Economic and Social Aspects of Geothermal Energy Resource Development

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ABSTRACT

Development of geothermal energy in the United States will be paced by a number of socio-economic impediments as well as by technological problems. The issues are associated with providing a financially viable base for exploration and development, assuring a market for geothermal steam or hot water, and accomplishing the required research and development in a timely manner.

Geothermal development will change the electric utility fuel mix by substituting for nuclear and coal generating plants. Businesses involved in the exploitation of geothermal energy and businesses which can uniquely utilize geothermal resources will be stimulated.

Macroeconomic factors will be affected because development of geothermal energy seems likely to furnish 5 to 10% of the total U.S. electricity demand by the year 2000. This level of development will stimulate construction of a national electrical grid.

Acceleration of geothermal energy development requires changes in certain marketing, financial, and other institutional arrangements. Currently, government regulations overlap and cause delays. Another major problem area is the securing of adequate financing for timely development.

The impacts on housing and cities stem from industrialization resulting from the development of the geothermal resource itself and from businesses which can utilize the heat and mineral content of the geothermal fluids. Economic and urban planning benefits will derive from geothermal space and process heat. Geothermal energy will affect international trade relations; foreign technological aid and geothermal markets can be expected to develop as early as the late 1970's.

INTRODUCTION

A number of institutional and regulatory impediments to the development of geothermal energy exist. None of these seems likely to prevent the development of this energy source, but in the aggregate, they will pace its growth as certainly as the technological issues. The issues are associated with the encouragement of exploration and development, assuring a market for geothermal steam, hot water or electricity, and accomplishing the required research and development in a timely manner.

The development of geothermal energy in the United States at a high level is apt to cause both favorable and unfavorable, though manageable, impacts which can be grouped into eight major areas, which are discussed in this paper.

Geothermal energy can be a relatively important energy source in the United States by the year 2000. It could supply 190 000 to 250 000 MWe of electricity, compared with an expected U.S. total capacity of 2 million MWe. At this level, by the year 2000, geothermal sources will be contributing more to our energy supply than hydroelectric sources.

Because geothermal sources are located primarily in the western part of the United States, the effects of geothermal energy will be considerably greater there than elsewhere in the country. For example, total electrical generating capacity in the western part of the United States is expected to reach about 480 000 MWe by the year 2000; geothermal sources may constitute 25% or more of the total supply in that region.

The contribution of geothermal resources to U.S. energy supplies seems likely to increase continuously; by 1985 it is reasonable to expect that geothermal sources will be producing 7000 to 20 000 MWe or so out of a total of about 1 million MWe in the United States. After 1985, growth could be very rapid. The use of geothermal energy for space heating and for process heat can be very substantial and requires much further attention.

ELECTRIC UTILITY FUEL MIX

The electric utility fuel mix will be changed by substituting for nuclear and coal-fired generating plants. The development of geothermal resources could lead to (by 2000) fewer nuclear plants (100 000 to 150 000 MWe could be saved) and fewer coal-fired plants (90 000 to 120 000 MWe could be saved). In total, these savings could amount to about 15% of the country's coal and nuclear generating capacity by the end of the century. Thus, while geothermal development has an important effect on these generating sources, it is by no means preemptory.

These shifts in fuel mix are likely to bring a number of secondary impacts, such as a reduction in the number of nuclear and coal-fired power generation sites, a reduction in the amount of radioactive material to be stored, a reduced need for the mining of coal for use in electrical generation, and so on.

EFFECTS ON BUSINESS

Two business sectors will be stimulated by geothermal development. These are businesses involved in the exploitation of geothermal energy and businesses which can uniquely utilize geothermal resources. The total investment in geothermal development (materials, land, equipment, and so on) could be on the order of $95 billion (1973) by the year 2000. The businesses affected by the advent of geothermal energy will be largely those which can utilize geothermal heat directly. Various business uses of geothermal energy are listed in Table 1 and policies to optimize the uses are suggested in Table 2.

A business which utilizes geothermal heat is, in effect, utilizing hot water. Hot water can come from many other sources (for example, power plant cooling-water effluent); thus, development of a technology which permits the use of waste heat is directly applicable to geothermal fluids. Businesses which utilize geothermal electricity could, as well, utilize electricity from other sources; one kilowatt is indistinguishable from another. The effect on such businesses will be only that realized as the result of increased availability of electricity.

