NATURAL RESOURCES JOURNAL

Volume 22
Issue 2 *Spring 1982*

Spring 1982

Energy Market Impacts of the Legal Definition of Geothermal Energy in the Western United States

Paul McDevitt

Del Wells

Paul McDevitt* and Del Wells**

Energy Market Impacts of the Legal Definition of Geothermal Energy in the Western United States

INTRODUCTION

Comprehensive energy market forecasts for the United States in both the mid term and the long term have proliferated in recent years.[1] As more is learned about the technology and economics of the newer, nontraditional energy forms, estimates of their market potential are appearing in the energy literature.[2] These forecasts are usually prepared without explicit recognition of the broad range of social, institutional, and legal considerations which frequently constitute the primary obstacles to widespread commercialization.

This paper examines the influence of one such impact on the energy market potential of a relatively new energy source in the United States. The energy which is considered is geothermal energy, and the market constraint which is examined is the legal one which results from the lack of a viable statutory definition of geothermal energy across the states.

The organization of the ensuing material is as follows. In the first section, the evolution of existing definitions of geothermal energy is described. Efforts within the individual states to formulate acceptable geothermal statutes will be traced, and some of the major issues will be identified. In the second section, a model which estimates the market potential of non-electric uses of geothermal energy will be introduced. This model will be implemented to estimate the energy market impacts of one approach for defining geothermal energy which seems to have

*Research Economist, Center for Business Research and Services, New Mexico State University.

**J.D., Associate Professor of Business Law, Department of Marketing and General Business, New Mexico State University.

1. *See, e.g.*, R. STOBAUGH AND D. YERGIN, ENERGY FUTURE: REPORT OF THE ENERGY PROJECT AT THE HARVARD BUSINESS SCHOOL (1979); H. LANDSBERG, ENERGY: THE NEXT TWENTY YEARS, A REPORT SPONSORED BY THE FORD FOUNDATION AND ADMINISTERED BY RESOURCES FOR THE FUTURE (1979); S. SCHURR, ENERGY IN AMERICA'S FUTURE: THE CHOICES BEFORE U.S. (1979); and C. WILSON, ENERGY: GLOBAL PROSPECTS 1985–2000 (1977).

2. *See, e.g.*, the following three reports by the Harbinger Research Corporation: The U.S. Shale Oil Industry: 1981–2000, The U.S. Ethanol Industry: 1981–2000, and The Emerging Synthetic Fuels Industry. *See also* Hill, *Coal Liquefaction*, 1 THE ENERGY J. 87 (1980); Renemann, *Biomass Energy Economics*, 1 THE ENERGY J. 107 (1980); McDevitt, Nowotny, *High Temperature Geothermal Energy Supply Forecasts for the U.S.A.*, ENERGY ECONOMICS 223 (1980); Houldsworth and McDevitt, *Geothermal Energy: Non-Electric Potential in the USA*, ENERGY POLICY (forthcoming, June 1982).

acquired substantial support in recent years. In the final section, the major conclusions will be summarized.

LEGAL DEFINITIONS OF GEOTHERMAL ENERGY IN THE UNITED STATES

Geothermal energy is the energy contained in the natural heat of the earth's core. A clear legal definition of geothermal energy has been difficult to formulate, because the heat, which results from radioactive decay of the earth, exists in three alternative forms. These include the relatively rare steam or vapor dominated systems; the relatively prevalent hydrothermal or hot water systems; and hot dry rock formations. The most widely recognized examples of geothermal energy are the steam regimes at Yellowstone in Montana and at The Geysers in Northern California. In fact, electricity has been generated at The Geysers since 1960, and the present capacity of 906 MW_e makes this the world's largest geothermal electric facility. For this reason, perhaps, much of the existing statutory and case history of geothermal energy in the United States deals with steam resources.

Steam Resources

The California legislature enacted the nation's first geothermal statute in 1965. This law dealt with the regulation of drilling methods and the prevention of waste. Two years later the state, recognizing the longer run economic potential of The Geysers and the attendant need for a leasing and royalty policy, changed the statute. However, the primary focus of the California Geothermal Act of 1967 remained the steam resource at The Geysers.

The Federal Geothermal Steam Act of 1970[3] followed the lead of California in focusing upon the relatively rare case of geothermal steam. This Act defines geothermal energy as:

> i. all products of geothermal processes, embracing indigenous steam, hot water, and hot brines;
> ii. steam and other gases, hot water and brines resulting from water, gas, or other fluids artificially introduced into geothermal formations;
> iii. heat or other associated energy found in geothermal formations; and
> iv. any by-product derived from them.

