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Property Systems in Geothermal Resources: A Critique and Recommendations

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ABSTRACT

The incentive pattern facing a developer depends on the rights bundle in the resource. To guarantee that exchange relations can operate to allocate resources to their highest value use, it is necessary that property interests be (1) certain and (2) freely transferable. Even when these elements of "marketability" are satisfied, resource misallocation may still obtain if the development of the resource generates external costs not borne by the developer.

In the case of geothermal fields, external costs in the form of (1) ownership competition for the underlying steam or water, and (2) retrieval costs imposed by exploitation may present developers with false cost alternatives and direct them to exploit the resource at nonoptimally rapid rates. Society will be denied the full value product of the energy field.

Preexisting legal classifications such as water and oil, when applied to geothermal resources, result in substantial societal loss by failing to provide marketability and by encouraging overutilization of the resource. Developing statutory law, such as the Federal Geothermal Steam Act, may also be deficient in the same respects. Field development by unitization may, if properly implemented, provide an adequate solution to the external costs problem. Marketability interests can be satisfied by structuring property rights so as to afford owners a determinate share in the underlying energy resource.

INTRODUCTION

Geothermal resources are now emerging from their status as relatively free to that of commercially desired economic goods. As interest in geothermal energy grows, lawmakers are in turn required to face the difficult task of developing legal systems to deal with this unique resource. The purpose of this paper will be to attempt an evaluation of the effect of various property systems on the utilization of geothermal resources. No pretension is made to completeness, but it is hoped what follows will prove a helpful addition to the debate. As a prologue to the main discussion, an outline of a basic legal-economic analysis of property systems is first offered.

ECONOMIC OVERVIEW

Desiderata of a Property Rights System

Even though a resource may be valuable, if the costs of defining and enforcing a property system with respect to that resource exceed the gains derived from enforcement, there is no economic reason for establishing rights in that resource. Thus, it may be rational from an economic standpoint to categorize some goods as "free" and subject only to a right of first use or capture. An example may be found in the free parking provided at shopping centers. Presumably, the costs of collecting rents from parking users and policing the transactions exceeds the value of the parking space (Alchian and Allen, 1972). But with changes in the relative value of goods, often associated with changes in technology, the resulting desire on the part of economic agents to engage in new cost-benefit relations may make it advantageous to establish well-defined rights in the use of formerly "free" (though scarce) goods.

Economics teaches the desirability of a market system to insure the efficient allocation of resources, but often it is forgotten that the efficiency of an output mix in a market system will in part depend on the rights system in force. Various definitions of the rights bundle associated with a resource will affect the relative value of the good to the "owner" and in part determine his cost/benefit options. If a policy in favor of private utilization of geothermal resources is to be effectively implemented, attention must be given to the resource allocational consequences of alternative rights systems (U.S. Code. & Ad. News, 1970, 5115-6).

Hirshleifer, De Haven, and Milliman (1969) have generally stated the requirements of property systems to be (1) certainty in the right and (2) free transferability. Several elements of the certainty requirement can be distinguished. First, the right should be given a quantitative or otherwise clearly understood definition that is not subject to arbitrary change. Second, resource allocation will be more efficient if the rights bundle includes the right to exclude others from the use of the resource. A nonexclusive rights system

> . . . fails to concentrate the cost associated with any person's exercise of his communal right on that person.

> If a person seeks to maximize the value of his [nonexclusive] rights, he will tend to overhunt or overwork the land because some of the costs of his doing so are borne by others. The [resource] will be diminished too quickly. (Demsetz, 1967)

The additional requirement of transferability insures that exchanges can be effected to shift resources to higher value uses as industrial/economic conditions change. These twin requirements of certainty and transferability will hereafter be referred to as "marketability" in property rights.

Externalities and the Common Pool Problem

Even though an owner's rights in a resource may be "marketable" in the sense just defined, his use of the resource may prove nonoptimal, even assuming a competitive market, owing to the existence of external costs or benefits resulting from his development of the resource. In the case that the owner's use results in external costs on others, not borne by the owner, too much of the good will be produced relative to the condition when all the costs of production are internalized on (that is, borne by) the producer. In the case of external benefits, the rate of output will be too low. Two factors may account for the presence of external costs or benefits: (1) the absence of rights in some aspect of a scarce good; or (2) transactions cost so high that market readjustment is not practically possible, even in the presence of a system of rights in the resources (De Vany, et al., 1969).