A major consequence of direct use of geothermal heat will be to bring certain industrial plants near the source of geothermal heat. Flowing from this impact will be a host of higher-order impacts associated with land use, demographic shifts, regional economics, and so on. Since the extent of geothermal resources is not yet clearly known, and since it is apparent that the first major use of geothermal energy will be for the production of electricity, it is difficult to project the intensity of these impacts; however, the effects of these impacts probably will not be large when viewed on a national scale. From the standpoint of the affected localities, however, impacts could be similar to those associated with mild industrialization and therefore could be viewed by various interest groups as being beneficial or detrimental as a result of changing land-use patterns, increasing population density, creation of the need for new public services, increases in the tax base, increases in the number of jobs, and so on.

Table 1. Business uses of geothermal energy.

Industries that utilize electricity
General industrial consumption
Heavy users of electricity
Aluminum
Chemicals
Electrified railroads
Agriculture
Industries that utilize process heat
Greenhouses
Fish farms
Field crops—soil warming
Food processing—canning and freezing
Paper and pulp
Chemicals
Lumber drying
Grain dying (corn and wheat)
Animal husbandry
Water desalination
Resort spas—health baths

Table 2. Policies to optimize impacts on business.

Basic research in utilization of process heat
Dissemination of information on use of geothermal heat and electricity
Local or regional backing of industrial parks where small firms can utilize geothermal energy, with possible federal loan assistance
Federal loans or subsidies for developmental geothermal projects
Federal assurance of flow-through to ultimate users of benefits of subsidies or loans to geothermal developers
Federal reliability insurance to ultimate users
Extension of oil and gas tax benefits to geothermal developers
Allocations of scarce supplies to geothermal developers who may not have purchasing history
Assistance to educational programs for geothermal specialists

MACROECONOMIC AND SOCIETAL FACTORS

Macroeconomic and societal factors will be affected. It seems certain that the demand for electricity will increase, and development of geothermal energy provides a way of helping to meet that demand. However, since geothermal sources seem likely to furnish about 10% of the total demand for electricity by the end of the century, the effect of its price "dilution" will be small. The marginal value of the geothermal energy, however, can be significant, as shown by Table 3. In this table, two cases forecasted by our power simulation model for the present regular geothermal development (base case) and for the accelerated case (all out development) are presented. The U.S. energy consumption was predicted and combined with the available geothermal energy to ascertain the marginal efffect. The effect is significant in the overall economy (for example, 164.5 billion dollars in year 2000 for the base case). This means that geothermal energy could support 164.5 billion dollars of the gross national product (GNP) in 2000 and thus help support prosperity and the standard of living.

Most of the specific societal impacts flowing from the development of geothermal energy will evolve from its significant characteristics: the small size of optimum installations and the location of the resources, which, in most cases, are in outlying areas. These factors are illustrated in Table 4.

Federal royalty income from geothermal development (190 000 MWe capacity) could amount to $1 billion (1973) per year by 2000, and local governments could realize about $475 million (1973) per year from local taxes by 2000. These sums are helpful but not overwhelming; for comparison, federal tax revenues in 1971 were $137 billion and local tax revenues $43 billion.

NATIONAL ELECTRICITY GRID

The development of geothermal energy will help bring about a national electrical grid. Using reasonable estimates of the cost of constructing and operating a transcontinental high-voltage dc transmission line, electricity derived from geothermal sources in the west can be supplied to the midwest and eastern portion of the United States at a cost of about 25 mills (1973) per kWh in 2000. Based on considerations of reliability, continued supply, diversity, and capital re-

Table 3. Marginal effect of geothermal availability on energy-limited U.S. gross national product.

Year	Geothermal energy 10^{12} Btu		U.S. energy consumption 10^3 Btu/$ GNP	Marginal effect of geothermal on GNP 10^9 dollars (1973)	
	Base program	Accelerated program*		Base program	Accelerated program*
1980	0.26	0.38	81.4	3.2	4.7
1985	0.42	1.25	79.5	5.3	15.7
1990	1.34	3.33	77.5	17.3	43.0
1995	4.47	7.51	75.7	59.0	99.2
2000	12.17	15.97	74.0	164.5	215.8

*Accelerated program is one in which virtually all technological and nontechnological impediments are removed.

quirements, it is plausible to expect midwestern and eastern utility companies to purchase on the order of 56 000 MWe (out of a demand of 1.6 million MWe in the east) of geothermally generated electricity from western sources by the year 2000. Table 5 illustrates forecasts made in the power simulation model.