Note that hot water and steam are included in this definition, thus creating potential conflicts with state water laws if the water is recharged by groundwater from the natural stream system of the state.

3. 30 U.S.C. §§ 1001-1025 (1970).

The most recent case law also focuses upon the resolution of issues which pertain to the commercial exploitation of The Geysers. Consider the case of *Reich v. Commissioner of Internal Revenue*.[4] The principal factual dispute between the parties before the Tax Court concerned the nature and exhaustibility of the steam reserves at The Geysers. After reviewing extensive documentary evidence and hearing expert testimony from geologists and engineers, the Tax Court made these findings of fact:

> Geothermal steam is a gas. The geothermal steam at The Geysers is contained with a closed reservoir in a finite amount with no significant liquid influx to or boiling within its confines. The geothermal steam at The Geysers is an exhaustible natural resource which has depleted and is continuing to deplete.[5]

The more difficult question presented to the Tax Court was whether geothermal steam is subject to the depletion allowance. The depletion allowance is designed to stimulate resource exploitation by ensuring that a developer can recover the capital invested in wasting assets. The Internal Revenue Code states:

> In case of mines, oil and gas wells, other natural deposits, and timber, there shall be allowed as a deduction in computing taxable income a reasonable allowance for depletion. . . .[6]

The Commissioner's position is that this favorable tax treatment applies only to petroleum and hydrocarbonaceous natural gas deposits and cannot be construed to cover geothermal steam reserves. The Tax Court disagreed, holding that the steam deposit at The Geysers is a gas within the meaning of oil and gas in the Code.

In *U.S. v. Union Oil Company*,[7] the ninth circuit reversed a lower federal court ruling that geothermal energy in The Geysers area of Sonoma County, California is actually superheated steam, which is water and which thus belongs to the surface owner. The case arose under the Stock-Raising Homestead Act of 1916, which had reserved the mineral estate of certain federal homestead lands in the federal government. The ninth circuit held, based upon a review of legislative history of the Act, that Congress intended to include all sources of energy in the government's mineral reservation, including geothermal steam.

The same holding was reached in a case between private parties in *Geothermal Kinetics, Inc. v. Union Oil Co.*[8] In this case the California

4. Reich v. Comm'r. of Internal Revenue, 454 F.2d 1157 (9th Cir. 1972).
5. Reich v. Comm'r of Internal Revenue, 52 T.C. 700 (1969).
6. I.R.C. § 611(9) (0000).
7. United States v. Union Oil Co., 549 F.2d 1271 (9th Cir. 1971).
8. Geothermal Kinetics, Inc. v. Union Oil Co., 75 Cal.3d 56, 141 Cal. Rptr. 879 (Ct. App. 1977).

Supreme Court held that a deed conveying the mineral estate to Geothermal Kinetics included geothermal resources. The court used the following reasoning:

> First, in this formation there was minimal interaction with replenishable groundwater; second, water is usually conveyed with the surface estate for domestic purposes, and the geothermal water involved here would be totally useless for that purpose and finally, separation of geothermal resources ownership based upon whether the resources contained water or not would be impractical and confusing.

In the more recent case of *Pariani v. The State of California*[9] it was decreed that the mineral rights reservations in the patents reserved to the state the geothermal resources within the patented lands commonly known as The Geysers. The court of appeals held that these geothermal resources were "mineral deposits" and were reserved to the state:

> The Geysers' geothermal system is being depleted by the extraction of steam and with or without reinjection the steam will eventually be exhausted.

The court further stated that the liquid condensate of the geothermal steam was not the life-sustaining "water" which the courts have consistently felt impelled to exclude from mineral growths or reservations, and that the geothermal fluid was "distinctly separate and different from, and is in fact not the 'water' which is the subject of the California water law."[10]

Hydrothermal Resources

Structural changes in global and national energy markets during the past decade have generated considerable interest in the discovery and utilization of the relatively more abundant hydrothermal geothermal resources. As illustrated in Figure 1, these resources are distributed rather generously across the western United States. While the authority of the individual states to regulate the use of these resources is clear, the capability to do so has often been hampered by the absence of statutes which clearly define both the resource in question and the correlative rights of the interested parties.