The economics of externalities can be illustrated by the example of the common pool, one particularly relevant to geothermal resources. Consider the case of an underground pool with a large number of persons owning the land surface lying above it. We will assume that each owner has a "marketable" right in the pool's contents. However, though the owner takes account of the effects on his interest by his exploitation of the resource, he does not take account of any costs imposed on others. If there is a large number of developers, the problem becomes acute, as each internalizes only a small fraction of the total costs imposed on the system. With reference to Figure 1, the **mpc** curve shows the marginal private cost to each producer; the **msc** curve shows the total or marginal social cost of his production. The **vmp** curve shows the value of the marginal product (equal to the marginal product of that output times the price of the product), and represents the producer's demand-price for the underground resource. The economic effect of the presence of externalities is that the producer extracts from the pool at rate B, whereas the socially optimal rate is A. The resource is depleted at too fast a rate. (A mirror analysis could be made for the case of external benefits by reversing the labeling of the **msc** and **mpc** curves.) If the surface owner's rights in the underground pool are imprecise or nonexclusive, an additional set of costs must be added to those above. In this case, the producer will not internalize even those costs borne by his "share" of the pool. A pure rule of capture will prevail, and the divergence between msc and mpc will be even greater.

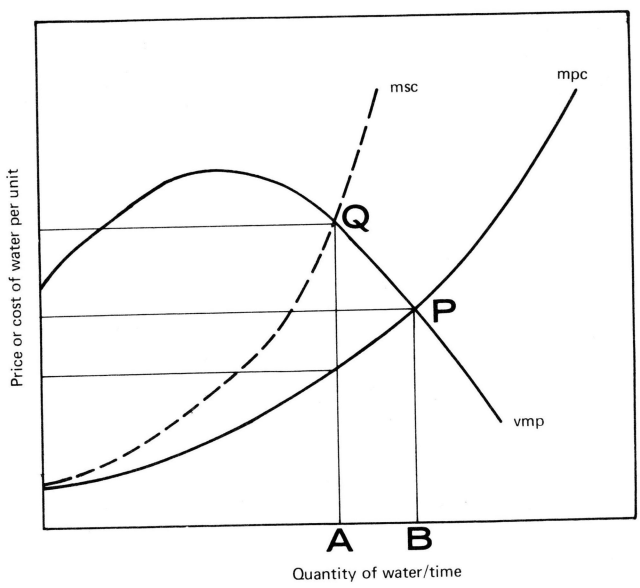

Figure 1. Relationships between cost or price and quantity over time (from Hirshleifer, De Haven, and Milliman, 1969).

This sketch of the economics of property rights is provided solely to suggest a context for the analysis of alternative property systems in geothermal resources. Before continuing to the comparative analysis of various legal paradigms, it will be useful to identify some of the physical characteristics of geothermal resources.

APPLICATION OF WATER MODELS

The following section will analyze some of the existing water law models on which legislatures and courts may rely in developing the ownership law of geothermal resources from the standpoint of each model's effects on the economic utilization of these resources. The underlying standard will be whether the particular rights bundle is consonant with the goal of efficiency in resource allocation. The concern for efficiency, of course, is not the sole criterion on which to decide between alternative property systems. Other interests, such as national defense or foreign policy, may require some loss of efficiency. But this fact does not vitiate the need for analysis of the relationship between various rights systems and that goal. The issue is essentially one of cause and effect, and answers are needed if the legislative (or judicial) process is to fulfill its responsibility.

Intuitive Analogy to Water

Survey of underground water law. No doubt one of the more frequent intuitive responses to the question of the legal character of geothermal resources is to rely on the analogy to underground water. This approach, it will be argued, has little economic merit.

The common law distinguished between those underground waters that run in definite channels ascertainable from the surface, and those that flow or "percolate" underground without any definite pattern. The former category was generally brought under the law of surface water, while the latter was subject to a distinct body of law.

The English (or common law) rule regarded percolating waters as a part of the surface owner's freehold, so that the owner had the absolute right to capture such water as might pass through his estate. (The rule bears a similarity to the ownership in place theory of oil and gas law, both in appearance and rationale. Like the oil decisions, the

English-rule percolating-water cases relied on the supposed "fugitive" and "fleeting" character of the underground fluid.) Thus, in the landmark English case of *Acton* v. *Blundell*, 152 Eng. Rep. 1223 (1843), the court held that a well owner had no cause of action against an adjacent mining operation who, by draining away percolating waters, had caused plaintiff's well to go dry.

The reasonable-use approach developed by the American courts restricts the right of the surface owner to uses that are "reasonable" in relation to the needs of adjacent landowners. The imposition of this standard necessitates a case by case adjudication of the owners' respective interests. The correlative rights doctrine, an offshoot of the reasonable use theory developed in California, regards all landowners over a common aquifer as joint tenants entitled to a reasonable portion of the annual recharge for the beneficial use on overlying lands. (Surplus over this amount is subject to appropriation.) Any extraction to the point that lowers the reservoir level is unreasonable *per se* and enjoinable without proof of damages. In the event of a shortage, each user is entitled to a proportionate share, assuming his use to be reasonable. Like the reasonable-use doctrine, the correlative-rights approach involves the court in difficult legal/factual determinations (*City of Pasadena* v. *City of Alhambra*, 1949; *Orchard* v. *Cecil F. White Ranches*, 1950).

