were based upon resource, economic, and system design conditions. These site-specific, case-by-case approaches provide valuable information necessary to specific end-user purchase decisions. This type of approach, however, does not provide long-range market assessment and market impact information that is a critical part of technical planning efforts. This study uses the following expressions to incorporate the applicable cost, engineering, and financial components required to generate geothermal cost estimates for each State.

$$ACG_j = \left(\frac{1}{EG_j}\right) [(KG_j) (CRF) (OM - TC_j + D_j)]$$

Where: ACG_j = annualized cost of geothermal energy for State j
 KG_j = capital cost of the geothermal system for State j
 EG_j = energy output of the generic system for State j
 CRF = capital recovery factor
 OM = operation and maintenance costs as a percent of capital cost
 TC_j = investment tax credit for State j
 D_j = combined affect on the amount of revenue of interest payments on the debt, depreciation, and cost of capital for State j

NOTE: Throughout the discussion of cost equations, variables may have a suffix of either an "R", denoting that it is a residential variable or expression, or an "I", marking it as an industrial variable or expression.

A detailed explanation concerning the variables that comprise the ACG expression for the residential and industrial sectors is presented below. Before this discussion, however, it is important to note a necessary assumption applicable to the residential annualized geothermal cost equation (ACGR). For the purposes of this analysis, it is assumed that potential residential consumers only use geothermal energy if it is provided to the community by a third-party. This assumption is strongly supported by a review of the types of active geothermal systems currently in use, and the costs to a homeowner of drilling a well and constructing a delivery system for his individual use. It is assumed that the third-party participant is some form of municipal utility company and that the mode of energy delivery of geothermal to the homeowner is through a district heating system. For potential industrial users, it is assumed that the geothermal system will be under the control of the specific industrial user. These conditions provide the generic framework required to compute the cost of geothermal energy in terms of dollars per millions of BTU's (MM/BTU's).

4.1.1 Derivation of the KGR and KGI Components

The most important component of the ACG expression is the State capital cost variable (KG_j). "Geothermal systems are capital intensive and the fixed costs often comprise 90% of the total annual costs."¹³ The residential and industrial capital cost equations are shown below.

13 Geothermal Resources Council, Direct Utilization of Geothermal Energy: A Technical Handbook, Special Report No. 7 (1979), p. 5-32.

$$KGR_j = WCR + TRANSR + DISTR + REINJR$$

$$KGI_j = WCI + TRANSI + REINJI$$

Where: KG_j = capital cost of the geothermal system in State j
 WC = well cost
 TRANS = transmission costs
 DIST = distribution costs
 REINJ = reinjection cost

The derivation of KGR cost values and associated cost components for the States selected for the market penetration analysis are based on a hypothetical generic geothermal energy system. This system considers space and hot water requirements in a particular area (based upon degree days and usage patterns). Resource information is then reviewed to obtain State geothermal related information. The generic system thus incorporates the amount of geothermal energy required to meet the residential energy demands in a populated square mile area in a specific State, and the costs of the geothermal system required to meet these demands.

Some studies suggest that geothermal systems not be sized to meet the peak load in a given area and recommend some form of conventional heating backup.¹⁴ Because of the large initial capital investment associated with geothermal systems, it is important to realize that if the system operates for shorter time periods, the annualized cost will be higher due to the relative decrease in energy output. This situation leads to a trade-off or optimal system design requirement.

During technical conversations with Pacific Northwest Laboratories, it was learned that an optimal rate of system design is approximately 92% of the peak power requirement.¹⁵ Since actual geothermal systems are designed to meet a considerable portion of the total energy requirement, the generic system in the model is specified to meet the total energy demand.

14 Ibid.; and EG&G Idaho, Inc., Residential Space Heating Cost: Geothermal vs. Conventional Systems (February 1978).

15 Technical discussion with staff of the Geothermal Energy Office of Pacific Northwest Laboratories during September 1980.

The generic system specified for the industrial case is based on the costs of one well supplying all the geothermal energy to the end-user. This assumption is used to enable one to move away from site-specific analyses because industrial process heat user demand varies according to plant size and/or process heat temperature requirements. The only advantage realized by knowing the number of wells required to supply each industrial facility with low temperature ($< 350^{\circ}\text{F}$) needs (which would be unrealistic to obtain) would be a reduction in transmission costs as a result of a greater amount of geothermal energy being pumped through the system. There are no economies of scale associated with drilling a greater number of wells.

Information for deriving and computing the costs attributable to the well cost (WC) expression have been obtained from a number of sources including DOE's Idaho Operations Office, Pacific Northwest Laboratories, and the Bureau of Census.¹⁶ The specific variables that comprise the KGR and KGI equations are as follows:

$$\text{WCR} = (\text{X}) [\text{DC} + .2(\text{DC}) + .15(\text{DC})] + [(\text{PVWR})(\text{X})]$$

$$\text{WCI} = [\text{DC} + .2(\text{DC}) + .15(\text{DC})] + \text{PVWI}$$

Where:

- WC = geothermal well cost
- X = number of wells required to satisfy residential energy demand in a square mile area within a State
- DC = cost per well for a given well depth
- PVWR = annualized residential present value of replacing a well at the end of its system life, i.e., 15 years
- PVWI = annualized industrial present value of replacing a well at the end of its system life, i.e., 15 years

The number of wells (X) value in the industrial case is assumed to be one. For the residential case, the model calculates the number of wells as described below.

$$\text{X} = \left[\frac{\text{DHL}}{500 (\text{DT})} \right] \left[\frac{\text{HH}}{\text{WFR}} \right]$$

16 Ibid., EG&G Idaho, Inc., Residential Space Heating Cost; Ibid., PNL technical discussion; and U.S. Department of Commerce, Bureau of the Census, Census of Population (most recent State report).

Where: DHL = delivered heat load
 DT = amount of heat extracted from the fluid flow in °F
 HH = number of household units served by the generic system (square mile area)
 WFR = well flow rate (in gallons per minute)

Based upon the winter design temperature determined from degree days in a given year, DHL is calculated¹⁸ in the following manner:

$$DHL = [1.25 (500)] [68^{\circ}\text{F} - \text{WDT}^{\circ}\text{F}]$$

Where: WDT = winter design temperature for a given State

The constant (1.25) is a factor that accounts for the overdesign of the system by 25%. This is a common factor incorporated in space and hot water heating systems. The (500) value, the setting for the desired inside temperature (68°F) and WDT are all used to determine the maximum heat load in terms of BTU's. Recommended values for the winter design temperature (WDT°F) are illustrated in Exhibit 12.