At the present time, state statutes which define hydrothermal geothermal energy differ considerably. To a major degree, this diversity reflects the efforts of the states to deal with the issue of whether geothermal

9. Pariani v. State, 105 Cal.3d 56, 164 Cal. Rptr. 683 (Ct. App. 1980).
10. *Id.*

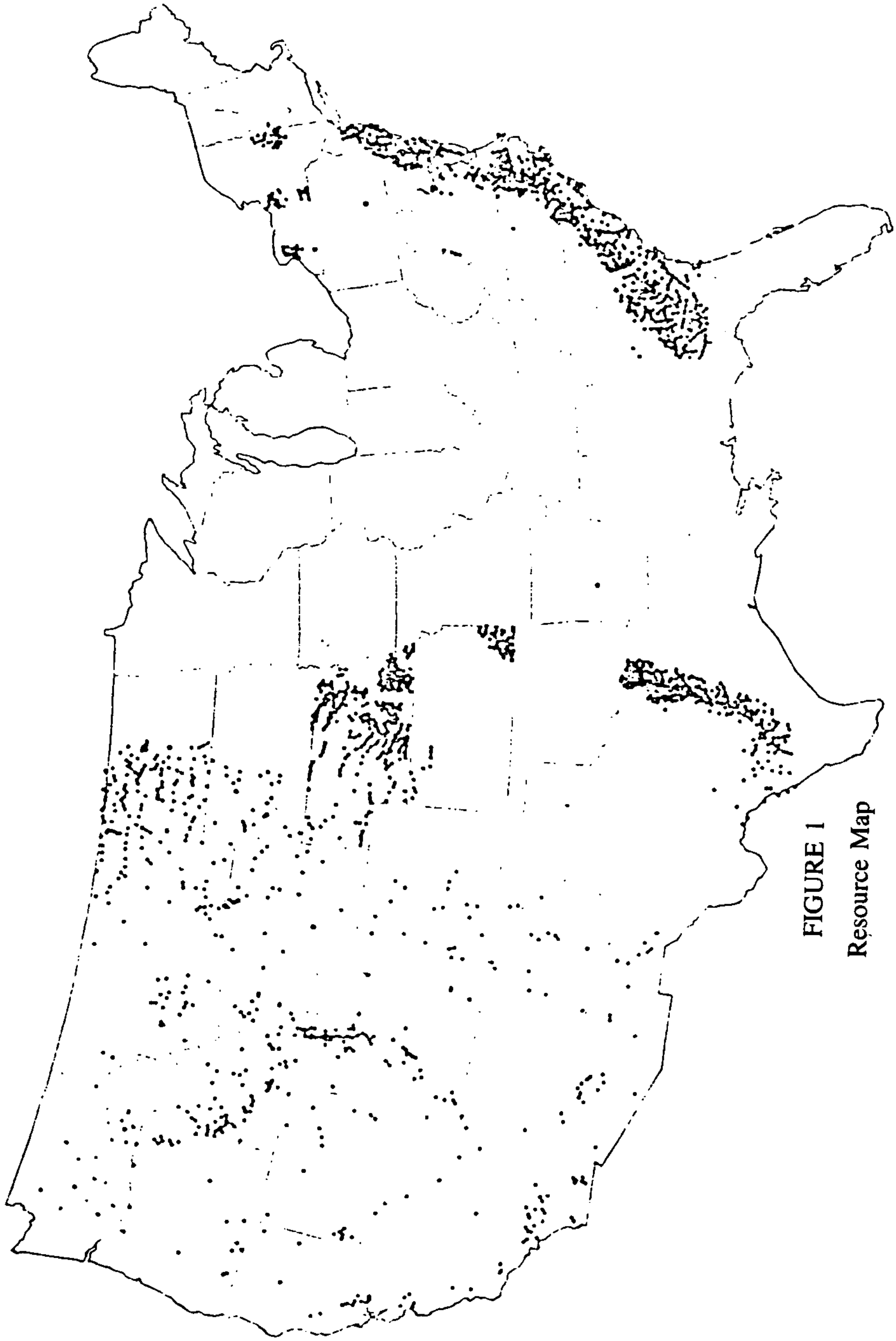

FIGURE 1
Resource Map

energy should be classified as water or as mineral. The outcome is crucial to the future of geothermal energy:

> The classification of geothermal resources will have far-reaching effects on treatment of the resource and on its economic potential for development. If the resource is treated as water alone, it will be subject to state water laws which may fail to account for many of the commercially valuable elements considered in a geothermal formation, such as minerals in solutions, gases, and the natural heat itself. If considered solely as a mineral, then ownership of most of the resource will be in the subsurface owner, with the resulting conflicts with water rights and state water law jurisdiction.[11]

While the interpretation and intent of existing statutes is not always entirely clear, definitions of geothermal fluids in the various states fall into the following classes:

- As a mineral
- As water
- As *sui generis*
- As either mineral or water depending upon, among other things, temperature or depth.