Economic evaluation of underground water law. Both the American and English systems subject underground water to a rule of capture, limited, under the American version, by a standard of reasonableness (Clyde, 1969). Such an approach is sorely deficient from the standpoint of marketability in property rights:

1. Under either system, the water user has no certainty as to the quantity of water to which he is entitled or the duration of his interest. The English rule allows neighbors to deplete the common water source at any time; the American rule subjects the water user to an ill-defined standard of reasonableness that may result in a restructuring of his rights at any time.
2. The American rule, operating from the assumption of joint tenancy, forbids transfers to nontenants of water reasonably needed by adjacent landowners. The restriction of transferability can only result in resource misallocation. The English rule may be superior to the American insofar as it recognizes the freehold ownership of percolating waters as they pass underneath. Thus, the landowner could convey a separate estate in the right to capture the water, and could sell his captured water to others for any use (*City of Corpus Christi* v. *City of Pleasanton*, 1955).

In summary, the English rule may be preferable from the standpoint of transferability insofar as it establishes certain incidents of ownership in underground waters, but both rules are to be faulted for failing to identify the landowner's interest with sufficient certainty. Interestingly, some western states, recognizing the similarity between the American rule as evolved and the riparian rule of surface waters, long rejected in the west, have substituted an appropriative approach to underground waters (*Wrathall* v. *Johnson*, 1935; Idaho Code, 1951).

Applicability to geothermal resources. Writing in *Geothermal Energy* magazine, geologist W. K. Summers made the following recommendation:

> Ground water laws in the western United States . . . have been in effect for many years. Large amounts of thermal water have already been appropriated for both thermal and 'non-thermal' uses under these laws. . . .
>
> I suggest, therefore, that the best interests of the United States would be served if geothermal rights were to be conveyed with the title to the surface, and discharging geothermal water were subject to existing water laws. (Summers, 1973)

The above discussion suggests that this deceptively simple solution has little to recommend it from the standpoint of resource allocation efficiency. The critique of marketability of percolating water rights is equally applicable to geothermal steam and water as to underground water.

It was suggested above that viewed solely as to marketability, the English rule has more to recommend it. However, marketability of a rights bundle does not guarantee socially optimal production rates owing to spillover effects unavoidable in a common pool situation. Under the English law of capture, a substantial divergence between private and social costs is to be anticipated. The correlative rights doctrine is more attuned to the problem of common pools in its restriction on each user's production to "reasonable" rates of output. Unfortunately, this is effected at the cost of substantial uncertainty in that the user's rights are defeasible at any time. Taking account of external effects, it is difficult to say which system might result in greater efficiency.

Possibly appropriation law offers a more workable approach to geothermal resources. The appropriative system is preferable to the riparian (relating to surface waters) in that it clearly defines both the priority and the quantity (annually) of the appropriator's right in surface waters. Modified to permit free transferability, it received the commendation of Hirschleifer, De Haven, and Milliman. However, the manner of establishing appropriative rights may lead to nonoptimal development of geothermal fields. Since the priority of rights under the appropriative doctrine depends on priority in time of appropriation, the geothermal developer will be under an incentive to extract at the highest possible rate in order to establish his priority over later appropriators. The result will be a race to appropriate steam analogous to the race to capture oil during the industry's early years. If, however, the "appropriator's" rights were initially defined independent of any capture—that is, the right to a quantified flow expressed in volume/unit of time—the requisite certainty would be obtained without the danger of a counterproductive appropriative race.

Note on the Federal Leasing Alternative

The approach of the United States government offers an alternative to the option of treating geothermal resources on a common law analogy to water. Federal law affords geothermal a *sui generis* statutory treatment, providing for the leasing of rights to develop geothermal resources under public lands and to use the surface estate as may be reasonably necessary for development. These developmental rights can be lost by failure to produce commercial quantities

of geothermal products within 10 years (30 USC, Sec. 1005a), or for failure to comply with regulations promulgated by the Secretary of the Interior. In no case can the term of the lease exceed 40 years (30 USC, Sec. 1005b); but the leaseholder has, if the land is not needed for other commercial uses, a preferential right to renew for a second 40-year period. The terms of the lease are subject to review and unilateral change by the supervisor at 10-year intervals, but not before geothermal steam is being produced on the site (30 USC, Sec. 1007; also Sec. 1005c, definition of "production of geothermal steam").