EXHIBIT 12: WINTER DESIGN TEMPERATURE DETERMINED FROM DEGREE DAYS

FARENHEIT DEGREE DAYS	WINTER DESIGN TEMPERATURE (°F)
1000	25
2000	15
3000	5
4000	0
5000	-5
6000	-10
7000	-15
8000	-20
9000	-25
10000	-30

18 The general DHL formula was found in Rules of Thumb for Geothermal Direct Applications. EG&G Idaho, Inc., (September 1980).

The extracted heat value (DT) is obtained by subtracting the reject temperature (100°F) from the resource temperature. Data for households are obtained from the Bureau of the Census.¹⁹ Two data tables from the referenced Census publication are of particular interest. The first lists population per square mile for cities having 25,000 or more inhabitants and the second lists population and land area for towns of 2,500 or more inhabitants. Average figures for population per square mile (population density) for cities and towns are divided by a constant (the number of persons per household, 3.2 persons) to obtain total number of households.²⁰ The WFR value is classified into three categories based on well flow rates in gallons per minute (gpm): fair resource flow (200 gpm); good resource flow (500 gpm); and excellent resource flow (800 gpm). Western States are generally considered to have a better flow potential than Eastern States. Hence, the model uses a range of 500-800 gpm for Western areas, and 200-500 gpm for Eastern States. Compilation of the above factors yields the number of geothermal wells required to service a generic residential area within a State.

Estimation of the cost per well for a given depth (DC) is similar for both the residential and industrial cases. The well cost variable is actually comprised of three elements:

- well cost at a given well depth;
- fraction of excess producing wells to provide spare wells; and
- fraction of dry wells.

Data on well costs at a given depth are shown in Exhibit 13.

19 U.S. Department of Commerce, Bureau of the Census, County and City Data Book, (1979).

20 This constant (3.2) is also the default value for number of persons per household used by PNL in their analyses.

EXHIBIT 13: WELL DEPTH AND COST ESTIMATES

DEPTH (ft)	COST (\$)
1000	\$ 50,000
2000	100,000
3000	200,000
4000	350,000
5000	500,000

Source: J. A. Engen, EG&G Idaho, Inc., 1978,
Residential Space Heating Cost, p. 33.

The dry well and spare well fractions included in the DC expression are the default values used in the Pacific Northwest Laboratory Geocity model.²¹

The transmission costs (TRANS) factor is also similar for both residential and industrial cases. The required transmission distance, heat content of the transported water, and flow rate tend to influence the cost of the transmission system. There is evidence that transmission distances for existing geothermal applications are short "rarely exceeding 15km."²² Depending upon the heat content of the geothermal resource and advances in transmission pipe technology, it may be possible to consider distances in the 50 mile range. The following expression is employed to estimate TRANS:

21 C. L. McDonald, et. al., Geocity: A Computer Code for Calculating Costs of District Heating Using Geothermal Resources. (Richland, Washington: Battelle, Pacific Northwest Laboratory, [1977]).

22 C. H. Bloomster, et. al., "Potential for District and Process Heating in the United States." Geothermal Energy, p. 372.

$$\text{TRANS} = (\$/\text{ft}) (D)$$

Where: $\$/\text{ft}$ = installed pipe cost

D = distance in feet

Exhibit 14 illustrates the cost options for installed pipe cost. For purposes of this analysis, the D value is set to 52,800 feet (10 miles).

EXHIBIT 14: TRANSMISSION COSTS

INSTALLED COST ($\$/\text{ft}$)	TEMPERATURE ($^{\circ}\text{F}$)	PIPE DIAMETER ($\$/\text{ft}$)		
		12"	20"	30"
Schedule 10 pipe with polyurethane	< 212	\$ 59	\$ 97	\$ 157
Schedule 40 pipe with calcium silicate	> 212	\$ 74	\$ 112	\$ 178

Source: C. H. Bloomster, et. al., Geothermal Energy, p. 372.

The distance variable (DIST) relates to the delivery system required to supply geothermal energy to a community. For the industrial case, a distribution system cost is not included in cost calculations because it is assumed that the delivered geothermal energy will be used directly at the plant site. For the residential case, the geothermal delivery system is based on features of a district heating system. The following equation is used to compute DIST:

$$\text{DIST} = (M) (\$/\text{MP})$$

Where: M = length of the distribution system in miles

$\$/\text{MP}$ = cost per mile of the distribution system

The cost of the distribution system is heavily dependent on the length of the piping network. A report prepared by Brookhaven National Laboratory (BNL) stated that a distribution network will be similar in length to the piping system of cities that supply water services.²³ The BNL study found that "street densities (i.e., length of street per square mile) were found ranging from 15 to greater than 35 miles per square mile, with a larger percentage of tracts having 20 to 28 miles per square mile."²⁴

In another study the Association of Danish District Heating Distributors developed a model to determine the costs of establishing a district heating network for low heat load density.²⁵ Data from the Danish study suggest a distribution network of approximately 26 miles of pipe for a square mile area. The results from BNL and the Danish report both suggest that a pipe length value in the 25-30 mile range (per square mile) is an appropriate estimate for M. The cost per mile (\$/M) estimate of a distribution network is obtained for various regions throughout the U.S. from information supplied by a BNL report and the Engineering News Record.²⁶

The value for the cost of reinjection (REINJ) is obtained through the following expression:

$$\text{REINJR} = .5 (\text{XDC})$$

$$\text{REINJI} = .5 (\text{DC})$$

This expression is similar to the one used in the PNL "Geocity" model. The reinject cost is dependent on the well cost and the number of wells drilled for a particular system.

23 R. G. Tessener and John Karkheck, Planning Analysis for Geothermal District Heating (Upton, Brookhaven National Laboratory, [December 1979]), p. 6.

24 Ibid.

25 Morgens Larsen, et. al., "Fundamentals and Economic Principles in District Heating Systems," (paper prepared for the Danish Board of District Heating).

26 R. Tesse, et. al., Data Base for District Heating Pipe System Design (Upton, Brookhaven National Laboratory, [August 1979]); and "Construction Scoreboard," Engineering News Record. (July 13, 1979): 31.

