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The Site Specific Nature of Geothermal Energy: The Primary Role of Land Use Planning in Nonelectric Development†

INTRODUCTION

Site specific energy resources throughout history played an important role in the maturing of society. The availability of water and wind power contributed early to the advance of civilization, and hot springs often served as gathering spots. The centripetal influence energy resources had on settlements waned with the increased use of transportable fuels such as wood, coal, and later, oil. Distant places, often sparse in local natural riches, grew with the expanded accessibility to these more concentrated and assured energy sources. In the ancient world, such trends melded with a greater control of food supply to prompt a sedentary life, and centuries later, incipient industrialization. Near the end of the 19th century, the development of electrical generation technology allowed access to energy anywhere transmission lines could be installed.

Soon after the commercialization of electrical generation, geothermal energy was in use as a power plant fuel (in Italy in 1904). Electrical energy generation today requires relatively high temperatures (a minimum of about 160°C). Geothermal resources of this temperature are not found in natural abundance. By contrast, the locales of lower temperature resources are plentiful. These latter resources are, however, strongly site specific in their usefulness. Although lower temperature geothermal resources can substitute for a substantial amount of fossil fuels, developers inescapably must work within the severe limitations of its immobility.

The most significant direct and indirect consequence of geothermal energy's site specificity is its close relationship with land use. This relationship, although more pronounced with geothermal resources, is not new to energy developments. For example, when oil was found in Alaska, the problem was protection of wilderness qualities; when oil was discovered beneath Beverly Hills, California, the reduction of the visual and auditory impacts became the task; and as the demand for coal increased

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TABLE 1.

Energy Phases

- RESOURCE DEVELOPMENT
  - EXPLORATION
  - EXTRACTION
  - TRANSPORTATION
  - PROCESSING
  - CONVERSION
  - DISTRIBUTION
  - WASTE DISPOSAL
- RESOURCE UTILIZATION

in farmland states like Indiana, protecting rich agricultural soils while allowing access to the coal beneath became the concern. The important role land use plays in geothermal development stems from the fact that it is not only site specific during the extraction phase (as are many energy resources), but also during other phases as well (Table 1).

Particular interest in nonelectric resources stems from the results of two previous studies which identified the significance which land use has in the development of geothermal energy for electricity.[1] Those studies found direct land use conflicts to have great impact on the development of the resource for electricity. While electricity almost always supplies a user away from the site of generation, nonelectric development requires the use of the geoheat directly after it is withdrawn from underground. In contrast to the long transmission potential of electricity, heat itself cannot be moved very far without paying a heavy economic and thermodynamic price.

The severe site specific nature of nonelectric geothermal energy suggests that the present land use, as well as the planning necessary for future use, plays an important role in the development of the resource. This paper will examine that role.

NONELECTRIC APPLICATIONS FOR SPACE CONDITIONING

In order to ascertain the actual and possible relationships between nonelectric geothermal development for space conditioning and the rel-

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[1] Pasqualetti, *Geothermal Energy and the Environment: The Global Experience*, 5 ENERGY: THE INT'L. J. 111 (1980); Pasqualetti, *Geothermal Energy, Site Specificity, and Resource Reserves*, GEOJOURNAL (supplementary issue on energy, 1982).

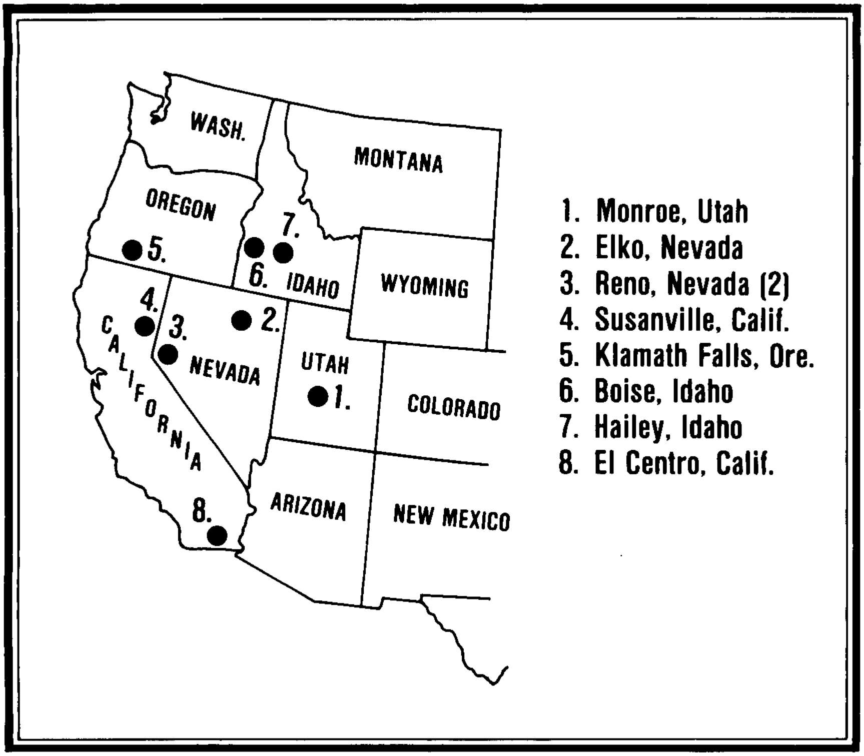

FIGURE 1. Direct use geothermal sites investigated. Two in Reno. All but Hailey and one in Reno funded under Program Opportunity Notices of the U.S. Department of Energy.

evant aspects of land use and land use planning, nine sites have been investigated in five western states (Figure 1). Development programs for seven of the sites were funded by the U.S. Department of Energy. At the suggestions of interviewees, two sites (Reno #2 and Hailey) were added during the field session. The nine sites were chosen because of the existence of development projects, proximity to one another, variety of population size, and the accessibility of data sources and project directors. The Susanville, Klamath Falls, and Boise sites have had development projects underway for several years; the longer history of these sites produced a more detailed literature.