The contingent nature of the leaseholder's interest introduces an element of uncertainty to the property interest that clearly conflicts with resource allocation considerations. The federal lease provisions fail also on the criterion of free transferability. Under the regulations (43 CFR, Sec. 3241.1-1), transfer of geothermal interests is prohibited if the retained portion of the transferor is less than 640 acres or if an undivided interest is created by the assignment of a lease of 640 acres or less. The latter prohibition appears particularly difficult to justify, since transfer for undivided interest is a useful means of aggregating small interests into economically workable units.

COMMON-POOL PROBLEM

The discussion to this point has focused on the effect of various definitions of rights on the ability of the market process to effect desired allocations of resources. It has been seen that water-law models prove deficient from this standpoint, and that their application to geothermal resources can be expected to retard proper commercial development.

The concern for marketability of rights-bundles is present with all resources. But for some goods there is an additional concern that efficient resource allocation may be impeded by the emergence of a common-pool problem, classically occurring whenever a particular resource is owned "in common" without clear definition as to the enforceable limits of each owner's rights. There is reason to believe, it will be suggested, that serious common-pool problems may emerge in geothermal fields and that legal solutions will have to be developed to avoid the consequence of over-rapid utilization of the resource. The experience of the oil and gas industry may be helpful to set a context for the discussion of the potential geothermal common-pool problem.

Survey of Oil and Gas Law

Not surprisingly, the first American courts to be called upon to determine rights in oil pools were impressed by the (spurious) analogy between the "free flowing" oil and the "free flowing" character of underground waters. More evocative was the analogy to wild animals running across a feeholder's land. Although these early analogies have now been rejected, they nonetheless strongly affected the development of oil and gas law (Hemingway, 1971).

Doctrines parallel to those of underground water were developed to deal with oil and gas. As noted earlier, the ownership-in-place theory closely relates to the English rule in that both allow for ownership of a corporeal real interest in the flowing underground fluid. But though transferable, the surface owner's right to underground oil was nonexclusive. The alternative view, known as the nonownership theory, also established a rule of capture (sometimes modified by a correlative-rights concept), and limited the interest the surface holder may transfer to his personal right to capture—called a *profit a prendre* in the common law (Cohen, 1958).

The inadequacies of the law of oil from the standpoint of marketability interests are similar to those cited in connection with water law, and need not be repeated. Of greater interest at this point is the similarity between common-pool problems in the oil and geothermal industries. The oil-law rule of capture led to a "riotous economic adventure characterized by . . . a madly acquisitive scramble for nature's bounties" (Merrill, 1941). Society paid for the unwisdom of this rule in the costs "not only of a resource too hastily depleted but also of resources put into unnecessary wells that sometimes lined surface boundaries like fenceposts" (De Vaney, et al., 1969). Similar results may be anticipated in the geothermal field unless attention is paid to the common-pool problem.

Nature of Externalities in Geothermal Fields

Preliminary to a discussion of possible legal solutions to the common-pool spillover problem, it will be useful to sketch the nature of external effects in geothermal fields. Following the valuable analysis of Friedman (1971), we can distinguish two sets of costs: (1) externalities resulting from ownership competition under a rule of capture, and (2) externalities in the form of retrieval costs.

External costs of the first type arise by reason of the divergence between private and social costs of production. Since the rule of capture gives no assurance that resources will be available for extraction later, developers are given a skewed incentive pattern that forces them to ignore the opportunity cost of extracting resources now that have value in the future (discounted by the rate of interest). The value of the resource over time is not maximized.

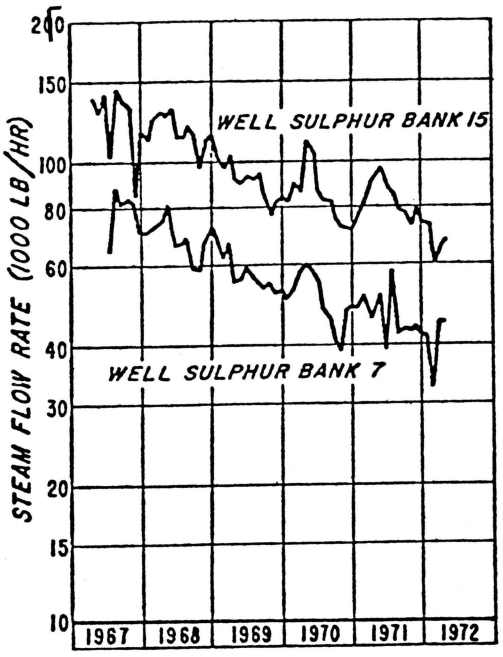

Figure 2. Steam production rate vs. time for steam wells at The Geysers (Budd, 1973).