4.1.2 Energy Output

A significant input to the calculation of annualized costs for residential and industrial geothermal systems is the energy output (EG) of a generic geothermal system for each State. Dividing the total annualized costs of the geothermal system by system energy output gives annualized energy costs in BTU's for each State as shown below.

$$EGR_j = [(28,000) (DD) (HH)] + [(6.25 \cdot 10^6) (HH) (3.2)]$$

$$EGI_j = [(GPM) (500) (DT) (HL)]$$

Where: EG_j = energy output of a geothermal system in State j
DD = annual degree days
HH = number of households served by a generic system in a square mile area
GPM = well flow rate
DT = temperature differential
HL = annual heating load

The first numerical constant used in the EGR expression (28,000 BTU's) represents the amount of energy consumed in a residential unit of average energy efficiency.²⁷ When this figure is multiplied by degree days (DD), a State average annual heat load is obtained. The second constant ($6.25 \cdot 10^6$) is an estimate of the energy expended (in BTU's) to meet the annual demand for hot water for one person.²⁸

Multiplication of the population by the average annual heating demand for space and water heating gives the total energy output required from the residential geothermal system. For the industrial case (EGI_j), values for GPM will be similar to those used in the KG variable of the residential model. The DT factor is equal to the difference of the resource temperature minus the reject temperature (212°F). Given this reject temperature, market potential of geothermal energy for industrial applications simply does not exist for some States because of low geothermal resource temperatures. The HL factor is the annual load requirement for the system. In this study the value of HL is set at 46%. This figure implies that the output of a geothermal system is used by an industrial plant that operates 16 hours a day, five days a week.

27 Ibid., EG&G, Residential Space Heating Cost, p. 2.

28 Ibid., Brookhaven National Laboratory, Planning Analyses, p. 8.

4.1.3 Compilation of Related Cost Factors

In addition to the capital cost and energy output of the generic geothermal systems, several other cost components affect the annualized system costs. These components include the capital recovery factor(CRF), operations and maintenance cost (O&M), the investment tax credit (ITC), and recurring financial costs associated with the system (D).

The CRF value used in the analysis is 12.4%. This value reflects current and expected interest rate values. The CRF is determined through the application of a standard financial formula regarding interest rates over time, as shown below:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Where: CRF = capital recovery factor
i = interest rate
n = number of years

The O&M costs are expected to approach approximately 8% of system capital costs. This figure includes consideration of fuel costs incurred in the operation of the geothermal well pumping station.

Values for the investment tax credit (ITC) allowed reflect the 15% ITC available to geothermal systems until 1986 as provided by the National Energy Act and Windfall Profit Tax Act. After 1985, ITC values in the model return to the 10% allowed under the U.S. Tax Code.

The value for D reflects the combined effect of interest payments on debt, depreciation, and cost of capital on the annualized financial requirements of geothermal systems. The result is the present value of all future cost factors. The expression used to calculate this parameter is shown below. The D values are calculated for each year of the anticipated life of the geothermal system and summed.

$$D = \sum_{i=1}^k \left[\frac{WC - WD - DF}{(1 + DR)^k} \right]$$

Where: D = present value of future cost factors
 WC = weighted capital recovery factor
 WD = weighted cost of debt
 DF = depreciation charge, sum of years digits
 DR = discount rate
 k = system lifetime

In order to compute a value for D the following subexpressions for WC, WD, and DF must be evaluated. These subexpressions are shown below:

$$WC = \frac{WCC (1 + WCC)^k}{(1 + WCC)^k - 1}$$

$$WD = (DBT) (r) (TXR)$$

$$DF = \left[\frac{2 (k + 1 - n)}{k (k + 1)} \right] TXR$$

Where: WCC = weighted cost of capital
 DBT = percent of investment financed by debt
 r = interest rate
 TXR = effective tax rate

This discussion of the D expression concludes the presentation and explanation of geothermal system cost components. The following section presents the methodology used to calculate conventional energy costs for residential and industrial applications.

4.2 Conventional Energy Costs

The calculation of conventional residential and industrial energy costs is relatively straightforward. The expression below is used for both residential and industrial sectors.

$$ACC_{j,1} = FCOST_{j,1} [(1 + \lambda)^k] (CRF) (FINFAC)$$

Where: $ACC_{j,1}$ = base year annualized cost of conventional energy
 $FCOST_{j,1}$ = base year fuel cost for State j
 λ = fuel cost escalation rate
 k = number of years of system lifetime
 CRF = capital recovery factor
 $FINFAC$ = compounded fuel factor (present value escalation factor) annualized over the system life

The FINFAC itself is calculated using the expression below.

$$FINFAC = \left(\frac{1 + L}{DR - L} \right) \left[1 - \left(\frac{1 + L}{1 + DR} \right)^k \right] (1 - TXR)$$

Where: $FINFAC$ = present value escalation factor
 L = annual fuel cost growth rate
 DR = discount rate
 TXR = effective corporate tax rate

The base year residential and industrial fuel cost variables ($FCOST$) are calculated for each State considered in the analysis. For residential users, $FCOST$ in the base year is the consumption weighted average price (in dollars per million BTU) of residential energy in each State. The source of energy consumption data for States is DOE.²⁹ Data concerning the cost of purchased conventional energy for industry is from the Bureau of the Census.³⁰ For industrial uses, $FCOST$ in the base year is the consumption-weighted average cost (in dollars per million BTU) of purchased conventional energy for seven major SIC industries. This value is adjusted for boiler efficiencies to arrive at a value for industrial end-use energy costs.

29 Ibid., State Energy Data Report.

30 Ibid., Fuels and Electric Energy Consumed.

V. GEOTHERMAL MARKET PENETRATION RESULTS

5.1 Overview

This chapter presents the results of the study - the information, analytical data, and insights realized in the course of the modeling effort. Previous chapters discussed the determination of the relevant energy markets available for capture by geothermal sources, and the approaches to critical components of the analytical system used to generate geothermal market penetration estimates. In this chapter, penetration results are presented for 1990 to 2020 at 10-year intervals for up to three distinct market segments: residences in cities; residences in towns; and industry. These segments are defined below.

<u>Market Segment</u>	<u>Definition</u>
● Residences (Cities):	Localities in identified and projected geothermal resource areas whose population exceeds 25,000 people.
● Residences (Towns):	Localities in identified and projected geothermal resource areas with a population between 2500 - 25,000 people.
● Industry:	Industrial market in identified and projected geothermal resource areas proportionate to the population residing in these areas.

Results for these segments are derived from a Base Case analysis of geothermal penetration and various other sensitivity cases. All cases are presented in detail in this chapter. The disaggregation of the residential sector into cities and towns is provided as a means through which one can examine the small community potential market for geothermal applications.

