MASTER

DRY-LANDS RESEARCH INSTITUTE

UNIVERSITY OF CALIFORNIA, RIVERSIDE • RIVERSIDE, CALIFORNIA 92502

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Summary of Final Reports on
Geothermal Energy Development
in Imperial County

April 1977

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This material was prepared with the support of National Science Foundation Grant # AER 75-08793. Any opinions, findings, conclusions or recommendations expressed are those of the author(s) and do not necessarily reflect the views of The National Science Foundation.

NSF/ERDA Grant No. AER 75-08793
Imperial County Contract CI75/76-1

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Summary of
Geothermal Energy Development in Imperial County

Contents

	Page
Abstract of Findings	1
Geothermal Resource Assessment	3
Engineering Aspects of Geothermal Development	11
Geographic and Environmental Analysis	18
Effects on Agricultural Resources	27
Population Analysis	37
Public Attitudes	43
Costs of Geothermal Development	47
Economic Impact	53
Multi sector Analysis of Imperial County	65
Regulatory and Policy Aspects	69
Summary of Policy Implications	74

Abstract of Findings

Imperial County appears to have a potential geothermal heat source of more than 10,000 megawatts of power, of which perhaps 4,500 megawatts of electricity appears feasible for development by current technology over the next forty years.

Geothermal energy development of electricity appears to be competitive and economically feasible at investment ranges for plant and field development from \$500 to \$750 per kilowatt of installed capacity (in 1976 dollars). However, the risks are fairly high due to many uncertainties, still, about the character of the reservoirs and the technologies for handling brines in relatively low-temperature conversion plants. These uncertainties may raise investment costs into the more marginal range of \$1,000 per kilowatt of capacity.

The benefits to Imperial County are largely in (1) increased tax revenues of about \$5,000 per megawatt in installed capacity, and (2) a modest increase in employment, of roughly one additional job of direct and secondary employment per megawatt of capacity.

The environmental impacts of geothermal development are likely to be small provided monitoring and regulation are instituted to control subsidence, strain release, noise, water and air quality.

The county has adequate management capacity and jurisdictional authority, particularly through zoning, both to encourage and to regulate geothermal development in the interest of the whole citizenry of the valley.

This document summarizes the final reports which were prepared by an interdisciplinary research team from the Dry Lands Research Institute of the University of California, Riverside and the Environmental Quality Laboratory of the California Institute of Technology. The research was performed to provide information to assist Imperial County to develop a Geothermal Element for its general plan.

Research Investigators

Stahrl Edmunds,	Director, Dry Lands Research Institute
Tod Larson,	Assistant Administrative Analyst, DLRI, UCR
Shawn Biehler,	Earth Sciences, UCR
Tien Lee	Earth Sciences, UCR
Martin Goldsmith,	EQL, Cal Tech
M. J. Pasqualetti,	Earth Sciences, UCR
Claude Johnson,	Earth Sciences, UCR
Edgar Butler,	Sociology, UCR
James Pick,	DLRI, UCR
E.M. Lofting,	DLRI, UCR
Adam Rose,	Economics, UCR
Vincent Buck,	EQL, Cal Tech

GEOHERMAL RESOURCE ASSESSMENT
OF THE IMPERIAL VALLEY

by

Shawn Biehler and Tien Lee

The resource assessment is concerned with determining the size, magnitude, production potential and physical character of geothermal resources in Imperial County, California. The report also examines possible interrelationships concerning subsidence, seismicity, withdrawal of heat, and reinjection of fluids.

Of the seven KGRA's (Known Geothermal Resource Areas), four were considered to be potentially economic:

1. Area south of the Salton Sea
2. Heber
3. East Mesa
4. Area north of Brawley

Many fields are not well explored or clearly delineated. Preliminary data would indicate that high temperature fields may also exist on the extreme flanks of some local gravity anomalies, as well as in the KGRA's.