This transportation of electrical energy from west to east will take advantage of intercontinental lines likely to be in place in support of western coal mine-mouth generation plants. The important secondary impacts flowing from this development include increased research and development in the fields of high-efficiency, high-capacity transmission lines, and esthetic effects which seem likely to arouse conflict. Cost considerations seem to preclude placing transmission lines underground; however, the use of hydrogen produced from electrolysis of water by geothermal electricity may be an economic alternative to high-voltage dc transmission.

INSTITUTIONAL ARRANGEMENTS

The complete flow chart of institutions concerned with developing geothermal energy is shown in Figure 1. It is essential that certain institutional arrangements change if the development of geothermal energy is to be accelerated. Currently, federal, state, and local regulations, particularly environmental regulations, overlap and cause delays.

At the federal level, research and development and programmatic planning were being accomplished by an Interagency Panel for Geothermal Energy Research composed of the National Science Foundation, the Department of the Interior, the Atomic Energy Commission, NASA, and the Department of Defense. Starting in January 1975, the new Energy Research and Development Administration has taken over the principal consolidated role for U.S. geothermal energy research and development. However, all of the aforementioned agencies still have some role, and their possible divergent views will require careful adjudication.

The laws pertaining to geothermal development, as presently constituted, encourage the participation of large companies and discourage small companies. For this reason a significant institutional impact is expected to be the increasing participation in geothermal development of major petroleum companies.

Arrangements developed in the past for selling other forms of energy may not be adaptable to geothermal, and indeed may hinder its development. As the system is presently constituted, utility companies are the only major buyers of geothermal energy. A major problem issue is ensuring an adequate flow of money to finance the timely geothermal development. This is illustrated by Figures 2 and 3.

REGIONS AND CITIES

Geothermal development will affect regions, cities, and buildings. The impacts on regions and cities stem from industrialization resulting from the development of the geothermal resource itself and from the potential influx of businesses which support geothermal development and which can utilize the heat and mineral content of the geothermal fluids. At the secondary level, this results in changing population levels, population density, and land-use patterns. However, these changes also bring an increased tax base, a potentially cleaner environment, and increased

Table 4. Macrosocietal factors influenced by geothermal energy.

Maintenance of lifestyle based on abundant energy
Redistribution of population nearer to geothermal resources
Local societal changes resulting from changing economic base
Local educational changes resulting from changing economic base
Effects of changes in pollution levels on health (pollution caused by energy industries)
Changes in recreational patterns

Table 5. Assumptions and forecasts of baseline scenario relevant to transcontinental electrical grid (1000 MWe).

Assumptions and forecasts	Year 1985	2000
Geothermal electrical capacity in the western U.S.	7	147
Geothermal electrical capacity in the eastern U.S.	0	41
Geothermal electricity transported west to east	0	56
Cost of geothermal electricity in the west (constant 1973 dollars)	10.4 mill/kWh	14.5 mill/kWh
Cost of geothermal electricity transported to east (2500 miles) (constant 1973 dollars)	19.3 mill/kWh	25.7 mill/kWh
Number of transcontinental corridors in operation (assuming standard FPC reliability criteria)	0	4