Not all of the 31 selected States (see Exhibit 8, p. 12) were included in each market analysis. A few States dropped out of the sectoral analyses typically because of low demographics or low resource temperatures. For example, in the

Residences (Cities) market sector analyses, four States³¹ are excluded from consideration because of a lack of population concentration in the resource area. One State - Hawaii - is not included because it exhibited an extremely low requirement for space heating thus affording geothermal little chance to become economically competitive and penetrate the market.

By contrast, all States are included in the Residences (Towns) sector analysis. An interesting and very distinguishing feature of this "small community" sector is its relative size. It is almost half the size of the large residential markets for cities, and about two-thirds the size of the relevant industrial market. Thus, the small community sector indeed provides a sufficiently large market for possible penetration by competitive geothermal sources.

A significant factor affecting the use of geothermal energy in the industrial sector is the temperature of the available resource. Resources exhibiting temperatures of 212°F or less are rejected for inclusion in the industry market analysis in this study because of the relatively low temperature of the resource for industrial uses. As a result of applying this constraint, 11 States are excluded from the industry analysis because of low resource temperatures.³²

5.2 The Base Case

A representative case (the Base Case) is defined to illustrate the penetration potential for geothermal energy. This Base Case can be most effectively used as a heuristic policy tool for decisionmakers. This means that the model's significance derives from the relative values and sensitivities of the input variables rather than the absolute values of the forecasted numbers. Key parameter values for the Base Case are as follows:

- Annual conventional fuel cost escalation factor is 3% greater than the corresponding geothermal factor;
- The Investment Tax Credit (ITC) used reflects current legislation and is valued at 15% through 1985 and at 10% thereafter;

31 All are Eastern States including Delaware, Maryland, North Carolina, and West Virginia.

32 States excluded are Alabama, Arkansas, Illinois, Indiana, Michigan, Mississippi, Missouri, New York, Ohio, Pennsylvania, and West Virginia.

- A system life of 30 years; and
- A market adjustment factor (MAF) which constrains geothermal market penetration to approximately 60% of the total relative potential geothermal market.

5.2.1 Base Case Results

Results for the Base Case are shown in detail in Exhibit 15. The exhibit shows (by year) the market available to geothermal (in quads), geothermal penetration into that market (in quads), and the percent of the available market captured by geothermal applications. Results for residences in both cities and towns in 1990 are dominated by the contributions of three Western States - Idaho, Montana, and Oregon. Geothermal residential applications contribute 0.02 quads per year by 1990. The three Western States continue to dominate the results for Towns (small community applications) through 2020, the last year studied. In the Cities market, however, after early results similar to that of Towns, penetration appears in all regions of the country by the year 2000. Geothermal's contribution in all residential applications in 2000 is 0.064 quads rising to 0.446 quads in 2020.

As expected, market penetration in Industry begins early in the West, but begins to show some promise in other regions by the year 2000. From a contribution of 0.001 quad in 1990, geothermal industrial applications can be expected to contribute 0.019 quads in 2000 and 0.289 quads by 2020. For all sectors in the Base Case, geothermal penetration will yield approximately 0.02 quads in 1990, 0.08 quads in 2000, and 0.74 quads in 2020. This amounts to about 0.5%, 2%, and 12% of the available market respectively.

One interesting result of the Base Case analysis is that three out of the four Eastern States excluded from the Cities sector (Delaware, Maryland, and North Carolina) penetrate in the Industry analysis before 2010. This result, in conjunction with residential penetration projections for several Eastern States, suggests that the Eastern market sector does present promising market development characteristics and that geothermal resources can be developed on a National basis for both residential and industrial direct heat applications.

5.3 Sensitivity Analysis

A key feature of the market penetration approach used in this study is that it affords the analyst an opportunity to examine geothermal market potential under differing conditions. For example, once Base Case estimates are obtained, key model parameters may be changed and the system re-estimated to assess the

**EXHIBIT 15: BASE CASE MARKET PENETRATION
(IN QUADS)**

RESIDENCES - CITIES

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.5	1.85	2.25	2.8
GEOHERMAL PENETRATION	0.015	0.046	0.219	0.410
GEOHERMAL MARKET SHARE	1.0%	2.5%	10.0%	15.0%

RESIDENCES - TOWNS

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	0.8	0.9	1.1	1.4
GEOHERMAL PENETRATION	0.005	0.018	0.028	0.036
GEOHERMAL MARKET SHARE	0.6%	2.0%	2.5%	2.6 %

INDUSTRY

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.3	1.5	1.74	2.1
GEOHERMAL PENETRATION	0.001	0.019	0.172	0.289
GEOHERMAL MARKET SHARE	0.1%	1.3%	10.0%	14.0%

TOTAL

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	3.6	4.25	5.09	6.3
GEOHERMAL PENETRATION	0.02	0.08	0.42	0.74
GEOHERMAL MARKET SHARE	0.5%	2.0%	8.0%	12.0%

"sensitivity" of the results to changes in the key parameters. This process of changing key parameters, obtaining new results, and comparing them to those received for the Base Case allows for the assessment of the significance or impact of key policy and exogenous variables on the market development of geothermal applications. Several factors that can affect geothermal market penetration include:

- Investment Tax Credits:
- Cost differential between conventional and geothermal energy;
- Market adjustment and consumer response;
- Higher initial industrial fuel prices; and
- Life cycle of the geothermal energy system.

Sensitivity analyses have been conducted with respect to each of the above factors. The results of these analyses are presented side-by-side with Base Case results for ease of comparison.

5.3.1 Investment Tax Credit Cases

The Investment Tax Credit (ITC) is an important policy tool available to the government which can be used effectively to assist private sector geothermal commercialization. The conventional tax credit for business investment has been 10% since the early 1960s. As a result of recent energy legislation (National Energy and Windfall Profits Tax Acts), the ITC for geothermal equipment is increased to 15% until 1986. The Base Case scenario incorporates the 15% value until 1986 and then returns the ITC value to 10% for the remaining years. Two sensitivity cases are constructed to help determine the effect of ITC legislation and policy on geothermal penetration. The first case keeps the ITC at its current level (15%) for all years. The second case increases the ITC from 15% to 20% after 1986 (reflecting several legislative proposals currently before Congress).