Estimates of the resource also vary somewhat from one source to another. Lack of data or exchange of information can result in conflicting interpretations of information. Field developers generally use proven reserves as their measure of a resource. A proven reserve is

that portion of an energy resource which can be economically utilized with present technology. One field developer's estimates may be lower than others because his assessment will include only proven resources, distinguishing them from recoverable or potential resources. One developer has stated that proven resources are only about 1/10 of the potential resources. The estimates to follow include both recoverable and potential resources.

Size, Magnitude, and Production Potential

Estimates of the magnitude of heat in storage for Imperial County were cited from Biehler, Towes, and Remner (Table 1A, p. 21) for each of the areas above as well as Dunes and Glamis. All were within an order of magnitude. The findings for the total resource assessment are summarized below.

Table 1
Total Resource Assessment

<u>Source</u>	<u>Joules x 10¹⁸</u>	<u>Thousands of Megawatts for 30 Years</u>
Biehler	67.4 - 202.1	7.12 - 21.4
Towes	21.1	2.2
White	174.4	18.4

The heat is stored in two mediums, liquid and rock. Approximately 15-20 percent of the heat is liquid, 80-85 percent is rock. The fluids can be withdrawn and utilized directly. To utilize the heat stored in the rock, fluids must be reinjected and recycled.

The specific yields (percent of reservoir which can be withdrawn as fluid) for each field were given in the text along with temperature and depth information. The table below shows the volumes of the usable reservoirs for each location. The table also displays the amount of power, in Megawatts, which can be generated over a 30-year period.

Table 2			
Location	Usable Reservoir (Million Acre Feet)	Fluid	Fluid and Rock
		Resource Assessment Thousand MW for 30 Years	Resource Assessment Thousand MW for 30 Years
Salton Sea	51.75	3.74 - 11.22	14.03 - 42.08
Heber	51.40	.88 - 2.64	3.30 - 9.90
East Mesa	26.19	1.10 - 3.30	4.13 - 12.38
Dunes	38.37	0 - .02	0 - .09
Brawley	<u>77.05</u>	<u>1.40 - 4.19</u>	<u>5.25 - 15.71</u>
Total	244.76	7.12 - 21.37	26.71 - 80.14

Biehler estimates that Imperial County's geothermal resources could generate between 7 and 80,000 MW for 30 years (1 MW for 30 years will consume 9.46×10^{15} joules). Conversion efficiency = 10 percent. About 7 to 20,000 MW (for 30 years) can be taken from the liquid resources and up to 80,000 MW (for 30 years) can be obtained from both liquid and rock. Biehler notes that even the most conservative estimates of geothermal potential indicate geothermal development to be feasible.

Tectonic activity is opening up the reservoir (Imperial County is gaining approximately 6 cm/yr), allowing an increase in the available

heat of 5×10^6 joules each year. However, this is not enough to offset the heat loss from geothermal energy development. Therefore, the lives of the geothermal resources are finite and are dependent upon the rate of withdrawal of heat in storage. The recharge rate is too small to give the resource an indefinite life span.

All three sources cited earlier agree that over half of the geothermal potential is associated with the Salton Sea fields. The Salton Sea fields are higher temperature but are also supersaline. The corrosive nature of the brines possibly makes exploitation of the fields technically and economically infeasible at this time (salinity is 260,000 mg/l compared with 25-30,000 mg/l at Cerro Prieto). Generally the quality of the fields becomes poorer as you go northwest through Imperial County.

Seismicity, Subsidence, and Reinjection

There are several active faults in the KGRA's and fracturing is occurring frequently in the geothermal fields. The fractures are self-sealing. Geothermal power production may induce a sequence of earth movements owing to thermal strain release. Tien Lee has estimated that 100 MW for one year may increase the frequency of earth movement by a factor of 2 and that 1,000 MW for one year may increase the frequency 6.5 times per year. The cut-off magnitude for 100 MW/yr is 4.1 and for 1,000 MW/yr is 4.8 on the Richter Scale. That means if the thermal strain accumulates for one year, while 1,000 MW have been generated, and is released in one earthquake, it is estimated to have a magnitude of 4.8. It is more likely that several minor earthquakes of lesser

magnitude would occur in the time period. If a 100 MW power plant operates for 30 years accumulating thermal stress, without any release, the maximum magnitude of an earthquake generated would be 5.4.