Each site's project manager, as well as DOE personnel, private planners, and many others who for one reason or another are involved with nonelectric geothermal programs were interviewed. Project managers were questioned on five topics: resource characteristics, demographic and economic aspects of the community (to allow comparisons and to gain appreciation for the type of project envisioned), current arrangement of utility supply and control, land use (*e.g.*, zoning, planning, juxtapositions of users), and environmental problems (e.g., noise, water pollution). These interviews were conducted in order to determine which land use characteristics are significant to direct-use development. The following section summarizes the analysis for each site. The paper then concludes with the application of the findings to the formulation of a geothermal development model.

Monroe, Utah

Monroe is a small but rapidly growing town of approximately 2,000 persons, located on the Sevier River in southwestern Utah. The town lies immediately west of the Sevier Fault. The Monroe Known Geothermal Resources Area (KGRA), located along this fault and characterized by two large tufa mounds, discharges up to 380 gallons (1,444 liters) per minute of warm water. Monroe Hot Springs Resort uses this water.

Monroe considered the development of the geothermal resource for district heating in order to permit it to decrease its dependence on more conventional energy sources.[2] The buildings to be served under the original plan included the South Sevier High School, an elementary school, a junior high school, a Latter Day Saints chapel, and 73 residences.[3] According to the plan, the city would own and operate the system and accrue revenues from its operation. Monroe plans to include considerations for geothermal development in the revision of its master plan.

The initial task of siting the well produced a land use conflict. Although the nearby geothermal resources are concentrated on federal land along the eastern city boundary, the best site for the well was determined to be on property of the private Monroe Hot Springs resort. Whereas negotiation for development rights on federal land would have been relatively routine, dealings with the resort owners proved difficult, time consuming, and expensive. Moreover, neither the actual drilling or accompanying flow tests proved promising: the temperature and flow rates were deemed insufficient to supply the needs of the envisioned system. Hence, the city abandoned the project.

The primary reasons for dropping the project can be given two interpretations: inadequate resource (e.g., temperature, flow rates) or, as we veiw it, insufficient user energy density. Greater energy density (usually

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[2] Interview with Duane F. Nay, Mayor of Monroe, Utah (July 5, 1980).

[3] Nay, Harrison, Blair, Sakashita, and Jones, *Direct Utilization of Geothermal Resources at Monroe, Utah*, in GEOTHERMAL DIRECT HEAT APPLICATIONS PROGRAM SUMMARY 123, U.S. Dep't. of Energy, Geothermal Energy Division (1980).

given in MW/km^2 or MMBTU/hr/ac) would have reduced the demands on the well, and the distribution costs would have been substantially lower.[4] It is the opinion of some that the project would then have been feasible. Energy density for such a system remains clearly an important concern.[5]

Elko, Nevada

Located along the Humboldt River in north central Nevada, Elko is another rapidly growing city. The design of the federally funded geothermal project demonstrates the technical and economic feasibility of the direct use of geothermal brines from the Elko KGRA for the purposes of providing space heating, hot water, and process heat.[6]

The developer of this geothermal project, a consortium, drilled a well at a site zoned for commercial use but located within 200 feet (60 m) of a residential section of the city. The consortium calculated the potential area of auditory and sight disturbance of the well drilling, and all residents within this area received a description of the project in terms of the nature of anticipated disturbance and potential for geothermal development in their community.[7] While the notice was not legally required, it was considered a prudent and useful opportunity for public education. All planned future wells have been sited on land zoned either industrial or commercial, and this fact is considered an important component in the reduction of land use conflicts during development of the resource.[8]

Reno, Nevada (Site #1)

Situated on the Truckee River near the highly fractured eastern edge of the Sierra Nevada, Reno rests atop substantial geothermal resources. The first of two nonelectric geothermal projects investigated in the Reno area lies within the Moana KGRA, in the southwestern part of the city, where geothermal energy has heated several dozen houses for many years. The federal project would retrofit approximately 350 condominiums, an elementary school, and a four-story bank building. The project, being developed by a single company, is the only one of the nine projects to be developed privately. All the other projects are either consortia or city-operated.[9]

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[4] E. WAGLMAN, ENERGY CONSERVATION THROUGH DISTRICT HEATING (1980).

[5] E. Allen, The Implications of Urban Land Use Standards for Geothermal Heating Feasibilities (June 1981) (unpublished).

[6] Rackley, *Project Summary*, in GEOTHERMAL DIRECT HEAT APPLICATIONS PROGRAM SUMMARY 173, U.S. Dep't. of Energy (1980).