The impact of the ITC variable on the market penetration potential of geothermal energy can be seen in Exhibit 16. Because the ITC is similar in all cases until 1986, one would anticipate the impact on 1990 penetration to be minimal. This outcome is amply illustrated in the results for Cities. It is important to note, however, that two large States (California and Pennsylvania) experience earlier market penetration (in 1990) as a result of higher ITC values. As the Cities results from the ITC cases are compared to Base Case results it becomes apparent that the ITC does play a role in aiding penetration in the early market development stages of geothermal energy (through the year 2000). Because the ITC

EXHIBIT 16: ITC MARKET PENETRATION CASES (IN QUADS)

RESIDENCES - CITIES

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.5	1.85	2.25	2.8
GEOHERMAL PENETRATION				
Base Case	0.015	0.046	0.219	0.410
ITC at 15%	0.017	0.090	0.244	0.922
ITC at 20%	0.018	0.114	0.363	0.988
GEOHERMAL MARKET SHARE				
Base Case	1.0%	2.5%	10.0%	15.0%
ITC at 15%	1.1%	4.9%	11.0%	33.0%
ITC at 20%	1.3%	6.2%	16.0%	35.3%

RESIDENCES - TOWNS

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	0.8	0.9	1.1	1.4
GEOHERMAL PENETRATION				
Base Case	0.005	0.018	0.028	0.036
ITC at 15%	0.007	0.021	0.028	0.044
ITC at 20%	0.009	0.022	0.029	0.091
GEOHERMAL MARKET SHARE				
Base Case	0.6%	2.0%	2.5%	2.6%
ITC at 15%	0.9%	2.3%	2.5%	3.1%
ITC at 20%	1.0%	2.4%	2.6%	6.5%

INDUSTRY

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.3	1.5	1.74	2.1
GEOHERMAL PENETRATION				
Base Case	0.001	0.019	0.172	0.289
ITC at 15%	0.001	0.029	0.192	0.385
ITC at 20%	0.001	0.045	0.207	0.561
GEOHERMAL MARKET SHARE				
Base Case	0.1%	1.3%	10.0%	14.0%
ITC at 15%	0.1%	2.0%	11.0%	18.0%
ITC at 20%	0.1%	3.0%	12.0%	27.0%

TOTAL

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	3.6	4.25	5.09	6.3
GEOHERMAL PENETRATION				
Base Case	0.02	0.08	0.42	0.74
ITC at 15%	0.025	0.14	0.46	1.35
ITC at 20%	0.029	0.18	0.6	1.64
GEOHERMAL MARKET SHARE				
Base Case	0.5%	2.0%	8.0%	12.0%
ITC at 15%	0.7%	3.0%	9.1%	21.0%
ITC at 20%	0.8%	4.2%	11.8%	26.0%

improves the economics of geothermal energy earlier in several States, a larger portion of the potential market is captured in the long term. In fact, the 15% ITC case quad contribution (1.35) is nearly double that of the Base Case (0.74). The 20% ITC case also provides for penetration in three States not penetrated by the other two cases - Alaska, Indiana, and Mississippi.

Penetration in small community applications (Towns) occurs at a slow pace. Three States (Idaho, Montana, and Oregon) comprise the market up to the year 2000 for all three cases in Exhibit 16. A major factor for this is the lower population density associated with the smaller communities. This leads to a lower overall amount of energy consumption which implies the cost of geothermal energy will be distributed over fewer BTU's. Comparison of the Base and 15% ITC Cases yields only minor differences in terms of BTU penetration. The 20% ITC case, however, does generate a significant impact between 2010 and 2020. During this period, penetration either continues or begins for 15 States. This is in contrast to 7 States in the Base Case and 10 in the 15% ITC Case.

A comparison of the Industry sector results shows that changes in the ITC generate small impacts until the year 2000. One reason for this outcome is that Base Case penetration is underway in all of the 20 applicable States before 2010. Because of the small values associated with the initial years of a particular State's penetration, the resulting difference between the Base and ITC Cases is small. The primary difference between the Industry ITC Cases and the Base Case is that for the ITC Industry Cases, a slightly larger amount of penetration occurs earlier in each State. This does tend to improve the acceptance of geothermal by users over time and results in larger penetration. This is illustrated in the long-term results. In the Base Case, for example, Colorado shows penetration in Industry markets in 2010, but yet geothermal captures only 0.006% of the potential market by 2020. For the 15% and 20% ITC Cases, however, Colorado shows Industry penetration earlier and stronger. By 2020, the ITC Cases project Colorado to capture 7.5% and 24% of the Industry market in the respective ITC Cases. This example illustrates how the long-term penetration difference occurs as a result of small, but earlier market penetration resulting from increased ITC allowances.

5.3.2 High Prices Case

It is anticipated that the future movement of energy prices will play a significant role in affecting geothermal energy use in both the residential and industrial sectors. Because of the variability and unpredictability of conventional energy prices, it was necessary to construct a sensitivity case to capture the

effect of possibly higher conventional fuel prices on the analysis.

The Base Case scenario accounts for the expectation that the cost of energy from all sources will rise over time. The Base Case also allows conventional fuel costs to increase 3% more per year than corresponding geothermal energy costs. Keeping all other Base Case parameters constant, the High Prices Case merely allows conventional fuel costs to rise at a rate 5% per year more than corresponding geothermal costs. In this way greater price differentials are factored into the market penetration analysis.

Results for the High Prices Case and Base Case are presented side-by-side in Exhibit 17. The anticipated higher prices for conventional fuels significantly affect the penetration for geothermal applications in the three market segments considered. The most pronounced impact occurs in the Cities market sector for the year 2000. A review of State penetration results reveals a strong penetration acceleration occurring during this time period in California, Colorado, New York, Utah, Virginia, and Washington. California accounts for approximately 33% of the total potential market in the Cities analysis. Therefore, a rapid increase in this State will strongly impact penetration results. Although the pronounced effect shown in the results would be difficult to achieve by 2000, it is worthwhile to note the degree of economic competitiveness associated with geothermal energy in these States.

For Towns, the fastest increase in market penetration occurs between 2000-2010. This result suggests that high, and rising conventional fuel costs can override a major constraint to small community applications - low population density. States showing penetration for Towns are also widely distributed across the United States. Geothermal energy is shown as being used in 19 States by the year 2010. It is important to note that the two largest potential geothermal State markets (California and Texas) are not showing market penetration in the Towns segment. The primary factors influencing the results for California are the low value for State average annual degree days that determines residential space heating requirements and a fairly low initial price for conventional fuels. For the Texas results, the influencing factors include a low value for degree days and small population density values.

The High Prices Case results for Industry indicate that industry users can be expected to be very responsive to price differentials between geothermal and conventional energy systems. Under the High Prices Case, for example, geothermal penetration rises from 0.4% in 1990 to 50% in the year 2020. This compares to an increase from 0.1% to 14% in the Base Case.