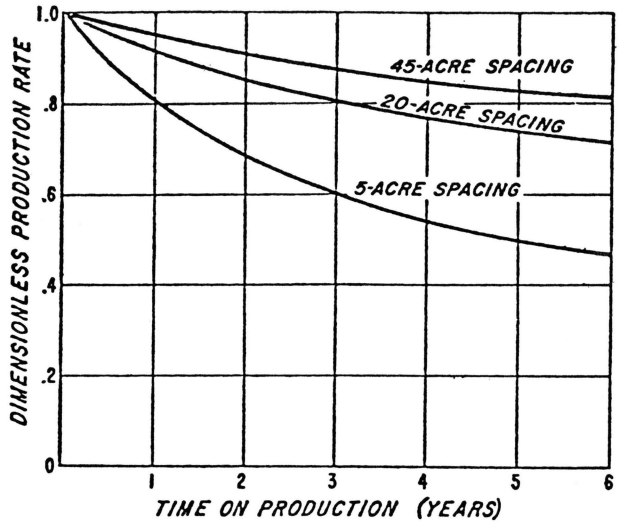

Figure 3. Steam production rate over time, from reservoir model simulation studies (Budd, 1973).

To date little in the way of external costs resulting from ownership competition has been observed, primarily for the reason that of the few geothermal facilities in operation, none have had adjacent competitors. However, data gathered at these facilities suggest that as the ownership of geothermal interest continues to diffuse, the prospect of the emergence of a serious externalities problem is likely. Contrary to initial speculation, it is now evident that the quantity of reserved geothermal water/steam is dependent on the number of wells and the rate of extraction from a given field. The experience of the Geysers has shown (Fig. 2):

> . . . the performance of one well is greatly influenced by the status of nearby wells. The static pressures of shut-in wells are reduced by production from nearby wells. And when producing wells are closed-in, the static pressures of the nearby shut-in wells usually recover to values near the static pressure prevailing in the reservoir. (Budd, 1973)

The production rate has also been found to vary with the spacing pattern of wells, with lower production rates associated with high density well spacing (Fig. 3). Obtaining maximum production life from a given field will depend on well spacing. A law of capture can be predicted to result in suboptimal high-density spacing arrangements.

Similar effects have been observed at the Wairakei hot-water field in New Zealand. Field pressures and temperatures were inversely related to production rate increases; once production rates were stabilized, temperature and pressure continued to drop but at a lower rate (Fig. 4). R. S. Bolton, design engineer of the Ministry of Works for New Zealand, reports:

> Exploitation has resulted in an almost uniform pressure decline of over 300 psi and *affecting an area considerably greater than the main production area* [emphasis added]. . . . Except for the first quarter of 1968, the number of wells on production has been substantially constant since 1963, but there has been a gradual decline in output. . . . Any substantial increase in draw-off will result in a further decline in pressures, temperatures and well output such that while there may be an immediate gain in total discharge, this would rapidly fall off, and there would be no long term gain. (Bolton, 1973)

Bolton concludes, after a comparative study of steam and hot-water fields, that geothermal systems are no exception to the rule that

> . . . substantial exploitation of any underground system will result in a decline in the pressure of the system.