[7] Interview with Ira Rackley, project manager of the Elko geothermal project (July 8, 1980).

[8] *Supra* note 6.

[9] Interview with Mark Pack, project manager of the Reno geothermal project (July 10, 1980).

The design of the project allows and encourages expansion. An arrangement has been made with the initial participants to permit the company to sell excess heat from the original wells to other future users, which may include the retail outlets of a nearby shopping center as well as private homes. This expansion would double or triple the gross income without adding proportionate increases in operating costs,[10] but is dependent upon early initial planning.

Because geothermal energy is a new commodity to most people, substantial time often is required to deal with the many concerns and questions which always arise in areas of its development. In Reno, many of the public's concerns (e.g., the noise of drilling, flooding of neighboring property, and subsidence following fluid withdrawal) related directly to the fact that the project is underway in an established residential (compared to a commercial or industrial) area.[11]

In response to these environmental concerns, the developers made various assurances and concessions in order to acquire the cooperation of the building owners. For example, certain areas have been specified as off limits for drilling, and the drilling itself is confined to the hours of 8 a.m. to 6 p.m. (except in emergencies). The pipelines and power lines are placed below ground "as often as practicable," and the aesthetic appearance of the property is to be maintained. Liabilities and insurance protection have been arranged carefully for all contingencies. Spent fluid will be rendered environmentally benign prior to ordinary disposal or it will be reinjected. Environmental compatibility is important because the length of the agreement is 20 years, and the agreement binds successors and assignees.[12] These types of considerations directly affect many aspects of land use planning.

Reno, Nevada (Site #2)

The second project, also privately funded, is located on the southeastern outskirts of the city on private agricultural land known as the Double Diamond Ranch. The encroaching city has greatly inflated land values there, and housing development has been suggested. The long experience of geothermal energy use at Moana has sensitized city officials to its possible uses, and planners recognize in this new development a rare opportunity to "idealize" the land use plan for maximum application of the geothermal energy resource.

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[10] Atkinson, *Multiple Use of Geothermal Energy at Moana KGRA, Reno, Nevada,* GEOTHERMAL DIRECT HEAT APPLICATIONS PROGRAM SUMMARY 87, U.S. Dep't. of Energy, Geothermal Energy Division (1980).

[11] *Id.*

[12] *Id.*

Susanville, California

Eighty-five miles (136km) northwest of Reno is Susanville, a city of 7,000 and the county seat of Lassen County. Situated at the northwestern edge of Honey Lake Valley, Susanville has high unemployment, and an unhealthy 50 percent dependence on government jobs.

The geothermal fluids occur in fractured volcanic and interbedded sediments in a roughly rectangular-shaped area in the southern part of the city. Several wells penetrate to the resource which are used by the Roosevelt municipal swimming pool, some greenhouses, and the heating of an LDS (Mormon) Church.

Susanville has been developing its resource, particularly for space heating, for many years. The city fathers' ambitions for geothermal development transcend the desire for cheaper and more assured energy sources, with the project being linked closely with the survival of the city in terms of providing a variety of jobs.[13]

The city plans to use the incentive of low energy rates to induce new users to locate in the community, especially greenhouse operators. The rising cost of fossil fuels threatens many greenhouses in other locations. A survey conducted by the city to determine the potential for voluntary relocation of greenhouses in the event low-cost heat were available in Susanville revealed a willingness by greenhouse operators to move once the resource was commercialized.[14]

The early phases will provide heat for higher density users such as hospitals, a court house, municipal buildings, and fire stations. Later phases will include expansion to residential consumers. Some of the planned geothermal uses will require planning changes. For example, it will be necessary to accommodate inter-agency arrangements with the federal government for the construction of geothermally heated low cost housing. Potential funding of this type is often contingent on the existence and appropriate wording of a land use plan and housing element.[15] The need for a land use plan for geothermal development has been recognized for several years.[16]

The need for an overall plan becomes most apparent when discussing the concept of a Park of Commerce, for low-temperature users such as greenhouses and aquaculture. Placed last on a geothermal water line, the

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[13] Interview with Charles Richardson, City Councilman of Susanville, California (July 12, 1980).

[14] *Id.*

[15] Interview with Phillip Edwards, project manager of Susanville geothermal project (July 13, 1983).

[16] "In order to prevent an uncontrolled disorganized growth, an Overall Master Plan was selected based upon utilization of the maximum resource heat . . . available." Longyear, *The Susanville Geothermal Utility System*, in SUSANVILLE GEOTHERMAL ENERGY PROJECT, Workshop Proceedings Final Technical Report, U.S. Energy Research and Development Administration, SAN-1077-4, Chapter XVIII (1976).

implementation of a park of this type requires careful analysis of the possibilities for "cascading" the resource (where a spent fluid of one user becomes the working fluid for another). This type of arrangement puts heavy emphasis on appropriate juxtaposition of users.