EXHIBIT 17: HIGH PRICES CASE (IN QUADS)

RESIDENCES - CITIES

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.5	1.85	2.25	2.8
GEOHERMAL PENETRATION				
Base Case	0.015	0.046	0.219	0.410
High Case	0.039	0.552	0.844	1.193
GEOHERMAL MARKET SHARE				
Base Case	1.0%	2.5%	10.0%	15.0%
High Case	2.6%	29.0%	37.5%	42.6%

RESIDENCES - TOWNS

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	0.8	0.9	1.1	1.4
GEOHERMAL PENETRATION				
Base Case	0.005	0.018	0.028	0.036
High Case	0.018	0.028	0.212	0.371
GEOHERMAL MARKET SHARE				
Base Case	0.6%	2.0%	2.5%	2.6%
High Case	2.2%	3.1%	19.3%	26.5%

INDUSTRY

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.3	1.5	1.74	2.1
GEOHERMAL PENETRATION				
Base Case	0.001	0.019	0.172	0.289
High Case	0.005	0.156	0.334	1.042
GEOHERMAL MARKET SHARE				
Base Case	0.1%	1.3%	10.0%	14.0%
High Case	0.4%	10.0%	19.0%	50.0%

TOTAL

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET PENETRATION	3.6	4.25	5.09	6.3
GEOHERMAL PENETRATION				
Base Case	0.02	0.08	0.42	0.74
High Case	0.06	0.74	1.39	2.60
GEOHERMAL MARKET SHARE				
Base Case	0.5%	2.0%	8.0%	12.0%
High Case	1.6%	17.4%	27.3%	41.0%

There are also several other observations of interest when comparing the two cases. The three largest potential industrial markets (California, Louisiana, and Texas) and the five Eastern Shore States (Delaware, Maryland, New Jersey, North Carolina, and Virginia) all have significant increases in predicted penetration in the High Prices Case as compared to Base Case results. Some of the relevant State specific market share results are shown below in Exhibits 18 and 19.

The responsiveness of the geographic markets shown in Exhibits 18 and 19 to higher conventional fuel prices suggests that the distribution of technical and resource related information directed to target groups (such as State two-digit SIC industry groups, or even individual firms possibly subject to higher conventional fuel prices) may be an effective way to assist private interests in evaluating and investing in geothermal energy applications. In this way, private sector geothermal market development activities can increase the pace of market penetration in markets exhibiting the greatest likelihood for successful geothermal energy contributions.

5.3.3 Market Adjustment Factor Case

The market adjustment factor (MAF) is a measure of the potential energy market response to the introduction of geothermal energy into the marketplace. One recent study examined this issue with respect to fuels.³³ For a new energy source, it usually takes between 40-60 years to capture 50% of the market. The MAF in the Base Case is constrained to approximately 60% of the market in the long run. The assumption underlying this value is that a defined market sector will generate a more rapid market response than the penetration rate applicable to the overall primary market.

Because changes in the MAF will affect projected penetration, a sensitivity case has been undertaken with the MAF constrained to 50% of the market, a lower value than that used for the Base Case. Results of this outcome are shown in Exhibit 20 for the Cities and Industry sectors. These results show that, for both sectors, penetration slows considerably (greater than the differential between the 50% and 60% values) as a result of using the MAF at 50%. Depending on the sector, this slowdown affects either the timing of initial penetration or the amount of penetration in a given year for the various States. A clearer indication of the

33 Ibid., Technology, "Substitution Models."

**EXHIBIT 18: MARKET SHARE COMPARISON OF LARGE POTENTIAL
INDUSTRIAL MARKETS
(IN PERCENT)**

STATE		1990	2000	2010	2020
CALIFORNIA	- Base Case	0.1	2.8	34.0	42.0
	High Case	0.6	37.0	49.0	53.0
LOUISIANA	- Base Case	-	0.005	0.03	5.9
	High Case	-	0.01	8.0	53.0
TEXAS	- Base Case	-	-	0.003	0.3
	High Case	-	0.003	1.0	52.0

**EXHIBIT 19: MARKET SHARE COMPARISON OF EASTERN
INDUSTRIAL MARKETS
(IN PERCENT)**

STATE		1990	2000	2010	2020
DELAWARE	- Base Case	-	-	0.0002	0.007
	High Case	-	0.002	0.2	44.0
MARYLAND	- Base Case	-	-	0.0003	0.01
	High Case	-	0.002	0.4	47.0
NEW JERSEY	- Base Case	-	-	0.001	0.05
	High Case	0.0001	0.005	1.0	49.0
NORTH CAROLINA	- Base Case	-	-	0.0002	0.007
	High Case	-	0.002	0.3	44.0
VIRGINIA	- Base Case	-	-	0.0008	0.03
	High Case	0.0001	0.005	0.9	49.0

EXHIBIT 20: MARKET ADJUSTMENT FACTOR (MAF) AND
CONSUMER RESPONSE CASES
(IN QUADS)

RESIDENCES - CITIES

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	0.5	0.85	2.25	2.8
GEOHERMAL PENETRATION				
Base Case	0.015	0.046	0.219	0.410
MAF at 50%	0.004	0.016	0.033	0.188
Increase in "λ"	0.019	0.067	0.239	0.347
GEOHERMAL MARKET SHARE				
Base Case	1.0%	2.5%	10.0%	15.0%
MAF at 50%	0.3%	0.9%	1.5%	6.7%
Increase in "λ"	1.3%	3.6%	10.6%	12.4%

INDUSTRY

	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.3	1.5	1.74	2.1
GEOHERMAL PENETRATION				
Base Case	0.001	0.019	0.172	0.289
MAF at 50%	-	-	0.001	0.004
Increase in "λ"	0.006	0.014	0.216	0.515
GEOHERMAL MARKET SHARE				
Base Case	0.1%	1.3%	10.0%	14.0%
MAF at 50%	-	-	0.05%	0.2%
Increase in "λ"	0.5%	1.0%	12.0%	24.0%

impact magnitude is presented in Exhibits 21 and 22. These exhibits compare the Base and MAF 50% Cases market penetration shares (as a percent of the potential State-specific markets) for every State that has penetration potential between 1990 - 2020.

5.3.4 Consumer Response Case

The market model estimates a value for the consumer response parameter, alpha. For sensitivity purposes, the values for the residential and industrial alpha's were doubled. This changed the residential alpha from 2.95 to 5.9 and the industry alpha from .79 to 1.8. The impact on market penetration potential is shown in detail in Exhibit 20. For Cities, penetration results are very close for the two cases through 2010. While the higher residential alpha does bring forth slightly greater levels of State penetration, there is no change between the two cases with respect to the States that experience penetration. The Base Case forecasts a greater amount of penetration in 2020 than does the response sensitivity case. This is the result of the differences in the shape of the response curves in each of the two cases. The increased value for alpha in the Response Case is such that the slope of the penetration curve levels off at an earlier time period, the result illustrated at the 2020 time period yielding a lower penetration value.