Five western states, including Hawaii, California, Colorado, New Mexico, and Arizona, classify hydrothermal energy as a mineral. All but the first of these, however, classify it as a mineral for leasing purposes only. Accordingly, water authorities within these states retain differing levels of authority over resource development. In contrast, the states of Nevada and Wyoming define hydrothermal geothermal categorically as water. The motivation in these states has probably been the protection of water resources for agricultural usage.

Three states, including Idaho, Montana, and Washington, define geothermal energy as *sui generis* or "of its own kind." This approach proposes that geothermal energy is a unique commodity and is not necessarily a mineral or water. Such a definition ostensibly allows the states the option to treat the resource as water, as a mineral, or as neither.

A final method for defining hydrothermal energy which appears to be gaining support is definition on the basis of one or more resource characteristics. Maryland, for example, has designated a temperature of 49°C as a benchmark level. All fluids possessing temperatures above this level are considered geothermal energy, while fluids with temperatures below this level are considered water. Oregon has designated 121°C as the minimum temperature for a reservoir to be classified as geothermal energy,

11. Comeau, *Geothermal Energy: Problems and Shortcomings of Classification of a Unique Resource*, 19 NAT. RES. J. 445 (1979).

and it has added a minimum depth of 2000 feet as well. More recently, Utah has adopted a statute which designates 120°C as a minimum temperature for classification as energy rather than as a water resource.

Further evidence of support for the temperature based definition of geothermal energy is provided by the strong interest demonstrated by the Internal Revenue Service.[12] Authorities at the IRS are proposing to designate 50°C as the temperature for distinguishing between geothermal energy and water. This agency is acutely interested in a clear definition of hydrothermal geothermal energy, because users of such resources are entitled to claim a depletion allowance for tax purposes while water users are not.

In a recent study, P. R. Grant Jr. thoroughly examined the alternative approaches for defining geothermal energy and their effects upon energy development.[13] Grant concluded that "although it may be technically feasible to draft legislation that statutorily distinguishes geothermal and groundwater regimes, as a practical matter the property right to water must be acknowledged or compensated for if the legislation is to be functionally successful."[14] Grant proposes that if moderate temperature resources are to be distinguished from water, consideration should be given to establishing a minimum temperature limit. Because of the apparently growing support for this approach to defining geothermal energy, the energy market impacts of temperature based statutes will be examined.

THE IMPACTS OF TEMPERATURE BASED DEFINITIONS UPON THE MARKET POTENTIAL OF GEOTHERMAL ENERGY

The evolution of a temperature based definition of hydrothermal geothermal energy may significantly influence the market development of geothermal energy. More specifically, if moderate temperature geothermal resources are defined in a manner which places them in a competitive posture with water, the energy market prospects of these resources are likely to diminish for several reasons. The first of these is attributable to the technology of geothermal energy use, and the second, as mentioned above, is a result of the vested nature of water interests in the West.

Current production technology requires that geothermal resources be colocated with (located proximate to) prospective users for direct or nonelectric utilization. The distribution by pipeline of geothermal brine is

12. 46 Fed. Reg. 7,289 (1981).

13. P. Grant, Geothermal Energy Development: The Question of Resource Definition as it Affects State Land Leasing Policies (Sept. 1981) (prepared for EG&G, Inc. and the U.S. Dept. of Energy, Albuquerque, N.M.).

14. *Id.* at iv.

not only expensive, but it may involve considerable heat energy loss. For this reason, the most attractive geothermal resources are those which are proximate to population centers. These are also the water resources which are most valuable for traditional consumptive purposes as well. Thus, a technologically imposed conflict between water use for energy and for traditional consumptive purposes appears inevitable.

When water rights conflicts do arise, the disposition of water for energy use may be expected to fare badly because of the powerful vested interests of existing water users. Although generalizations about attitudes toward water usage across the western states are difficult to render, the following proposition seems clear in most cases: the seemingly inviolate nature of contemporary water use doctrine and water law as well as the intensity of feeling regarding the importance of water will inhibit its use for energy purposes.[15] Strong negative reactions have already surfaced against energy proposals which embody sizeable water demands, *e.g.*, coal slurry pipelines or hydrothermal geothermal electricity generation.[16]

Accordingly, for lack of a clearer alternative, the following is advanced as a maintained assumption in the analysis to follow:

- If hydrothermal geothermal energy is defined in a manner which suggests conflict between water demands for traditional consumptive and for energy uses, the allocation of water resources for consumptive use will prevail.