Part of the Master Plan concept in Susanville entails the development of ordinances. The City Council on July 2, 1979 passed a geothermal ordinance which proposed to devise the land use plans, policies, and zoning regulations to be structured to protect the environment; to protect the community way of life through land use planning and the resulting municipal and county zoning ordinances; and to protect the resource by establishing the spacing of supply and reinjection wells.[17] Although the council was aware of the unique Geothermal Element of Imperial County, California, they decided not to emulate quite so structured an approach, preferring instead flexibility suited to the rapidly changing knowledge of the resource.[18]

Klamath Falls, Oregon

Klamath Falls, with its surrounding unincorporated suburbs, has a total population of 40,000. It is one of a very few areas of the United States known for its geothermal development. Six hundred wells have been drilled in the urban area, most of which are fitted with down-hole heat exchangers for the purpose of space heating individual homes, schools, a hospital, and a multitude of commercial and industrial users. The Oregon Institute of Technology has been completely geothermally heated for a decade, and a geothermal cooling system was added in 1980.

The city plans to construct a municipal geothermal district heating system. The first of three phases will heat 14 government buildings and 120 residences in the downtown area. Phase II will expand this system to heat 11 blocks. Phase III will heat the entire 54-block central business district.[19] The city will own and operate the project.

Consultants to the city stressed the importance of land use considerations, including the demarcation of pumping districts for the geothermal distribution system.[20] The boundaries of these districts were determined

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[17] City of Susanville, Ordinance No. 79-605 (1979), Providing Procedures for Establishment of Geothermal Drilling Sites and Establishing Limitations, Safeguards, and Controls for Geothermal Drilling and Production. Cade and Jeskey, *The Definition of an Institutional Structure*, in SUSANVILLE GEOTHERMAL ENERGY PROJECT, Workshop Proceedings Final Technical Report, U.S. Energy Research and Development Administration, SAN-1077-4, Chapter XIII (1976).

[18] Imperial County, California, Geothermal Element to the County General Plan, Imperial County Planning Department 1977.

[19] Lund, Lienau, Culver, Higbee, *Klamath Falls Geothermal Heating District*, EXPANDING THE GEOTHERMAL FRONTIER *381* (1979).

[20] Interview with Eliot Allen, Eliot Allen Assoc., Salem, Oregon (July 20, 1980); personal correspondence with Eliot Allen (June 30, 1981).

using four criteria: 1) the location of natural topographic obstacles, 2) the location of man-made features, 3) the location of political boundaries, and 4) land use.[21] Natural features, such as railroads and canals, were considered barriers which would be expensive to cross. They usually were used as district boundaries.

One of the pumping districts is the "Commercial District." Location of the boundaries of this district was based on four considerations: 1) "the location of the supply lines for the 14 government buildings; 2) the location of private commercial buildings in the central business districts; 3) the location of a proposed mini-heating district for 10 church complexes in the downtown area; and 4) consultation with City of Klamath Falls officials."[22] Although the heating loads have not been determined for each district precisely, they are considered to be approximately equal, and generally increase in size away from the Central Business District (CBD) due to the reduction in energy user density.

Several environmental concerns have been identified: depletion of the reservoir, surface thermal pollution, and the potential for lowering the level of existing wells. On this last point, the goal of the project is "to minimize the effect of production and injection on adjacent wells in terms of level and temperature."[23] The people who already have their own wells often oppose the planned heating district most strongly because of possible hydro-geological interference with their system. Interestingly, the early wells lie in the areas of the best resource, and those parcels were among the most quickly settled by the affluent citizens in the early history of the city. Today, a zoning pattern exists "which is backwards in terms of land use, energy requirements and reservoir capabilities, i.e., the best resource areas have been given over to low-density residential use, while commercial and industrial users have been sited in only marginal or nonproductive geothermal areas."[24] By the summer of 1981, voters rejected the ordinance designed to rectify some planning barriers to geothermal development. As an alternative, mixed use zoning is being considered.

Boise, Idaho

Boise boasts the longest continuous use of geothermal energy for district space heating in the United States. In 1890 when the town population was 2,500, geothermal energy use included spas, greenhouses, and space heating. The initial two wells, still operating, have supplied up to 250

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[21] *Supra* note 19.

[22] *Id.*

[23] *Id.* at 386.

[24] *Supra* note 20. For further elaboration *see* Allen, *supra* note 5, and Allen, *Klamath Falls Municipal District Heating and Reservoir Management Ordinance: A Preliminary Oregon Model Ordinance*, 4 GEOTHERMAL RESOURCES COUNCIL TRANSACTIONS 760 (1980).

residences concentrated along Warm Springs Avenue. Recently, developers marketed and developed a new housing tract around available geothermal heating.

Three geothermal projects are now underway in Boise: 1) refurbishing the existing system, 2) space heating state office buildings, and 3) space heating commercial outlets and office space in the downtown area. The third project will be addressed here. The large downtown establishments comprise most of the potential users of this system. Twenty buildings in downtown Boise account for almost 90 percent of the potential system load. The proposed downtown mall itself will total about 800,000 square feet (74,320 sq m). Expansion of the system will require drilling of additional wells.

To minimize the cost of transmission lines, wells for the downtown system should be located as close to the user as possible. Boise Barracks, formerly federal land now dedicated to the city, straddles the Foothills Fault, the principal conduit for much of the upward migrating geothermal water which occurs along the Boise front. This largely vacant parcel of land sits only about one mile (1.6km) from downtown. The fortuitous geographical arrangement of vacant land, resources concentration, and users promises to facilitate geothermal development in Boise.