Fluid withdrawal may induce seismic activity and subsidence.

These effects are dependent upon many variables including:

- A. Production rate
- B. Injection rate
- C. Heat capacity
- D. Thermal diffusivity
- E. Viscosity
- F. Pressure
- G. Porosity
- H. Permeability
- I. Water-rock chemical interaction

Until actual plants go into operation these problems cannot be studied. The lack of operating experience and hard data allows for little analysis of fluid withdrawal and reinjection at this time.

Physical Character of the Resource

The temperature of the geothermal fluids ranges from high temperature ($> 150^{\circ}\text{C}$) to intermediate ($90^{\circ} - 150^{\circ}\text{C}$). The field temperatures are designated below.

Table 3

	<u>Temperature</u>
Salton Sea	340°C
Brawley	200°C
Heber	190°C
East Mesa	180°C
Border	160°C
Dunes	135°C

Well-head pressures and production rates are given for specific wells in Table 3 of the text. Production rates reported generally ranged between 100,000 lb/hr to 625,500 lb/hr. Well-head pressure varies between 18 and 585 psi.

The composition of the fluids varies from well to well in a given geothermal field. The available data for the Salton Sea and East Mesa fields are given in Tables 5-1 and 5-2.

Table 4 below illustrates the salt contents (mg/l) of brines in these two geothermal fields.

Technologies Utilized

The resource was evaluated using several different techniques, none of which is definitive as a source of information by itself.

A. Gravity Studies. There is a good coorelation between gravity maxima (higher density rocks) and the location of potential geothermal reservoirs.

B. Temperature Profiles. Measuring geothermal gradients in shallow test wells allows estimates of the heat-flow coming out of the

Table 4
Salt Contents (mg/liters) of Brine in the Geothermal Fields

	<u>Na</u>	<u>K</u>	<u>Ca</u>	<u>Mg</u>	<u>HCO₃</u>	<u>Cl</u>	<u>SO₄</u>	<u>SiO₂</u>	<u>TDS</u>
<u>East Mesa</u>									
5-1	798	48.9	46.5	4.01	705	825	196	130	2,390
6-1	9,002	1,047	896	15	126	15,868	192	128	28,110
6-2	918	65.3	40		1,248	776	206	195	2,830
8-1	723	42	41.1	1.6	668	556	225	263	2,463
31-1	782	25	96.6	1.1	467	490	172	88	2,311
<u>Salton Sea</u>									
IID.1	55,500	18,200	30,500			168,000	30		278,000
IID.2	53,000	16,500	27,800	10	390	155,000			258,765
Sportsman 1	70,000	24,000	34,470	18		201,757	34		334,987
Sinclair 3	36,340	7,820	14,550	780	60	93,650	58		183,700
Sinclair 4	78,000	20,690	37,735	2,225		210,700	75		387,500
Brawley	19,900	2,400	2,560	1,360	1,562	31,000	865		59,949
Western Geothermal	14,500	3,000	3,880	194	200	31,600	162		53,975

subsurface to be made. There is a correlation between high temperature profiles and gravity anomalies.

C. Seismic Studies. Refractive techniques have been applied to locate the subsurface shape of the anomalous mass associated with the geothermal reservoirs. Seismographic readings have been used to monitor ground noise in two of the KGRA's. There appears to be a good correlation between seismic noise and the location of a geothermal reservoir.

D. Ground and Aeromagnetic Methods. Geothermal anomalies are associated with magnetic highs (or positive magnetic anomalies).