The slopes of the penetration curves for the two cases run for the Industry sector are very similar until the final time period. Because of the lower industrial value for the industry response parameter, alpha, the doubling of the industry alpha for the Response Case analysis does not cause the slope of the curve to level off at an earlier time period as was the case for the Cities sector. Instead, this sector is still projected to be on the rising portion of the curve. This results in a greater amount of Industry penetration occurring from 2010-2020 in the Response Case than in the Base Case.

5.3.5 Industry High Initial Prices Case

Results for the Industry market segment in the Base Case and all previous sensitivity cases have implicit in them the use of a weighted average of conventional fuel prices paid by the SIC industries included in the State-level analyses. In this sensitivity case, State conventional fuel prices for industry reflect the highest price paid for any conventional fossil fuel by any included SIC industry in each State studied. Thus, this case is constructed to measure the effect on Industry market penetration of increased conventional fuel

**EXHIBIT 21: RESIDENCES - CITIES MARKET SHARE COMPARISON
(IN PERCENT)**

STATE		1990	2000	2010	2020
ARIZONA	- Base Case	-	-	0.0007	1.0
	MAF at 50%	-	-	-	-
CALIFORNIA	- Base Case	-	-	0.004	5.0
	MAF at 50%	-	-	-	-
COLORADO	- Base Case	0.07	13.0	56.0	60.0
	MAF at 50%	0.002	0.02	3.0	46.0
IDAHO	- Base Case	50.0	57.0	60.0	60.0
	MAF at 50%	15.0	43.0	47.0	49.0
ILLINOIS	- Base Case	-	-	-	0.04
	MAF at 50%	-	-	-	-
MICHIGAN	- Base Case	-	0.0009	1.5	59.0
	MAF at 50%	-	-	0.00001	0.05
MONTANA	- Base Case	21.0	54.0	59.0	60.0
	MAF at 50%	0.9	26.0	45.0	48.0
NEVADA	- Base Case	0.006	0.03	9.0	57.0
	MAF at 50%	-	-	0.0009	0.1
NEW MEXICO	- Base Case	0.06	6.2	55.0	59.0
	MAF at 50%	0.002	0.01	0.8	45.0
NEW YORK	- Base Case	0.001	0.8	55.0	61.0
	MAF at 50%	-	0.001	0.3	40.0
OHIO	- Base Case	-	0.001	1.0	59.0
	MAF at 50%	-	-	-	0.004
OREGON	- Base Case	51.0	58.0	60.0	60.0
	MAF at 50%	12.0	44.0	47.0	49.0
PENNSYLVANIA	- Base Case	-	0.02	47.0	60.0
	MAF at 50%	-	-	0.008	3.7
UTAH	- Base Case	0.0001	0.0005	0.1	50.0
	MAF at 50%	-	-	-	0.001
VIRGINIA	- Base Case	0.001	1.2	59.0	60.0
	MAF at 50%	-	0.002	0.5	47.0
WASHINGTON	- Base Case	0.005	0.5	59.0	60.0
	MAF at 50%	-	0.001	0.3	46.0
WYOMING	- Base Case	1.7	53.0	58.0	60.0
	MAF at 50%	0.05	2.3	44.0	48.0

**EXHIBIT 22: INDUSTRY MARKET SHARE COMPARISON
(IN PERCENT)**

STATE		1990	2000	2010	2020
ALASKA	- Base Case	3.0	35.0	41.0	46.0
	MAF at 50%	0.1	0.4	3.0	21.0
ARIZONA	- Base Case	0.0002	0.002	0.08	6.4
	MAF at 50%	-	-	-	-
CALIFORNIA	- Base Case	0.1	2.8	34.0	42.0
	MAF at 50%	0.003	0.005	0.01	0.1
COLORADO	- Base Case	0.002	0.006	0.06	1.8
	MAF at 50%	-	-	-	-
DELAWARE	- Base Case	-	-	0.0002	0.0007
	MAF at 50%	-	-	-	-
HAWAII	- Base Case	-	-	0.0003	0.01
	MAF at 50%	-	-	-	-
IDAHO	- Base Case	0.1	2.8	35.0	42.0
	MAF at 50%	0.003	0.005	0.01	0.1
LOUISIANA	- Base Case	-	0.005	0.03	5.9
	MAF at 50%	-	-	-	-
MARYLAND	- Base Case	-	-	0.0003	0.01
	MAF at 50%	-	-	-	-
MONTANA	- Base Case	0.02	0.2	5.8	37.0
	MAF at 50%	-	0.0003	0.006	0.006
NEVADA	- Base Case	1.0	10.0	33.0	39.0
	MAF at 50%	-	0.02	0.06	0.3
NEW JERSEY	- Base Case	-	-	0.001	0.05
	MAF at 50%	-	-	-	-
NEW MEXICO	- Base Case	0.1	1.8	27.0	39.0
	MAF at 50%	0.004	0.004	0.007	0.04
NORTH CAROLINA	- Base Case	-	-	0.0002	0.007
	MAF at 50%	-	-	-	-
OREGON	- Base Case	1.4	22.0	38.0	43.0
	MAF at 50%	0.04	0.08	0.4	4.0
TEXAS	- Base Case	-	-	0.003	0.3
	MAF at 50%	-	-	-	-
UTAH	- Base Case	0.001	0.006	0.1	4.3
	MAF at 50%	-	-	-	-
VIRGINIA	- Base Case	-	-	0.0008	0.03
	MAF at 50%	-	-	-	-
WASHINGTON	- Base Case	0.06	1.8	35.0	43.0
	MAF at 50%	0.001	0.003	0.01	0.1
WYOMING	- Base Case	0.005	0.03	0.8	24.0
	MAF at 50%	-	-	-	0.0002

prices at the outset of the analysis. The results of this construct are shown below in Exhibit 23.

Case I denotes the use of high initial industrial fuel prices and the assumption that conventional energy prices will escalate 3% per year faster than will geothermal. Case II again denotes the use of the high prices, but the growth differential between conventional and geothermal costs is changed to 5% per year. As can be seen in Exhibit 23, the higher prices in Case I result in a rapid increase in geothermal market penetration from 1990 to 2000. In the longer term (2000-2020), however, penetration is only 10% greater as a result of higher initial industrial prices. This result suggests that there exists the potential for accelerating near-term market development of geothermal resources for specific industries located in or near geothermal resource areas that are currently using high-cost conventional fuels.