Although some of the potential users are located downtown, many others are at a distance from the resources; i.e., commercial and industrial users historically have been located on the relatively inexpensive land in the west, southwest, and southern parts of the city. Those sites are removed significantly from the resource and, generally speaking, transmission of geofluids to distant locations is considered uneconomic. Moreover, present zoning does not favor the location of industrial users near the resource. "It is felt that few industrial enterprises have located close to the resource because of prevailing unfavorable zoning regulations. Too few parcels near the resource are zoned for enterprises. Even the greenhouses using the resource are located on land that is residentially zoned."[25] Some of the industrial users who happen to be close to the resource will encounter increasing economic pressure to relocate as land costs rise, unless some changes are made at the planning level. Current plans provide for single or multi-family residential housing near the resource, but the need for changes in planning policy has been recognized.[26]

Issues of proximity and zoning are two parts of the broader requirements of user density. Greater use of heat capital dollars will make the system more economical. The Boise project utilized Battelle's GEOCITY model

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[25] CITY OF BOISE, BOISE GEOTHERMAL ENERGY SYSTEMS PLAN, City of Boise Energy Office, at 101 (1979).

[26] *Id.* at 102-103.

TABLE 2.

Cost as a Function of User Density

District Type	*Cost of Heat ($/Therm)*	*Residences/ Sq Mi*
1. Suburban	.799	2,560
2. High Density, Single Family	.787	4,480
3. Garden Apartments	.382	17,580
4. Townhouses or Rowhouses	.432	11,190
5. High Rise Apartments	.328	41,580

Source: City of Boise, *Boise Geothermal: Energy Systems Plan,* City of Boise Energy Office, 1979.

in the analysis of their system.[27] The GEOCITY model divides residential districts into five types: suburban, high density single family, garden apartments, townhouses, and highrise apartments. Assumed conditions of heat loss, insulation, degree days, and similar factors were calculated and cost was determined for each density (Table 2). High density uses, such as for offices, commercial establishments, and hospitals would be more economic than low density uses, such as detached single family dwellings.

Environmental impact is another land use consideration in geothermal development. In Boise, environmental interest has focused on the issue of flouride content in the geofluid. While the fluids are of generally high quality (only 200mg/1 of dissolved solids), the flouride content is from 15 mg/1 to 24 mg/1 and, thus, far exceeds the acceptable limit of 1.8 mg/1 set by the U.S. Environmental Protection Agency and the Idaho Department of Health and Welfare.

Several mitigation measures have been discussed as possible remedies to the flouride problem. River disposal provides one potential remedy. Small quantities of geothermal water currently are being rejected into the Boise River, and they do not appear to be affecting the river ecology in any measurable way.[28] Estimates show, however, that the disposal of several thousand gallons per minute of geothermal water could produce marked impacts on drinking water quality should a dilution ratio of 22:1 not be attainable.[29] High concentration also poses a threat in terms of

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[27] HUBER, McDONALD, BLOOMSTER, AND SCHULTE, USER MANUAL FOR GEOCITY: A COMPUTER MODEL FOR GEOTHERMAL DISTRICT HEATING COST ANALYSIS, Battelle Memorial Institute, Pacific Northwest Laboratory, PNL-2742 (1978).

[28] CITY OF BOISE, PRELIMINARY BOISE GEOTHERMAL ENERGY SYSTEMS PLAN, Energy Task Force, at 52 (1977).

[29] *Id.*

consumption by livestock. Several other disposal schemes have been proposed. One idea has been to reinject the fluid. This of course requires additional drilling sites and transmission pipes. As part of such a scheme, it would be possible to cascade the fluid for other possible applications.

Other environmental problems directly related to land use include noise and waste water discharge during exploratory drilling. Estimates show that noise level would be 70–80 dB(A) at 50 ft (15m), if unabated.[30] Recent events in Boise, however, indicate that these noises may not be as much of an annoyance as is sometimes believed. The state recently drilled a well near the Capitol Mall across the street from a convalescent hospital. As the drillers began to erect sound and sight barriers to buffer the impact, those in the hospital quickly indicated they did not want either, but, rather, were pleased to have something new and interesting to observe.[31]

Some routine activities also require consideration of land use. All wells have to be pumped periodically during exploration. In most cases, quantities will be minimal. However, "at least one production test will be required for a 12-hour period discharging 200 gallons per minute (760 lpm)."[32] This should be considered a bare mimimum, but at this low rate, the volume would amount to 144,000 gallons (547,200 liters) of geothermal fluid. This water will be conveyed by irrigation pipe to dry basins and allowed to percolate. Existing empty ponds within Boise Barracks could serve as storage and percolation pits for wells drilled nearby.[33]

As elsewhere, environmental geology will play a role in geothermal development in Boise. Neither subsidence nor mounding appear to be a severe threat to the Boise project since the production and reinjection depths are a relatively shallow 1,000–1,500 ft (300–450m). Nevertheless, because many buildings are nearby, both possibilities will receive close monitoring as the system developes.[34]

Hailey, Idaho

Hailey, a rapidly growing city of 2,000 people, lies 140 miles (224 km) east of Boise. Of the several sites in Blaine County, Hailey has been one of the most prominent users of the resource. As one example, Hailey's Hiawatha Hotel was heated geothermally for 60 years until it burned in 1979. The hotel had been supplied with hot water from Hailey Hot Springs, 2 miles (3.2 km) west of the City in Democrat Gulch. Consid-

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[30] U.S. Bureau of Land Management, *Geothermal Leasing on Boise Front,* ENVIRONMENTAL ASSESSMENT RECORD #ID-101-7-88, U.S. Dep't of the Interior (1979).