E. Electrical Measurements. The resistance of rocks increases as temperature increases, delineating possible high temperature gradients.

F. Remote Sensing. Surface fault structures and geologic activity can give indications of features of the geothermal resources.

ENGINEERING ASPECTS OF GEOTHERMAL DEVELOPMENT
IN THE IMPERIAL VALLEY

by

Martin Goldsmith

The engineering assessment includes discussion of potential production techniques (flash vs. binary), drilling methods (slant and straight), plant-siting requirements, water requirements (for cooling and reinjection), and plant and drilling costs as well as commentary on several engineering issues.

Plant Siting

The surface area requirement for one geothermal well is one acre per well of which half the area can be returned to other uses after services are established.

By the use of slant drilling a wide area may be covered from a single drilling location. At 6,000 ft. reservoir depth, a single well-head location having wells with a 30° slant can cover about 300 acres. With a 45° slant almost 1,000 acres can be covered. A single drilling location would be able to serve a small plant. Slant drilling is especially beneficial for deeper reservoirs because a larger area can be covered. Offset wells cost 20 percent more than vertical wells to the same depth.

Several environmental factors discussed in the report include the problems of:

- A. Twenty-four hour activity and resulting noise pollution.
- B. Drilling mud containing detrimental trace elements.
- C. Offshore drilling may be required to utilize resources under the Salton Sea.
- D. Reinjection.
- E. Organic and nutrients in reinjection water.
- F. Drift from cooling towers depositing minerals in the area.

Reinjection

Reinjection of fluids will be required for three main purposes:

1. Get rid of detrimental waters.
2. Prevent subsidence
3. Maintain longevity of the field (five times as much heat is in the rocks as in the fluid).

Goldsmith discusses a hypothesis whereby geothermal fields can operate in a convection system where the fluids are circulated within the reservoir. In such a system reinjected fluids are introduced at a location where they may flow through the reservoir and be reheated. Care must be taken so that fluids are not reinjected in a manner that would prematurely cool the field. The location of the reinjection wells may be critical.

There may be a 20-25 percent deficit in volume of water available for reinjection because of evaporation. Additional water may be needed. Surface water, irrigation drainage, as well as Salton Sea fluids, were considered as possible water supplements. There may be a problem of possible organic material and nutrients existing in these water supplies causing organic growth in some reservoirs.

Transmission Lines

Transmission pipelines will be needed as gathering systems to transport geothermal fluids from wells to the plant. Transmission pipes may be hazardous. They contain dangerous fluids at elevated temperatures and pressures. Goldsmith suggests installing pipe on the surface so that leaks in the pipe may be spotted and corrected easily. It is difficult to monitor problems with the pipes if they are buried. A major pipe failure could occur, resulting in large-scale contamination, because the problem couldn't be detected and corrected in time.

Production Techniques

Goldsmith regards the flash steam power plant technologies as more feasible, at the present state of the art, than the binary systems. The Environmental Quality Laboratory research shows flash steam to be superior at both high (250°C(+)) and medium (150°C(+)) temperatures. He acknowledges that noncondensable gases may require the use of binary systems; however, he believes that the necessity for binary plants is undetermined in proposed plants.

The following normalized power plant costs were cited from different sources:

<u>Source</u>	<u>Cost/KW</u>
Geysers (based on Unit 14)	\$243/KW
Geysers (based on Unit 13)	263
Cerro Prieto	115
Ahuachapan (with well costs)	415
Bechtel (without well-pumping power)	810
TRW	878
INEL	602

Unless otherwise noted, the costs of wells, pipes, separators, and other field equipment is excluded. Moreover, these plants are designed for differing reservoir conditions. A factor of 2 increase in cost is not unlikely due to locational differences.

Geothermal power plants are less efficient than conventional power plants. They require more steam per KWH because of lower temperature. Larger turbines are needed and this governs the size of a power plant. 135 MW is the largest plant designed for The Geysers. For Imperial County, 50 MW plants seem to be the most feasible with a maximum of 100 MW being most likely.