The results for Case II indicate the very noticeable impact of higher initial prices and higher price growth rates in every time period. One reason for the larger impact is that the three States with the largest industrial potential (California, Louisiana, and Texas) have greatly enhanced penetration relative to the other cases during 2000-2010. The Eastern Shore States (Delaware, Maryland, New Jersey, North Carolina and Virginia) also project much larger increases over the other cases starting in 2010. These results indicate industrial geothermal penetration is very sensitive to both higher industrial conventional energy prices, and higher relative prices as reflected in the price growth rates. This result may take on increased importance if conventional prices for industry were to experience moderate initial increase (perhaps as the result of fuel shortages, embargo, deregulation, utility rate and rate design changes, etc.) or grow at a rate moderately faster than geothermal.

5.3.6. System Life Case

The annualized cost equation specified in the model (and applicable to all cases thus far) is based on a projected system life of 30 years. Residential markets are excluded from this analysis for two reasons:

- The analysis assumes residential users will not own the geothermal system themselves, but will have geothermal energy supplied to them by a third party (notably a utility-type company); and
- Utility -operated systems are usually financed over longer time intervals (20-30 years).

The industrial sector treatment of investment procedures, however, is strongly linked to payback financial criteria. In the real world, a payback period of

EXHIBIT 23 : INDUSTRIAL HIGH INITIAL PRICES CASE
(IN QUADS)

	<u>INDUSTRY</u>			
	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.3	1.5	1.74	2.1
GEOTHERMAL PENETRATION				
Base Case	0.001	0.019	0.172	0.289
Industrial Case I*	0.002	0.034	0.190	0.333
Industrial Case II**	0.007	0.180	0.377	1.055
GEOTHERMAL MARKET SHARE				
Base Case	0.1%	1.3%	10.0%	14.5%
Industrial Case I	0.2%	2.2%	11.0%	16.0%
Industrial Case II	0.5%	12.0%	22.0%	50.0%

* Case I = 3% escalation factor

** Case II= 5% escalation factor

between 3-7 years is usually a necessary condition in the investment evaluation and decision process.

An examination of the market potential of geothermal energy with respect to usual industrial investment criteria requires the specification of system costs to reflect payback criteria. This type of process would require an alteration in the current model format outside the scope of this effort. One way to obtain a rough approximation of the way geothermal systems may fare in the payback investment climate is by restricting the life-cycle of a system and re-measuring market penetration. This method differs from the payback approach in that the restricted life-cycle actually shrinks the investment life, thereby determining a different expected life of the system. The payback approach would have to be designed to restrict cumulative costs and benefits to be equal over a specified period of time within the expected life. For sensitivity purposes, then, system life is set to 10 years in the Base and High Prices Cases to arrive at two new cases reflecting restricted system life: the Base System Case (BSC) and the High System Case (HSC). All other case parameters remain unchanged.

The results of the System Life Case are presented in Exhibit 24. The restricted system life curtails geothermal penetration in the BSC and delays geothermal development in the HSC. As a result of these industrial results, it may be useful to undertake a closer examination of the industrial sector, with emphasis on incorporating a payback equivalent approach into the market penetration model.

EXHIBIT 24: SYSTEM LIFE CASE (IN QUADS)

	<u>INDUSTRY</u>			
	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
MARKET POTENTIAL	1.3	1.5	1.74	2.1
GEOHERMAL PENETRATION				
BSC	0	0	0	0
BSC with ITC at 15%	0	0	0.001	0.007
HSC	0	0	0.011	0.227
HSC with ITC at 15%	0	0.001	0.024	0.256
GEOHERMAL MARKET SHARE				
BSC	-	-	-	-
BSC with ITC at 15%	-	-	-	0.3%
HSC	-	-	0.6%	10.8%
HSC with ITC at 15%	-	-	1.4%	12.0%

VI.

SUMMARY AND CONCLUSIONS

The market penetration results estimated during the course of this study provide some interesting insights and conclusions regarding opportunities for the continued and enhanced development of geothermal energy applications. One important result of this study is the identification of a significant small community (Towns) market segment that exhibits geothermal market potential. This sector is one-half as large as the residential Cities sector and about two-thirds the size of relevant Industry markets. Because rural and small communities generally face higher conventional energy prices than do more urban, more densely populated centers geothermal prospects in these smaller communities may be significant. Because of the large market size for Towns and the future economic competitiveness of geothermal in these applications, geothermal program officials may wish to consider future research and development activities specifically targeted to small community geothermal systems and market strategies.

Base Case results generated by the analysis provide the foundation for the examination of geothermal market potential. This potential is estimated to be approximately 0.015 quads for residential applications in Cities of 25,000 persons or more, 0.005 quads for residential applications in Towns of 2,500-25,000 persons and 0.001 quads for industrial low-temperature heat uses (all in the year 1990). For 2020, these values increase to 0.41, 0.036 and 0.289 quads respectively for the appropriate sectors.

Aggregate results for all market segments considered in the Base Case analysis show that the overall use of geothermal energy applications is generally distributed among the States. The analysis further reveals, however, that State geothermal penetration in one market segment should not be taken to imply penetration in another market sector. For example, industrial penetration is shown in a larger number of States than is residential penetration, even though 11 out of the 31 States were excluded from the delineation of the available industrial market in the study because of insufficient resource temperatures.

Sensitivity results also provide insight into how differing policy and exogenous variables may affect geothermal development. One sensitivity case concentrated on the possible effects of changes in allowable Investment Tax Credits (ITC) for geothermal systems. It is shown that raising the ITC to 15% across the board would likely have a small impact on geothermal penetration. Increasing the credit to 20%, however, results in a much greater geothermal contribution in all three markets studied.

As expected, results indicate that relative prices also play an important role in determining geothermal market potential. Accordingly, geothermal energy applications will probably reap the benefits of the eventual decontrol of natural gas, a major competitor fuel. Results from two sensitivity cases using higher conventional price scenarios show improvements in short-term penetration due to more favorable relative prices.

In sum, it appears that geothermal penetration potential can be assisted by the clear identification of residential and industrial potential users who are confronted with higher than average conventional fuel costs. Further examination may also reveal particular geographic markets exhibiting high conventional fuel costs which can serve as an early commercialization focus for geothermal developers. The experience gained in these markets, combined with the emergence of a geothermal infrastructure and experience base, will directly help the overall development of geothermal energy as a viable National energy resource.

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