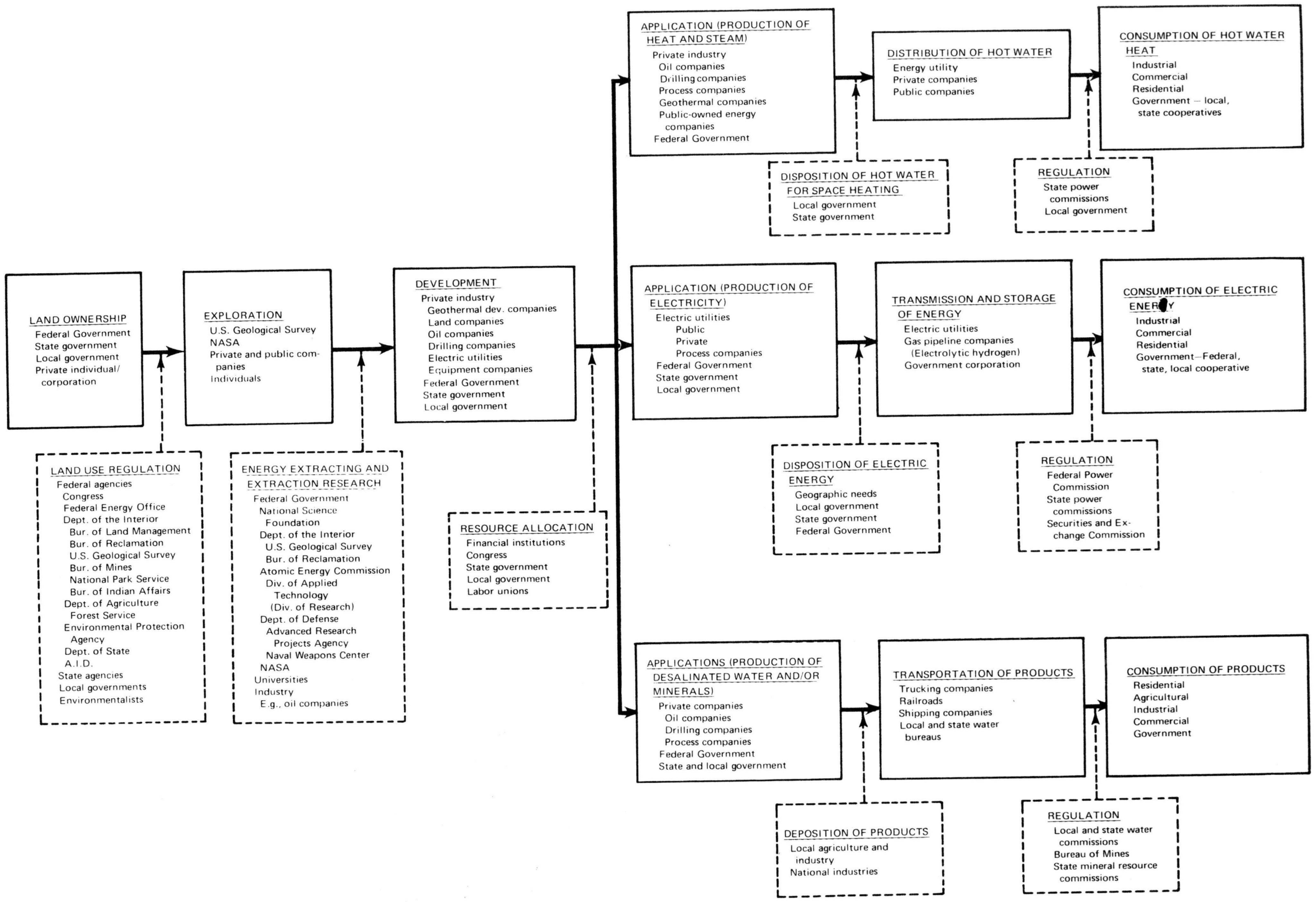

Figure 1. Institutions having a role in geothermal energy development. Boxes with solid-line arrows indicate line activity functions. Boxes with dashed lines indicate regulatory and interface functions.

employment. Cities near geothermal resources will have the opportunity to develop district heating. Rekjavik, Iceland, which now supplies almost all of its residents with inexpensive geothermal heat, can serve as an example. District cooling systems have not yet been attempted anywhere in the world, but the cooling of a tourist hotel in New Zealand using geothermal heat as an energy source establishes the feasibility of such an approach.

INTERNATIONAL RELATIONS

Geothermal energy will affect international relations. At least 70 countries have geothermal potential. Some of these countries have already developed a portion of their geothermal resources; others have not. Development of geothermal technology in the United States will not only create the opportunity for technological aid, particularly to countries with relatively low GNP per capita, but it will lead to the creation of new markets throughout the world. Technological aid and geothermal markets can be expected to develop as early as the late 1970's. When foreign countries develop indigenous geothermal resources, their demand for imported fuel will diminish. Similarly, as the United States develops

PRINCIPAL ISSUE: Provision of capital for a high-risk, long-time return, capital intensive industry

POLICIES

Loans, subsidies, insurance guarantees, purchase agreements
Tax incentives
Development of new methods of private financing
Demonstration of reliability in pilot plants
Quasi-public development corporations
Publicly owned geothermal plants to act as industry barometers

Figure 2. Financial institutional arrangements.