[31] Interview with David W. McClain, project engineer, Morrison-Knudson Company, Inc., Boise, Idaho (August 4, 1980).

[32] *Supra* note 30, at 11.

[33] *Supra* note 31.

[34] *Supra* note 25, at 1.

eration is now being given to using the same heat source for space conditioning throughout the entire city.

Although Hailey is not one of the federal Program Opportunity Notices (PON) sites, it is one of the very few locations where land use is recognized specifically as a barrier to the significant use of geothermal energy. For example, a proposal submitted to the Idaho Office of Energy by the Blaine County Community Council asserted that the orderly development of geothermal energy in Blaine County would require the removal or adjustment of land use barriers. It called for full study of site, market potential, pipeline routes, current zoning of sites and routes, identification of existing easements, site access, property ownership, and future energy needs. The crux of the study is "the identification of land use barriers to geothermal sites and pipeline development programs."[35]

Current zoning presents one of the more apparent land use problems faced by geothermal developers in Hailey. Confined by mountains, the city has limited land suitable for agriculture, all of which is under zoning protection to encourage orderly housing development. The area around Democrat Gulch is zoned R-5 explicitly to limit land use to residential/agricultural developments of one unit per 5 acres (2.1 ha). Thus, residential development, particularly a subdivision, on the west side of Hailey is "not considered realistic."[36] A geothermally heated housing tract on the east side of town would require uneconomically long transmission lines.

In addition, land use is tied to funding geothermal development around Hailey. A more recent study suggested changes in the current status as a means to encourage a more favorable atmosphere for private financial investment outside the city limits. The study dealt with environmental restrictions and legal considerations, as well as factors related to economics, bureaucratic procedures, and land use. The land use considerations included a redesignation of zoning and the process of land assembly for geothermal district system.[37]

El Centro, California

Since El Centro has an average July temperature of 95°F (35°C), it is not surprising that the geothermal project there is centered around the need for cooling. In that regard, the El Centro project is similar to many

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[35] Sweat, Eldredge and Nelson, A Proposal for the Identification and Analysis of Barriers in Geothermal Land Use Planning, *submitted to* Idaho Office of Energy by the Board of County Commissioners, Blaine County, 2 (May 27, 1980) (unpublished manuscript).

[36] McClain and Eastlake, Hailey, Idaho Site Specific Development Analysis 18, Idaho Office of

[37] Harris, Klein and Associates, An Analysis and Identification of Barriers to Geothermal Development in Blaine County Which Can be Mitigated by Land Use Planning Efforts, *prepared for* the Idaho Office of Energy (1981).

geothermal projects envisioned for the southwestern United States. Cooling requirements, along with the lesser need for space heating and water heating, account for the 78 percent of the total energy consumed in the residential and commercial sectors of the city. These energy requirements can potentially be supplied by geothermal energy.[38]

The El Centro project includes the development of a geothermal energy utility core field experiment to demonstrate the engineering and economic feasibility of using moderate temperature geothermal heat, on a pilot scale, for space cooling, space heating, and domestic hot water. The first phase of the project will provide space heating and cooling, as well as water heating for the El Centro Community Center, a public recreational facility, located approximately one-half mile (0.8 km) south of the present well site. At 1979 prices, about $5,800 per year could have been saved if the Center had been part of a large district-wide geothermal system.[39]

Several sites were considered for production wells. The original choice, one mile (1.6 km) south of the Community Center, was based on the combined land use advantages of available resources, city ownership, and accomodating zoning (M-1, restricted manufacturing and light industry).[40]

Ironically, this parcel, originally chosen largely because it possessed favorable land use characteristics, was abandoned because of a land use conflict. The original drilling site is located in a sector of the city generally considered to be in the lower socio-economic range. Local residents objected to the addition of "industrial land use" (i.e., the geothermal well), and consequently, the drilling site was relocated a half-mile (0.8 km) north of the Community Center, immediately adjacent to a fossil fuel power plant. These changes, along with the accompanying dissension, robbed the project of much of its momentum, and for some time serious question existed as to whether the project would be completed.[41]

Because El Centro's winter heating load is quite low, especially compared to the very high demands of summer, the annual load factor (the amount of the time the system is required) is only 20 percent for combined heating and cooling.[42] Either industrial application or the use of cascading, or a combination of the two, could improve this load factor and thus the

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[38] SHERWOOD, PROVINCE, YAMASKI, & NEWMAN, MULTI-PURPOSE UTILIZATION OF HYDROTHERMAL RESOURCES WITHIN THE CITY OF EL CENTRO 29, Westec Services, U.S. Dep't. of Energy, SAN-1741-4 (1979).

[39] *Id.*

[40] "The zoning classification and the suitability of nearby property for the location of an industrial geothermal energy park enhanced the site's attractiveness for geothermal operation and applications." *Id.* at 102.

[41] Interviews with Dutch Scholz, Geothermal Coordinator for Imperial County (April 15, 1981); Sharon Province, Westec Services, Inc. (April 14, 1981).