The table on the following page displays the relationships of several variables as a function of fluid temperature. Costs go down as temperature goes up, output in MW per well increases directly with the temperature, and the cooling water rate goes down as temperature goes up. (Because geothermal resources are at a low temperature, the thermodynamic efficiency is low and the cooling requirements are greater than conventional plants.)

Water and Cooling Requirements

Using flow through cooling water a 100 MW plant at 250°C requires 254,000 acre ft/yr of water (half the flow of the New river) and a 1000 MW plant would use the entire flow of the All American Canal for cooling flow, increasing its temperature 20°F. The Canal would not be consumed, only heated.

Another method of cooling is to use evaporative cooling towers. Condensed steam can be used as makeup water, resulting in a net withdrawal of fluid from the reservoir. Supplemental fluid might then be

Information Relating to Well Temperature

<u>Temperature</u>	Cost of 2 Stage Flash Geothermal Power Plants	<u>Cost of Wells \$/KW</u>			<u>Output Per Well MW/Well</u>		
		<u>Pumped</u>	<u>Straight</u>	<u>Stepped</u>	<u>Pumped</u>	<u>Straight</u>	<u>Stepped</u>
150	\$459/KW	167	333	167	3	1.5	3
200	318	63	100	45	8	5	11
250	272	38	45	24	13	11	21
300	235	33	25	16	15	20	31

<u>Temperature</u>	<u>Once-Through Cooling Water Rate Requirements Acre Ft/Yr/MW</u>		<u>Evaporative Cooling Water Requirements Acre Ft/Yr/MW</u>	
	<u>Flash</u>	<u>Binary</u>	<u>Flash</u>	<u>Binary</u>
150	4,950	7,800	97	167
200	3,140	4,670	61	101
250	2,540	3,580	50	77
300	2,070	2,750	41	59.5

required from other sources for reservoir injection. Another way is to use surface waters for the evaporative towers. A 100 MW flash plant at 200°C requires 6,100 acre ft/year (+ 10-20 percent to account for blowdown).

Air-cooled towers could also be used; however, they are a less efficient transfer mechanism. The towers need a greater transfer surface. Also, the high air temperatures in Imperial Valley (100°F+ for 100 days out of the year) limits the effectiveness of air-cooled towers. A combination wet and dry cooling tower is suggested but higher costs are involved.

Cooling water availability is of importance for geothermal development. 2.8 million acre ft/yr of Colorado River water is diverted to the Imperial Irrigation District via the All American Canal. One-third of this is drained away as waste. Waste water elimination is necessary in Imperial County to keep salt contents of the river from poisoning the land.

A possible source of water is fresh irrigation water. Relinquishing 1,000 acres of agricultural land would provide water for a 100 MW plant. However, this choice may not be necessary, because irrigation drainage water is another viable source (from the New or Alamo Rivers). The seasonality of the river flows may create the need for some water storage. A 1,000 MW plant requires 60,000 acre ft/yr. The New and Alamo Rivers are capable of supporting 5,000 MW each, without storage capacity. The high salinity of these water and organic substances and nutrients in the drain waters can lead to fouling problems in the cooling towers.

Water treatment may be required and should have an upper cost limit of .4 mill/KWH.

Dissolved solids accumulate in the cooling towers and must be disposed of. They can be collected in evaporative ponds or reinjected.

Cooling towers allow a small amount of water to escape as drift (fine droplets) which contain dissolved salts and organisms which can deposit on the ground.

Desalination was considered as a method of creating a fresh water supply. Several of the methods described are very costly, and could not be used to cost advantage for agricultural use. However, the cost of desalted water in the cities would be 10-15¢/day per household if the residents would be willing to pay for higher quality water. A 250 MW plant would provide 15,000 acre ft/yr, the amount needed for the population of Imperial County.