On this basis, the energy market potential of the geothermal resource endowment will clearly be greater or lesser as a minimum statutory temperature requirement is lower or is higher.

While such an assumption is admittedly extreme for all cases, it is perhaps not unduly so. At any rate, this assumption provides a useful basis for preparing "worst case" estimates of the market impacts of temperature based definitions of geothermal energy.

The Distribution by Temperature of Geothermal Resources in the U.S.

A preliminary impression of the impacts of defining geothermal energy by minimum temperature may be obtained by examining the distribution of the national resource endowment by temperature. A recently completed baseline inventory of known geothermal resources has been compiled and is available for this purpose.[17]

15. For an excellent appraisal of the importance of water to the economics of the states, *see* Gerald W. Thomas, Water for the Sunbelt: a Global Perspective (March 26, 1981) (speech presented at the New Mexico Water Conference, New Mexico Water Resources Research Institute, New Mexico State University).

16. *Supra*, note 13.

17. P. O'Dea, Description of Data Files of the Geothermal Operations Research Project (1980) (New Mexico Energy Institute, Las Cruces, N.M.).

TABLE 1
The Distribution by Temperature
of Hydrothermal Geothermal Resources Across the United States

	Temperature (°C)			
	0–50°	51–70°	71–90°	91–Above
Frequency	45	264	143	113
Percent	8	47	25	20

Table 1 summarizes the distribution of colocated geothermal resources by estimated temperature for the United States. Each of these 566 resources is located within at least 25 miles of a prospective population center and/or an industrial consumer whose energy demand could be partially or entirely met by geothermal energy. The data reveal that nearly 72 percent (407 of 566) of the resource endowment possesses estimated temperatures between 51°C and 90°C. Eight percent (45 of 566) of the resource temperatures are thought to be below 51°C, and 20 percent are estimated to be above 90°C. Thus, for example, the designation of 91°C as a minimum geothermal temperature would place nearly three-fourths of the geothermal anomalies in a perilous, *i.e.*, competitive, position with respect to water, while a minimum of 50°C would jeopardize only 8 percent of the resource endowment. On this basis, those states which wish to encourage the development of geothermal resources should designate a lower rather than a higher minimum temperature for statutory purposes.

While the data in Table 1 are enlightening, they may also prove misleading. Although all of these resources are colocated with one or more users, in some instances geothermal may be unable to compete with the currently prevailing prices of alternative fuels. A more meaningful examination of the impacts of temperature based definitions of geothermal energy should examine

1. the market potential of geothermal energy as determined by the price competitiveness of geothermal versus prices of other fuels during some meaningful period of time; and on this basis,
2. the impacts of alternative temperature based statutes upon the market potential of geothermal energy.

The Energy Market Potential of Geothermal

The market potential of direct geothermal use is defined as the sum of the energy demands for which geothermal is at least price competitive with alternative fuels.[18] The determination of market potential requires

18. The term market potential also has been referred to as capture potential in similar solar energy research. *See, e.g.*, J. Scott, Solar Water Heating Economic Feasibility, Capture Potential, and Incentives (February 1977) (prepared for the National Science Foundation, Washington, D.C., NTIS PO-279-855).

the calculation of a delivered price of geothermal energy and a comparison of this with forecasted costs of alternative fuels. For each prospective user, the demand for energy constitutes a share of the geothermal potential if and only if

(1) $P_G \leq P_A$

where

P_G = estimated delivered price of geothermal energy
P_A = price of alternative fuels.

The calculation of geothermal market potential requires an aggregative resource pricing capability which has only recently become available.[19] The broad diversity of (1) resource characteristics (*e.g.*, temperature, depth, flow rates, total dissolved solids) and 2) usage (*e.g.*, average and peak heat demands, distance to resource, size) makes the calculation of a delivered price extremely site specific. However, the results of a number of detailed engineering economic analyses have revealed that five factors are of primary importance in determining the price of geothermal energy use. These include resource depth, resource temperature, climate, distance between the resource and the user, and the size of the user.

The following geothermal energy pricing model is proposed in order to investigate the relationships between the price of geothermal energy, P_G, and each of these five determinants of price.