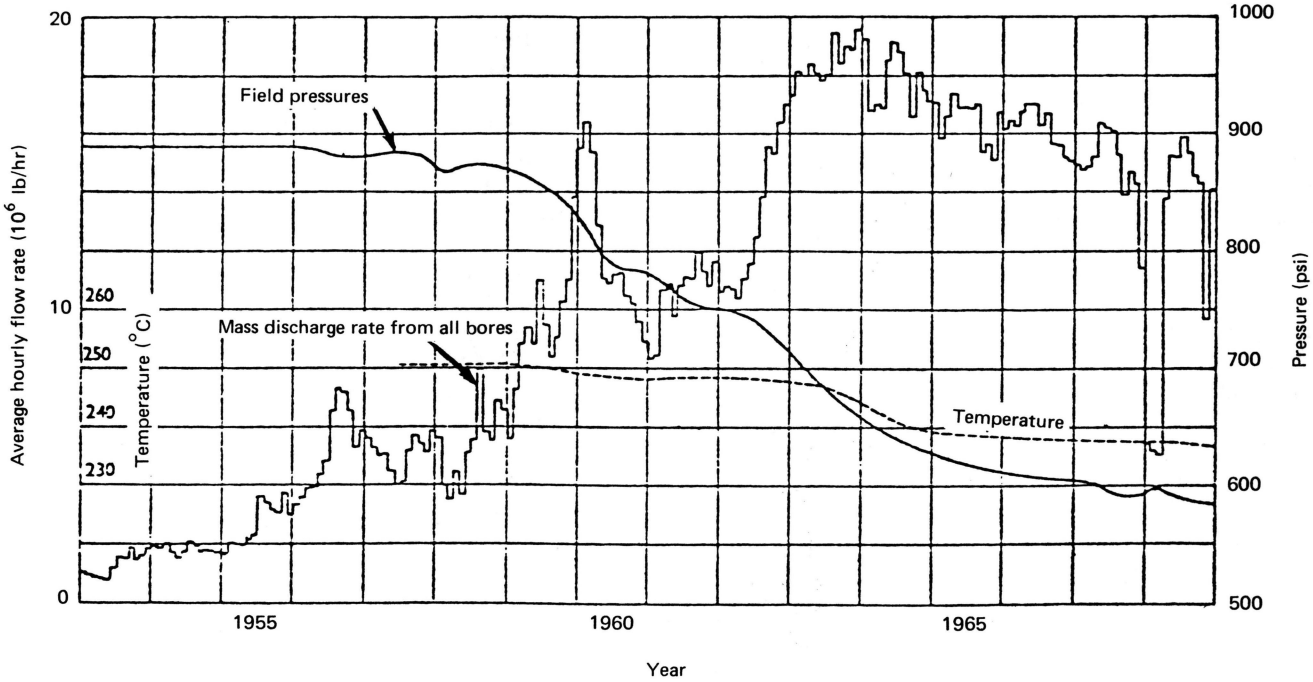

Figure 4. Field pressure changes with flow rates over time.

> . . . In the case of fields discharging under thermo-artesian conditions, outputs also fall. The extent of fall in output and pressures is governed by the rate of replacement of the discharged fluids, which is in turn a function of the permeability of the system as a whole. At present, the magnitude of these effects cannot be predicted from early investigations, and can only be assessed after a period of exploitation (Bolton, 1973).

Moreover, there is evidence that aquifer permeability may be itself affected by the rate of extraction. In at least dry and wet steam fields, aquifer permeability may be lowered by the release of minerals into the aquifer when geothermal water flashes. The result is two-fold: (1) a "cap" may form over the upper part of the reservoir, inhibiting water recharge, thus (2) lowering the pressure level, allowing natural formation of steam in the upper part of the reservoir. The lifespan of the field is shortened by the prevention of recharge and additional costs must be incurred to drill deeper past the impermeable cap. Ultimately the aquifer may be rendered useless as a geothermal resource (Schuster, 1974).

Legal Solutions to the Common Pool Problem

The problem of overutilization of a resource owing to external costs incident to production can be repaired by various legal and institutional arrangements. In all the solutions sketched below, the underlying concept is to alter the incentive pattern faced by the developer so that the full (that is, the social) cost of development is ultimately borne by him.

Single ownership. The simplest and most direct method is to place a given geothermal field under single ownership. The effect is to internalize both sets of costs on the field owner, so that he is faced with the "correct" set of cost-benefit alternatives (Alchian and Allen, 1972). The federal act's provision for cooperative plans among geothermal leases for the development of shared fields, subject to approval by the Secretary of the Interior (30 USC Sec. 1017), may provide a means of reaggregating interests. However, if limited to voluntary unitization, the federal law may prove to be of little practical significance if ownership of geothermal leases is scattered over a large number of parties in a single field. Voluntary cooperation as well as single-ownership arrangements are more likely to occur where a large geothermal resource owner is adjoined by smaller interests. The larger interest will have more to gain by rationalization of production, and consequently will be in a better position to buy out smaller interests to the benefit of all. Even this development may be stymied by a "hold-out" problem, as adjacent small owners or lessees delay and maneuver for the enviable position of being the last to be bought out.

The presence of substantial transactions costs impeding voluntary reassociation is of course at this point purely conjectural. All that can be said is that as interest fractionates in a given field, the transaction costs of reassociating them into a coordinated scheme must increase. If ownership is restricted to a small set of firms with a history of mutual accomodation—as is often the case among oil companies—internalization costs may be low and of no social concern. Nonmembers of the "club" may nonetheless be compelled to cooperate by the high initial cost of geothermal production. Significant transaction costs may still emerge in areas where noncompetitive leases are awarded to more individualistic developers. Moreover, given the vagaries of corporate strategy, cooperation cannot be assumed even between the big operators. Finally, the argument that high capital requirements will compel cooperation fails to recognize the nonelectricity generating uses of geothermal resources, which have low capital requirements. Thus activities such as hydroponics, refrigeration, or mineral extraction may impose external effects on other field users and may be expected to develop adjacent to larger electrical generating operations.