Table 6. Oil equivalent saved by substitution of geothermal energy.

	Amount of energy			
	MWe capacity		Substitution, annual millions of barrels of oil equivalent (5.8×10^6 Btu/bbl)	
Year	Base case	Accelerated case	Base case	Accelerated case
1973	0.40	0.40	4.21	4.21
1976	0.73	0.73	7.68	7.68
1979	3.59	4.10	37.78	43.15
1982	4.82	9.26	50.73	97.46
1985	6.58	19.50	69.25	205.24
1988	13.39	36.79	140.93	387.21
1991	24.68	59.74	259.76	628.76
1994	54.67	96.94	575.40	1020.29
1997	108.33	158.44	1140.17	1667.58
2000	188.11	249.22	1979.85	2623.04

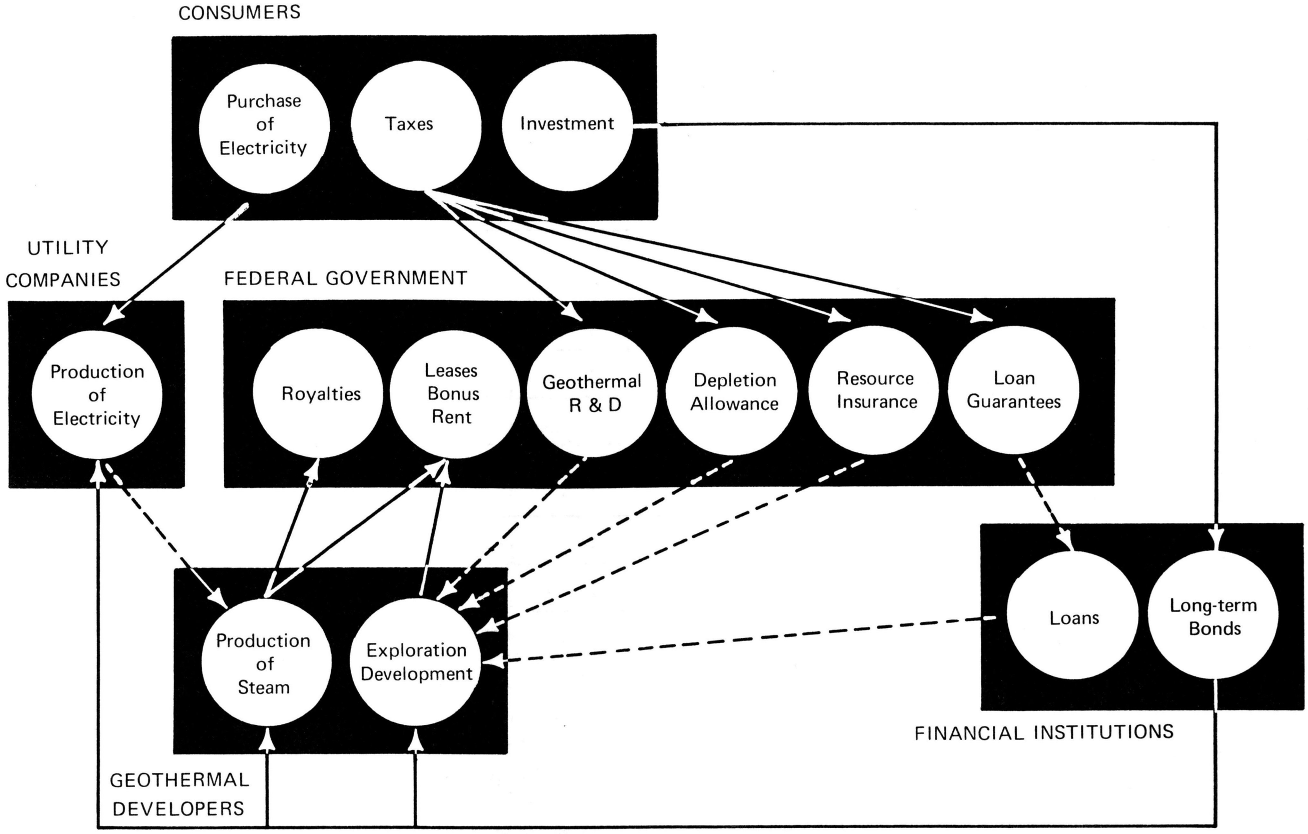

Figure 3. Financial flow in geothermal energy development. Dashed lines indicate factors which modulate monetary flow.