(2) $\ln P_G = (\text{Depth})^{b1}(\text{Temp})^{-b2}(\text{Dist})^{b3}(\text{Clime})^{b4}(\text{Size})^{-b5}e$

where

P_G = estimated price of geothermal for a prospective user
Depth = estimated geothermal resource depth
Clime = degree days of heating, index of climatic conditions
Dist = distance between resource and user
Temp = estimated geothermal resource temperature
Size = system size
e = residual
$b_{1\text{-}5}$ = coefficients to be estimated.

The signs of the coefficients indicate that the price of geothermal energy is expected to be positively dependent upon resource depth, distance, and climate (measured in degree days of heating), while the price is inversely related to resource temperature and user size.

The data necessary to estimate the pricing model were obtained from the results of 496 detailed engineering studies of prospective geothermal

19. M. Houldsworth, The Potential For Direct Use Geothermal Energy Supply in the United States, 1980–2000 (1980) (New Mexico Energy Institute, Las Cruces, N.M.).

energy users which were conducted between 1978 and 1980. Each of these analyses involved the design of a geothermal energy installation for an actual or proposed user and the calculation of a delivered price of geothermal energy over the life of the system investment. The coefficients of the model were estimated using ordinary least squares. The findings are presented in Table 2.

The results of this model are excellent. The estimated coefficients all assume the correct sign; the coefficients are all highly significant; and the R^2 value is very high. Thus, the predicted price of geothermal energy provided by this model very closely approximates the actual values which the engineering studies provided. On this basis the model provides an economical vehicle for approximating delivered prices of geothermal energy for large numbers of users.

The model in Table 2 was employed to calculate an annual predicted geothermal energy price for each colocated energy consumer during the period 1985–1995. During each year, a price of geothermal energy was calculated for each colocated user and was compared with forecasted prices of alternative fuels. Annual estimates of geothermal energy market potential were then compiled using the decision rule in (1). The results of these calculations are presented for selected years in Table 3 and are illustrated in Figure 2.

The non-electric market potential of geothermal energy in 13 western states in 1985 is estimated to be 472,945 10^{12}Btus. Moreover, forecasted market potential expands by 26 percent to 595,012 10^{12}Btus in 1990 and by 23 percent more to 728,242 10^{12}Btus by 1995. The primary impetus for the forecasted expansion of market potential is the predicted real increase in prices of alternative fuels during this period (5 percent/annum). As these prices escalate through time, geothermal energy becomes an increasingly more attractive energy form, assuming that competing water demands do not preclude utilization. Moreover, the market potential of

TABLE 2

Geothermal Energy Price Model

$$\ln P_G = \underset{(.065)}{-.4065^*} \ln \text{Temp} + \underset{(.018)}{.15^*} \ln \text{Depth} + \underset{(.020)}{.1193^*} \ln \text{Dist} + \underset{(.046)}{.6413^*} \ln \text{Climate} - \underset{(.014)}{.124^*} \ln \text{Size}$$

$R^2 = .980$

( ) = standard error

* = statistically significant at the .01 level (one tail test)

n = sample size = 496

TABLE 3

Estimated Market Potential (10^{12}Btus) of Direct Applications of Geothermal Energy in the United States, 1985, 1990, and 1995

	1985	1990	1995
Arizona	27,602	35,600	50,165
Colorado	52,404	91,672	107,316
Idaho	44,747	51,273	56,105
Montana	26,057	27,379	28,537
Nevada	25,959	31,944	35,321
New Mexico	17,818	26,624	33,493
North Dakota	25,815	27,501	28,712
South Dakota	10,900	11,818	12,323
Utah	34,785	41,841	60,735
Wyoming	12,566	14,209	15,551
California	189,989	228,437	292,238
Alaska	273	424	552
Oregon	4,030	6,290	7,194
	472,945	595,012	728,242

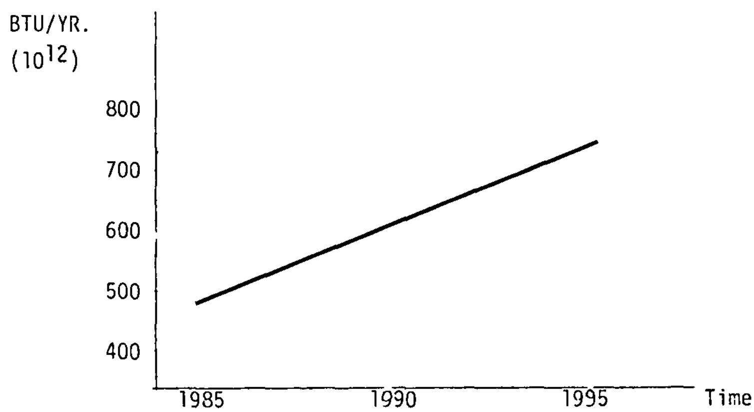

FIGURE 2

Estimated Market Potential, 1985, 1990, and 1995 geothermal energy grows at a faster (slower) pace as future energy prices increase by more (less) than 5 percent per annum.