[42] *Supra* note 38.

system's economic attractiveness. A higher energy user density, implicit in such options, can be carried through the entire scheme, incorporating higher energy density such as commercial outlets and multiple family dwellings. Westec Services, Inc., estimated the costs and utilization efficiencies for several of the possible options (Table 3). Not surprisingly, the most cost-effective option incorporates high density residential, commercial, and industrial users in a cascading arrangement.

Environmental concerns for the El Centro project would be similar to other projects with two exceptions. First, the cooling application will require wet mechnical-draft cooling towers. The towers will be in operation to cool the process liquid in the absorption chiller during the summer months. Cooling-tower blowdown will probably be transported to an approved Class II-1 disposal site, unless there is adequate land available on site. In the case of the original well site, an evaporation pond covering some 1,000 square feet (90 sq m) was to be located adjacent to the equipment pad to handle blowdown.[43] Second, make-up water for that lost to evaporation, drift, and blowdown will come from city supplies during the demonstration phase, but another source will have to be found before full-scale operations can be implemented. This could be a serious impediment to the future of such projects in this very arid area (less than 3 in. [7.6 cm] annual average). Both of these problems, however, will have to be resolved to allow the better known and more advanced electrical development to proceed around El Centro.

IDENTIFIED CONSIDERATIONS

Our examination of the relationships between land use and nonelectric geothermal energy resources has identified several key factors. The most significant lies in how such developments differ from those of electrical generation. In electrical development, increasing impact perception and control is tied closely to a decreasing degree of isolation. Space conditioning (heating or cooling) projects, on the other hand, cannot escape the full range of conditions and regulations which regularly accompany city life. Of the many regulations of a technical nature which accompany developments within cities (e.g. drilling permits), this paper focuses on the regulations tied directly to land use. Several of those factors are divided below into retrofit and new developments (Table 4). The former situation will be the most common.

Any development involving the conversion from electric to geothermal will require the accomodation of existing conditions. These existing conditions can be altered, but not easily. Very few changes will be received

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[43] *Id.*

TABLE 3.

The Effects of Energy Density on Cost and Utilization Efficiency

	A. Annual Cost	B. Annual BTUs Delivered	C. Cost/10^6 BTUs (A/B)	Utilization Efficiency
Residential/Commercial Citywide Modular System[a]	\$9.78 × 10^6	0.98 × 10^{12}BTU/yr	\$10.04	20%
Industrial Park Concept (no cascading)	\$0.30 × 10^6	0.23 × 10^{12}BTU/yr	1.31	76%
Combined City Model and Industrial Park (cascading)	\$9.93 × 10^{6b}	1.21 × 10^{12}BTU/yr	8.21	23%
Residential/Commerical High Density Modular System (cascading)	\$4.50 × 10^6	0.46 × 10^{12}BTU/yr	9.79	20%
Combined High Density Model and Industrial Park (cascading)	\$4.65 × 10^{6b}	0.69 × 10^{12}BTU/yr	6.74	27%

[a] This system incorporates the use of several chiller units instead of a central plant.

[b] This figure includes the incremental annual cost of \$0.15 × 10^6.

Source: Sherwood, P. B., et al *Multi Purpose Utilization of Hydrothermal Resources Within the City of El Centro*, Final Report, WESTEC Services, Inc., San Diego, CA., U.S. Department of Energy (Springfield, Virginia: National Technical Information Service, 1979, pp. 92–93).

TABLE 4.

Significant Land Use Characteristics
(nonelectric)

RETROFIT SITUATION:	Zoning (areas occupied) Present Land Use Energy Density
NEW AREAS:	Vacant Land—Unplanned Future Land Use—Planned Zoning (areas unoccupied) "Ideal" Patterns
RETROFIT AND NEW AREAS:	Parcel Ownership Parcel Size Rights-of-Way Environmental Impacts

enthusiastically, although they may be tolerated if the perceived benefit is substantial enough and an education program is successful. In the cases of Boise and Klamath Falls, historical familiarity obviates the need for many of the steps necessary to educate local residents about geothermal energy. In other cases, notably El Centro, incomplete understanding of the prospective project reduces enthusiasm and support.

Nonelectric development must be compatible with the existing land use system. Zoning plays an important role in identifying areas which, ostensibly, would be most suitable for geothermal activities, particularly drilling. For example, industrial zoning would generally be more compatible than residential zoning.

Present land use must be considered from at least three perspectives. First, land use which varies from the zoning must be identified. Second, present land use will determine the potential for early energy cascading. The third, and perhaps most important consideration in determining the economic viability of the project, is energy density, or the concentration of energy use. In that regard, hospitals and commercial establishments seem to be more amenable to conversion to geothermal energy than single family housing.

The vacancy of land parcels reduces some encumbrances to geothermal development, especially when they allow idealized land use patterns. Those patterns would reflect the peculiarities of the resource itself (e.g., cascading potential, low temperature, high cost of pipelines, etc.). The more limited the previous planning has been, the easier "optimum geothermal planning" will be to implement.

Several considerations are common to both retrofit and new-area situations. Parcels owned by the city, especially where a geothermal system is also city-owned and operated, can be a positive ingredient in the success of the project. On the other hand, if the drilling location is controlled by uninterested or unsympathetic landowners, the project could falter. Parcel size is particularly important environmentally because large parcels will buffer the effects of drilling and other early steps.