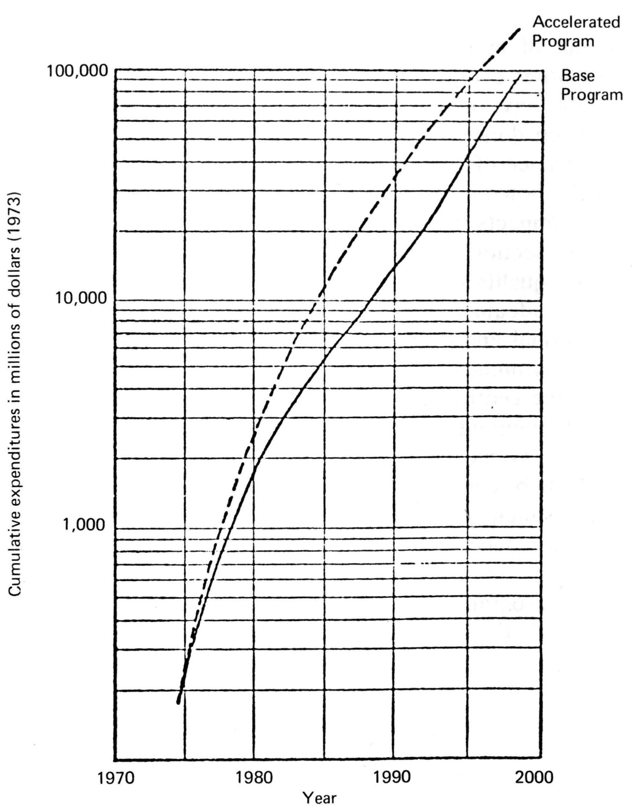

Figure 4. Cumulative expenditures if forecasted amount of geothermal electricity were produced with oil costing $10/bbl.

geothermal energy, fuels which might have been used for the generation of electricity can be put to other uses (or not be mined or imported at all). The impact is significant: geothermal energy "frees up" enough coal for export to bring into the United States a total of between $13 and $20 billion (cumulative 1973 dollars) by the year 2000. The effect on U.S. oil imports is even more dramatic, as shown by Table 6 and Figure 4. By 1994, accelerated geothermal development could save the importing of 1 billion barrels of oil per year equivalent.

ENVIRONMENTAL ISSUES AND LAND USE

If geothermal technology is developed under existing economic constraints, the evolution of pollution-control technology will probably keep pace. Adequate environmental rules and regulations are presently on the books to ensure only nuisance-level impacts if all leasing, pollution control, and monitoring procedures are literally applied. Most states have promulgated ambient air quality standards which often exceed federal standards. Except for accidents, geothermal sources should not exceed these limitations for more than short periods of time. Hydrogen sulfide emission from steam and hot water sources can be reduced to safe levels by natural dispersion and dilution or, if necessary, by a scrubbing apparatus expected to be available shortly.

Contamination of surface water by geothermal operations is a potential problem, but with careful study it should be possible to avoid unanticipated or irreversible consequences.

Seismicity and subsidence are possible geothermal issues

IMPACT AREA	SIGNIFICANCE	NUMBER OF PEOPLE AFFECTED	LASTING QUALITIES	TIMING	SUM OF IMPACT JUDGMENT
Biota	0	1	1	2	4
Seismiscity	3	3	2	2	10
Subsidence	1	1	3	2	7
Contamination of surface and subsurface waters	2	3	2	3	10
Blowouts	3	1	1	2	7
Aesthetics	1	1	2	2	6
Release of H_2S	1	1	0	3	5
Release of NH_3 and other atmospheric contaminants	1	1	0	2	4
Noise	1	1	1	3	6
Land use	2	2	2	1	7

KEY:

Significance	Number of people affected	Lasting qualities	Timing
3 = Potentially killing	3 = A great many	3 = Irreversible	3 = Immediate concern
2 = Very dangerous or important	2 = Many affected	2 = Reversible with a great deal of effort	2 = Of concern within 5 years
1 = Some danger or importance	1 = Localized	1 = Some effort to reverse	1 = Of concern within 5-10 years
0 = Trivial	0 = None	0 = Self-correcting	0 = Of concern within 10-20 years

Note: The release of radon gas (radioactive) has been identified at a few geothermal sites. However, the concentractions are negligibly small or not quantified. Further data should be acquired.