The issue of primary interest here pertains to the likely impact of temperature based definitions of geothermal energy upon its estimated energy market potential. The geothermal price model verifies that, all other things equal, the hotter the geothermal fluid, the relatively cheaper its delivered price will be and the greater its market potential will be. Quite clearly, the higher each state chooses to designate a minimum geothermal resource temperature, the more penurious will be the effect on the energy potential of its resource endowment.

The effects of three alternative minimum geothermal resource temperatures are examined here: 50°C, 100°C, and 150°C. All water in excess of these designated minima are *sui generis* geothermal energy resources; all water with temperatures below these minima are considered water and must compete with traditional consumptive water demands. As postulated earlier, a working assumption is that in these latter instances, consumptive water demands will prevail. The estimates of market potential in each of the three minimum temperature scenarios cases are presented in Table 4.

These results convey a great deal of information about the prospective impacts of temperature based statutes upon geothermal energy market potential. The first and most obvious finding is that the restrictive influence upon market potential in any given year is greater as the minimum resource temperature is higher. Quite clearly, this occurs because the successively higher minimum temperatures force proportionally more resources to compete unsuccessfully with consumptive water demands. This conclusion is illustrated in Figure 3 for the year 1990. The market potential at 150°C (141,305 10^{12}Btus) is only 24 percent of the full market potential; at 100°C the market potential is 83 percent of full potential; and at 50°C the proportion is 99 percent. The same relationship is evident for 1985 and in 1995 as well.

TABLE 4

13 State Market Penetration (10^{12}Btus) with Minimum Geothermal Temperatures of 50°C, 100°C, and 150°C

	50°C		100°C		150°C	
	Potential	% of Full Potential	Potential	% of Full Potential	Potential	% of Full Potential
1985	472,929	99.99661	390,414	83	113,418	24
1990	595,007	99.99915	497,150	83	141,305	24
1995	728,231	99.99999	622,329	86	200,592	28

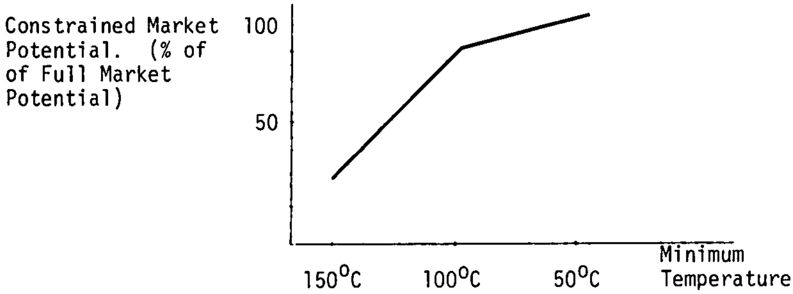

FIGURE 3

The Impacts of Alternative Temperature Minima Upon the Market Potential of Geothermal Energy in 1990

A second finding in Table 4 is that the temporal distribution of the impacts of temperature based definitions is nearly uniform. While at each temperature, the most restrictive impacts are experienced earliest, these become only slightly less severe through time. This finding is illustrated in Figure 4. At the 100°C temperature, for example, the estimated market potential is only 83 percent of full market potential in 1985; this estimate rises to 86 percent in 1995. This same relationship is also evident at 50°C and 150°C.

A third finding which is illustrated in Table 5 is that the precise impacts within individual states of alternative minimum temperatures vary considerably. The factors which ultimately shape the impacts in each state include the temperature distribution of a state's resource endowment, the characteristics and the extent of colocation between resources and users, and the level and expected rate of escalation of prices of competing fuels. The data in Table 5 report the estimated percent of full market potential that would be attained in each of the 13 western states at minimum