The location of rights-of-way presents important and significant considerations both in new-area development and in retrofit situations, though differences exist between the two. For example, the distance of transmission lines, and thus their cost, can be minimized when the new developments can be designed around the pipeline pattern. In a retrofit situation, the rights-of-way usually would have to be longer and probably have to reflect existing patterns.

Direct use of geothermal energy presents varying degrees of environmental impacts, impacts that are different from those associated with electrical development. For example, the close proximity of people presents a problem with direct use a result of noise, visual aesthetics, and water contamination. Nonelectric developments, on the other hand, have small geofluid volumes and release few air pollutants. Moreover, most of the environmental impacts concentrate into the relatively short period of well drilling and testing.

CONCLUSIONS

Investigation into the relationships between the development of geothermal energy and land use began with the statement that geothermal energy was site specific. It was hypothesized that nonelectric development would be linked closely to many land use characteristics and that those close ties would critically influence its development potential. The evidence presented supports those hypotheses. Evidence also suggests that steps have been taken to counteract many of the land use difficulties.

Although the initial steps taken at the nonelectric sites indicate a degree of recognition of the important relationship between land use and geothermal development, few people involved in these developments (outside of El Centro and Monroe) comprehend the full power land use can have. Land use factors have the potential to halt a project completely. This power places the signficance of land use on par with the resource itself in the developmental potential of the resource.

The best known development sites are already receiving attention, but attention will soon turn to other locations. What will guide this future phase? Will it be an almost random effort, guided by the influence of local politicians, administrative whim and public relations, or will it have some overall coordination? The facts presented advise in favor of the following approach: Investigate potential nonelectric sites for compatible land use in advance of concerted efforts to define or delimit the resources precisely. Inasmuch as rapidly rising costs of conventional energy supplies could well stimulate a rapidly enlarged, but even more disorganized, geothermal development in the future, the existence of communities which have geothermally-sensitized land use planning will help speed commercialization.

The key element to this proposed course of action is community planning. Planning postures and requirements should be implemented with regard to all future development. Plans should be devised which would approach sensibly the potential of geothermal resources in existing neighborhoods and in all new construction. Under this type of program some of the more obviously difficult areas would be avoided, some of the more adaptable would be identified, and direction would be given to costly resource evaluation. Without plans, cities would continue along their current path, and any "compatibility" between the land use and the characteristics peculiar to geothermal energy would be almost entirely coincidental.

Our suggested "Compatibility Plans" could be devised and promulgated at a much faster pace and much lower cost than the reservoir analyses (at present, the first stage in a geothermal program), thereby creating a significant advantage for this approach. The cost of drilling is so much greater than land planning that we calculate that one could plan possibly as many as 100 communities for less than half the cost of many a single deep geothermal well.

Communities tend to object to a proposal for advanced planning because they are asked to commence planning for a resource whose characteristics often remain relatively vague until sometime after the planning has been largely completed. This type of "Resource-Second" planning runs counter to prevailing practice, if not logic. Our investigation, however, suggests that a community which defers planning until the resource is "proven" can face substantial extra retrofitting cost. In turn, waiting for information on the resource characteristics can continue to deny impetus to do the planning itself, and a cycle can be established which tends to push the economic breakeven point forever into the future.

A variety of factors can partly mitigate the natural resistance to Resource-Second planning. This type of planning is relatively inexpensive, and it is largely conceptual, at least initially. It aims to assemble materials in a form which is useful in its own right, apart from the potential of the geothermal resource. It also aims to work within the established infrastructure of each community.

Clearly, the most important single factor in deciding whether geothermal energy will or will not be utilized in a community will be its relative economic advantage vis-a-vis conventional energy resources. The goal of the geothermal planner is to devise a plan as acceptable as a current or suggested land use plan, but which also reflects the peculiarities of geothermal resources. For example, if a community had two equally acceptable plans, Plan A (which did not take geothermal energy into account) and Plan B (which did), the community would be shortsighted not to choose Plan B. By their choice for Plan B, they would be keeping their future options open. Even if current economic conditions were not favorable to instant conversion, the rapidly rising cost of conventional fuel sources could change the situation quickly. Those communities which had plans already prepared would be "protected." Moreover, all new-area development would be undertaken with geothermal energy in mind. Guidelines could either remain informal (and flexible) or constitute something more exact, such as a Geothermal Element of a local General Plan.

The relationships which result from the nature of geothermal energy illustrate the impact land use itself can have on the realization of alternative resource potential. Although geothermal energy is more site specific than other energy sources, the preceding is but one of the earliest and most definitive examples of the important role land use can play in all energy developments. The future holds many related challenges.

POSTSCRIPT—Since the completion of this article, a methodology has been developed to test the principal conclusions. The methodology was developed in Scottsdale, Arizona as part of a project to choose the most likely spot to develop their potential geothermal resource. Maps were prepared showing Land Ownership, Zoning, Vacant Lands, User Energy Density. These were overlayed, and sites were chosen which maximized the geothermal potential while minimizing the potential for land use conflict. Subsequently, a resource evaluation was completed using existing data and geochemical analyses of existing water wells. The six potential areas suggested from the land use planning were then reduced to a single "best" site. It was suggested that Scottsdale "protect" that site for use in geothermal development.