Goldsmith cites Hazen Research, Inc., which concludes that only the Salton Sea brines appear to be promising for commercial development of brine minerals. "Valuable constituents" include iron, manganese, lead, zinc, strontium, barium, lithium, bromine, and ammonia. However, current markets and the economics of production do not appear favorable to early mineral production.

Geographical and Environmental Analysis

by

M. J. Pasqualetti

Many investigations into the potential environmental impact from geothermal resource development in the Imperial Valley are in progress, but interim conclusions can be made. Environmental effect from the initial phases of geothermal development in the valley will be minimal. Continued investigations are a necessity and may help reduce the number of environmental studies necessary before the development of other geothermal areas, but a benign judgement of environmental effects in the Imperial Valley may be considered justification to expedite construction of commercially-sized facilities. Indeed, many of the data which are necessary for further and more accurate evaluations of environmental effects will be forthcoming only from such operations. This is particularly true in adjudging the scale and significance of subsidence; no method of prediction is likely to substitute for the experience of actual operation.

Application of presently accepted methods for mitigating significant adverse environmental impacts of geothermal operations should be considered sufficient when instituted in concert with recommendations relevant to an agricultural oasis such as the Imperial Valley. Operators

should be alerted to an eventual policy of environmental nondegradation as an ultimate goal, but its strict enforcement should await the construction of the Valley's first 200 megawatts (roughly one 50-megawatt facility for each of the four KGRAs presently recognized and should not be required for these initial operations in an absolute sense. A policy of this type would hasten initial development and would avail each consortium an opportunity for first-hand experience with a minimum of questionably relevant environmental obstructions and expense. The collection and evaluation of resulting information should then be applied to future plants. It would also demonstrate to potential developers the commitment of Imperial Valley residents and officials to develop the resource.

In addition, two hundred megawatts should be a quantity of electricity large enough to export while producing an environmental change small enough to be acceptable but significant enough to measure. These recommendations should be coupled to the reality that different areas of the valley will have different sensitivities to impact. Thus, formulation of strict county-wide standards may not be practicable.

An ad hoc geothermal board might be established to resolve disagreements and recommend new policies regarding geothermal development in the County.

In a section entitled "Location of Geothermal Transmission Lines in the Imperial Valley", Dr. Pasqualetti presumes that a potential 1,000 megawatts will be realized within the County within the next 10 to 15 years. (The County has adopted a power projection as follows:

<u>Year</u>	<u>The Installed Capacity in Megawatts</u>
1980	150
1985	700

<u>Year (cont.)</u>	<u>Megawatts (cont.)</u>
1990	1,650
1995	4,950
2000	6,150

The report also states that it will be necessary to consider future geothermal areas in devising a plan for transmission lines. Thus far, however, the majority of the potential geothermal areas appear to be west of a longitudinal median line drawn through the Valley. If the Sun Desert nuclear plant is approved, it appears inevitable that one of the Sun Desert transmission lines will pass through the Valley, and it seems reasonable to attempt to tie the geothermal lines into them. The report specifically finds that the existing capacity of the I.I.D. is inadequate for transmitting any large magnitude of geothermal energy. There is a question also of reliability concerning the fact that brush fires below transmission lines tend to trip circuit breakers and whether or not the numerous and continuous agricultural burnings will have any effect on the reliability of transmission lines. Under aesthetics, the report recommends steel lattice towers on power lines that are routed away from all cities and towns wherever possible. Land for transmission towers should be located to take advantage of canals and roads and thus avoid placement in producing fields, to minimize the disruption of agriculture. For safety of aircraft, power lines should be between six meters and twelve meters in height, and guy wires are particularly dangerous to agricultural flying. This means that the towers in the Valley should be free standing. In order to avoid the negative effects of corona discharge, transmission lines should be routed as far away from population centers and feedlots as possible. Presuming that there will be 500 kv lines going through the Valley somewhere, the geothermal lines, at least the initial