Figure 5. Evaluation of important environmental impacts.

of considerably more concern. As much information as possible should be developed about these issues on a theoretical basis. When deep injection is to take place in areas where faults are likely or possible, or when reinjection is possible, seismicity and subsidence should become primary foci of environmental impact analyses.

The extensive geothermal provinces which have been identified to date are predominantly of the liquid-and-vapor-dominated reservoir type. These resource types are expected to produce a major portion of the geothermal power output in the future. Therefore, under a crash program, it could be assumed that rather large tracts in the states of California, Washington, Idaho, Oregon, Nevada, Arizona, New Mexico, and others would be thoroughly explored and developed into multiple-unit power generating complexes with interconnecting transmission lines. The intermingling of these plants with mineral extraction plants, water reclamation units, and other related industries could result in refinery-type complexes, with interconnecting pipelines, buildings, water holding ponds, and cooling towers which might, in some areas, cover several square miles. Of course, high-voltage transmission lines would be installed in these developments also. Based on the forecast energy development assumptions, a maximum of approximately 1500 to 2500 square miles of surface will ultimately be required to accommodate the development of all of these geothermal and ancillary facilities.

Although the indications are that the environmental impacts created out of the development of geothermal energy are not of major significance when compared with those from other energy forms, it is desirable to evaluate these possible environmental impacts in a summary manner. This has been done and is presented in Figure 5. The relative significance of these impacts was based on the numerical key as shown in the figure.

The impacts listed in the figure summarize the discussion of this section. The weightings given to the columns on lasting qualities and timing indicate the importance for making adequate and timely plans at the beginning of the geothermal energy development. By doing this it appears that environmental disruption can be kept to a minimum while the geothermal resource can be a valuable domestic energy component.

The two most important environmental impacts were judged to be contamination of surface and subsurface waters, and seismicity. It is no coincidence that these two impacts are also judged to be the most important in the Department of the Interior environmental statement for the geothermal leasing program (1973). The points made in this study are similar to those made in the Department of the Interior statement.

IMPACTS ON INTEREST GROUPS

Detailed assessment of selected potential impacts indicates that the interest groups in society most likely to support geothermal development because of the benefits it provides, are the financial community, the U.S. government, busi-

Table 7. Impacts likely to be perceived as having greatest positive consequences in developing geothermal energy.

Increased geothermal research and development for the environment
Improvements in inflation control over a "nongeothermal world"
Lower-than-expected price for electricity
Improvements in gross national product over a "nongeothermal world"
Improvement in government income over a "nongeothermal world"
Decreasing rate of depletion of oil
Decreasing rate of depletion of natural gas
Increased geothermal research and development exploration
Diminution of the amount of imported energy
Movement of businesses that use geothermal electricity, heat, or minerals into geothermal regions

Table 8. Impacts likely to be perceived as having greatest negative consequences in developing geothermal energy.

Increased possibility of seismicity near geothermal installations
Increased possibility of land subsidence near geothermal installations
Delayed development of solar energy
Increasing rate of depletion of geothermal resources
Diminished air quality near geothermal installations
Relocation of local population in order to accommodate geothermal installations
Preemption of recreation, park, and wilderness areas for geothermal installations
Increased noise near geothermal installations
Diminished water quality near geothermal installations
Use of agricultural and forest lands for development of geothermal installations

nesses that supply the geothermal industry, the geothermal industry itself, and the new research community involved in geothermal research. The groups likely to react to the threats of geothermal energy are environmentalists, the Environmental Protection Agency, groups of homeowners near geothermal installations, and the utility companies affected by the transcontinental grid. Lists of the more important positive and negative impacts are presented in Tables 7 and 8. The policies likely to be viewed most desirable (that is, policies which increase the perceived positive consequences, minimize the perceived detriments, and promote agreement among the groups involved) are those which address the environmental implications of the use of the resource and help to resolve potential land-use conflicts.

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REFERENCE CITED

The Futures Group, 1974, A technology assessment of geothermal energy resource development: Glastonbury, Connecticut, The Futures Group.