Compulsory unitization. Where voluntary behavior cannot affect centralized decision making, reliance has been placed on legislation to compel cooperation upon petition by a requisite number of interest holders. Commonly such arrangements take the form of unitization plans providing for the "surrender of competitive withdrawal rights in exchange for a fractional share in the whole pool" (Hirshleifer, De Haven, and Milliman, 1969). Compulsory unitization is a widely used method of dealing with common pool externalities in the oil industry. Unless leasing patterns are structured to provide for single-firm development of individual fields, some form of compulsory unitization may be necessary.

The statutory authorization for unitization is ambiguous as to the supervisor's authority to compel unit plans (30 USC Sec. 1017). However, the regulations appear to assume this authority (30 CFR Sec. 271.1), and the federal standard form lease expressly authorizes the supervisor to compel unit planning when necessary for "the conservation . . . or to prevent the waste of the resource." (Question: can the supervisor compel unitization in order to circumvent capital raising problems?) To date, according to K. Cargill, unit operations manager, U.S.G.S. (private commun., 1975) this authority has not been exercised. However, as suggested earlier, unless substantial changes are effected in leasing policy, resorting to this means will be all but unavoidable.

Production quotas and use taxes. The scattered lessee/owner pattern may be left undisturbed but the external effects minimized by establishing production quotas or setting use taxes on production. In either case the purpose is to restrict output to rates socially more advantageous than would obtain under unrestricted capture. Quota systems, however, involve the regulator in the difficult task of determining the correct rate of extraction. In effect, the regulator is called upon to perform the operations of the market. Standards such as "safe yield" tend to be arbitrary from an economic standpoint. Considerable loss of efficiency can be avoided by permitting free exchange of quota rights among owners/lessees.

The use-tax solution has the appeal of economic elegence: a tax equal to the difference between marginal social cost and marginal private cost at given output rates would be levied on producers. But again this solution begs the question of what this difference is, and the actual computation may prove a task beyond the ken of regulatory agencies. Yet it can be argued that lacking another solution, some tax is to be preferred to none.

Property right restructuring. The property right restructuring approach seeks to take advantage of the market

mechanism to alleviate the social-cost problem by establishing a property rights system that will permit the effective internalization of external costs by exchange readjustments (Demsetz, 1966, 1967).

Ownership competition can be theoretically eliminated by allocating to each lessee/owner some definite interest in the common pool, so that a pool with Q resource and n owners is effectively converted into n separate pools each containing Q/n of the resource (if each owner is given an equal share). As stated by Friedman:

> This transformation internalizes the basic externalities of the common pool, and seems to result in a socially optimal production rate if it is assumed that every producer feels that no change in his output will affect price. (1971)

The exact means of apportioning the pool presents hard problems. The theoretical ideal would grant to each lessee/owner a volume in the pool equal to the capitalized value under a rule of capture of each lessee/owner's share. This ideal cannot be determined since the essence of the capture is to make each interest indeterminate. Nevertheless, clearly some apportionment is preferable to none. Provisions for readjustments in each interest holder's reserved share may be necessary as subsequent knowledge casts doubt on the basis for the initial allocation, or if natural conditions in the pool change its productivity.

The problem of recovery costs is far more knotty. Generally stated, some way must be found to compensate geothermal interest holders that develop later at higher costs owing to earlier utilization of the pool. Several formulas for arriving at workable estimates have been suggested (Friedman, 1971). It may be that in attempting to assess recovery costs rough estimates must be tolerated.

RECOMMENDATIONS

The problems impeding the emergence of a viable geothermal industry have been said to be more institutional than technical (Fuchs and Huttrer, 1975). It has been suggested that both the federal statutory scheme and the common-law water models may impede the development of geothermal resources and render more costly the rational management of a geothermal field once development begins. The following will attempt to outline some recommendations as to possible reforms in the structure, content, and duration of geothermal interests in order to create a more desirable incentive pattern.

Structure

The various solutions to the common-pool problem outlined above suffer alike from information-gathering obstacles, although the information problem is less severe for some than for others.

The following suggestion is offered as a means of effecting a rights restructuring that will ameliorate the common-pool problem and provide the necessary incentive to gather the information needed to allocate geothermal interests wisely. A government agency should initially issue exploratory permits subject only to a bonding requirement to protect against possible environmental damage. These permits would grant nonexclusive right to explore and evaluate the geothermal potential in a given (large) region (such as a state) for a specified time. (Currently, federal leases confer an exclusive right to appropriate geothermal resources but only a nonexclusive right to explore.) When a prospective developer can satisfy the agency that it has determined a particular region to be subject to development as a single field, and can provide a development plan, together with backing, contingent only on government approval, the prospective developer should be granted an exclusive leasehold in that region. No consideration should be required save a bonding requirement. Present leasing procedure requires substantial cash outlay, often in the hundreds of thousands of dollars, merely to secure a lease. Apart from the objectionable restriction of entry to cash-rich enterprises, principally oil companies, the procedure also no doubt inhibits development by raising initial fixed costs in an already capital-intensive operation. From the standpoint of effecting early (but not suboptimal) development, a bonding requirement would seem sufficient to safeguard the public interest.