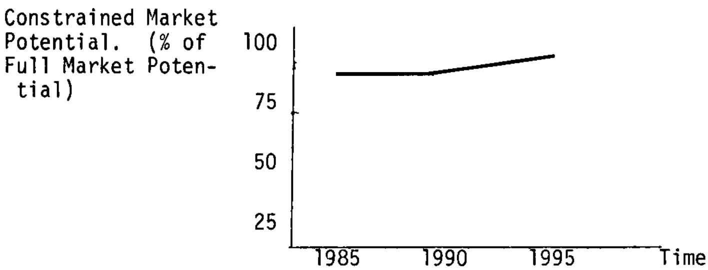

FIGURE 4

The Temporal Impacts of a 100°C Minimum Temperature Level Upon the Market Potential of Geothermal Energy in 1985, 1990, and 1995

TABLE 5

Estimated Percent of Full Market Potential, by State, for Temperature Minima of 50, 100, and 150°C for the Year 1990

	50°C	100°C	150°C
Arizona	0	99	99
Colorado	2	53	99
Idaho	0	35	100
Montana	1	96	100
Nevada	12	100	100
New Mexico	0	73	100
North Dakota	22	100	100
South Dakota	60	100	100
Utah	0	100	100
Wyoming	5	78	100
California	53	97	100
Alaska	48	79	100
Oregon	4	66	99

temperatures of 50, 100, and 150°C for the year 1990. The substantive differences between, for example, Idaho and South Dakota are illustrated in Figure 5. Comparable differences exist among all these states. For this reason, if geothermal water is to be defined on the basis of a minimum temperature, the impacts should be thoroughly examined within each state.

CONCLUSIONS

This paper has examined the energy market impacts of temperature based statutory definitions of geothermal energy. These statutes typically define geothermal energy to be all water in excess of a minimum des-

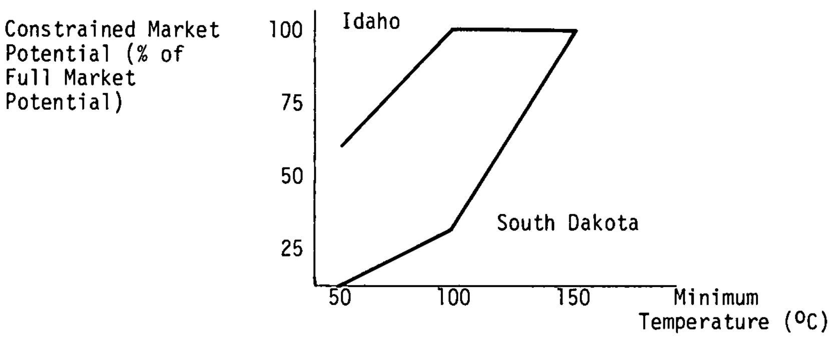

FIGURE 5

Estimated Energy Market Impacts of Temperature Minima for Idaho and South Dakota, 1990 ignated temperature. The goal of these statutes is to enable the states to distinguish between water to be used for traditional consumptive purposes and those to be employed for energy applications.

The energy market impacts during the period 1985–1995 were examined for three temperature minima. Employing the relatively strict assumption that no resources with temperatures below the minima would be developed for energy uses, three conclusions have been drawn.

First, the energy market potential of geothermal is positively and functionally dependent upon the temperature minimum selected. If 50°C is designated as a minimum temperature, nearly all (99 percent) of the energy market potential of geothermal is preserved from 1985–1995. However, for a minimum of 100°C, market potential would only be 83, 83, and 86 percent of full potential in 1985, 1990, and 1995, respectively. Finally, if the relatively penurious 150°C is chosen as a minimum, geothermal prospects are reduced to 24, 24, and 28 percent, respectively, of full potential in the same three years. The message is clear: states wishing to promote geothermal energy development should designate the highest possible minimum temperature in order to avoid conflict between traditional and energy water demands.

A second finding is that the restrictive impacts of minimum temperature upon geothermal energy development are felt in the earliest years following enactment of such legislation. This finding of geothermal use is an important determinant of adoption by prospective users.

Finally, the market impacts of proposed temperature based definitions will vary markedly across states. These impacts result from the site specific nature of the resources and users as well as existing energy market conditions in each locale. Thus, the minimum temperature which has been deemed appropriate in Utah, 120°C, may be inappropriate for the same purposes in New Mexico. No general rules of thumb for selecting a minimum temperature seem to exist.

A final note pertains to the reliability of the conclusions (as distinct from the quantitative estimates) which have been drawn above. These conclusions will be equally valid without the assumption which has been employed here—that no resources with temperatures below the minimum would be developed for energy purposes. While this assumption will not hold for all cases, there can be no doubt that competition with traditional water uses will diminish the market potential of geothermal energy. The precise effects will depend upon locally prevailing water use attitudes and markets.