Economists have objected to the "giveaway" approach on the grounds that substantial windfall benefits are passed to lease recipients (Dam, 1975). However, there is no reason why the government as lessor could not recover any such benefits over time by royalty payments on production. Assuming perfect capital markets, it should make no difference which method was employed: high lease payment, no royalty or no lease payment, or high royalty. But since capital markets are not perfect, and substantial difficulty can be encountered in raising large cash amounts for initial lease payments, the royalty recovery method appears preferable.

Substantive

The question of the structure of rights is common to oil, water, and geothermal law. But an additional problem in present in geothermal law—the question of to *what* the rights being granted pertain. Given the multidimensional character of the geothermal resource, what should be the content of geothermal interests?

The federal statute has taken the approach of a nearly all-inclusive definition:

> "geothermal steam and associated geothermal resources" means (i) all products of geothermal processes . . . (ii) steam and other gases, hot water and hot brines . . . or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any byproduct derived from them . . . (30 USC, Sec. 1001c).

If anything, this definition may raise questions by reason of its breadth. For example, unit agreement usually relates to a specified substance (for example, oil or gas). In the event of geothermal unitization, could an interest holder claim that the unit agreement pertained only to steam and not to water? Such arrangements might be desirable, if, for example, field externalities compel unitization as to steam/water but not as to heat content, which may be raised nonaqueously and with fewer external costs to aquifer permeability.

More significantly, the federal definition focuses on the constituent aspect of geothermal resources to the exclusion of the geothermal formation or geothermal processes (Barnea, 1973). Unlike water or oil, geothermal is a multidimen-

sional resource that embraces not only aqueous constituents but also a geologic container and ongoing geothermal processes.

Rights may be granted, for example, to definite storage volumes in the aquifer, thus encouraging conservation of aquifer permeability and use of artificial storage and recharge. Perhaps rights should be established in the geothermal processes themselves. Alternatively, the geothermal processes could be viewed as legal entities. A geothermal system is more akin to an organism than to a pool of oil or gas; delicate geologic processes must continue for the heat to be easily available through steam or water. Might it be inappropriate to speak of a trespass or even a battery to geothermal systems? Should the owners or lessees be viewed as trustees or guardians?

The heat aspect of geothermal resources may deserve particular attention. If an estimate of the recoverable heat in a given field could be made (and it may be; see Bolton, 1973), it might be more direct and rational to define each lessee or owner's interest not in terms of steam or water volumes but in terms of calories or Btu. Separate estates could be granted in the nonheat components of the geothermal resource package (for example, water or minerals), and these various estates could be developed separately or jointly by one producer as the economics of development might indicate. The appropriate output mix among these "resources" can be left to the market to determine if each aspect of the resource package carries a rights bundle that meets the marketability requirements discussed above, and if provision for common-pool externalities has been made.

It is difficult to concretize these observations into specific proposals. One suggestion may be to rely on an analogy to water law. Like water flow, geothermal processes are best expressed in terms of rates (rather than quantities or volumes) and are subject to variations in flow rates from year to year. These factors could be allowed for by establishing priority rights to a given amount of heat per unit of time. As in appropriative water law, second priority holders could not extract the resource unless first priority holders are able to remove their share. This suggestion would prove of considerable significance should a fractional interest property rights approach be attempted to meet a common pool problem.

Duration

The uncertainty attending the duration of federal lease interests has been noted. The adverse effect of such uncertainty on the attraction of capital has not gone unnoticed (Stone and McNamara, 1975). The problem was in fact raised by one of the first commentators on the legal problems of the geothermal industry:

> The heavy expenditure of time and money to erect a plant to convert geothermal steam or water into power, coupled with the fact that such plant must be quite close to the well itself, seems to require a permanent type of title, as against the lease method employed in Oil and Gas fields. (Randall, 1964)

To make a case for fee simple ownership perhaps requires a degree of faith in free market ordering that few are willing to avow. But whatever the estate in geothermal resources may be, assurance should be given that the duration of the interest will be sufficient to amortize the cost of a power generating facility from the time of beginning operations.

Concluding Remarks

The above discussion has attempted to indicate some of the problem areas in the creation of a rights system that will implement the twin goals of early and optimal development of geothermal resources. It is hoped that this paper may help others in their contribution to the legal dialogue on geothermal resources that has only recently begun.

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