ones, should be planned in such a way as to take advantage of the 500 kv lines. Presumably the best route for geothermal electricity would be the shortest distance necessary to meet a north-south 500 kv line which passed near Niland, between Westmorland and Brawley and south to Heber before turning westward. A route similar to this has been proposed by SDG&E but problems of access to the Chocolate Mountain Gunnery Range might prevent the adoption of this route. Alternatively, if the Sun Desert east-west corridor passes close to Heber, then geothermal electricity from Niland, Brawley and Westmorland and other northern fields would require transmission southward to a junction with that 500 kv line. At this location it would be necessary to construct a substation to transform the geothermal voltage up to 500 kv. Another possible route is to transmit the geothermal power out of the agricultural, populated areas as quickly as possible by means of a single east-west line (probably 161 kv) located at an average position between existing geothermal fields for the movement of power from the northern fields. The individual fields could tie into this line with shorter lines. Alternatively, a 161 kv line could be constructed from each of the fields as they are developed and then tied into a single 161 kv line perhaps south of Westmorland which led out of the irrigated fields to the West Mesa where all such lines could turn to meet the 500 kv line. At that location, a substation could be constructed which would require no agricultural land displacement. Such an additional substation might also be constructed on East Mesa. Should the 500 kv transmission lines not be approved, some variation of these routes could be devised.

In the section entitled "Water Desalination of Geothermal Fluids in the Imperial Valley" it is concluded that although desalting could indeed take place, the question of economic feasibility has not been

determined and it certainly does not appear at all likely that brine desalting on a large scale will become established until after electrical production is well under way in the Valley.

In a section entitled "Geothermal Brines in the Recovery of Their Dissolved Solids in the Imperial Valley", the values of the various minerals is assessed but it is felt that generally speaking, the minerals will not be important under current economic conditions without the prior generation of electricity.

In a section entitled "Summary of Environmental Impacts Likely from the Development of Geothermal Energy in the Imperial Valley" Dr. Pasqualetti considers subsidence, induced seismicity, and water availability as the potentially most significant environmental effect of geothermal development. It is suggested that perhaps the reinjection can be used to control seismicity caused by thermal extraction or by natural seismicity. A comprehensive water policy planning study is recommended. It is recommended that the ambient standard of 0.03 ppm of hydrogen sulfide within one mile of the geothermal plant be maintained. It is recommended that transmission pipelines be placed in open ditches and covered with grating with expansion loops horizontal where possible. Planting of oleander or some other camouflaging ornamental along the fence lines of facilities is recommended for aesthetical aspects.

Under the subject of Land Reallocation, Dr. Pasqualetti assumes that 250 acres will be used per 1,000 megawatts of power production which is an insignificant figure. He recommends that well pads be placed on corners of property and that directional drilling be required when technically feasible.

In a section entitled "Policy Alternatives and Recommendations for Imperial County" a sliding scale of increasingly rigorous standards is

proposed to encourage initial development of the Valley's geothermal resources. It is recommended that an ad hoc panel consisting of representatives from the University, US Geological Survey, development companies, county officials, and the local citizenry be formed when there are substantial disagreements regarding geothermal development. It is recommended that the practice of accepting compensation in lieu of a desist order be reviewed as a policy. Under induced seismicity, actual production and subsequent comparison with base line seismic data will be required prior to any firm decisions. Lubrication of faults could well reduce earthquake severity. There should be little difficulty in supplying geothermal operators with cooling water for the first decade of development. It is recommended that the County consider legally preventing selling of water rights to the geothermal operators without County approval or approval of the ad hoc panel should it be instituted. It is recommended that reinjection be required for as much of the waste fluids as possible. A contingency plan for the possible occurrence of a blow-out and tests of crops to determine those least susceptible to potential geothermal pollutants are recommended. As with many other aspects of possible damage, geothermal operators should be bonded. A limit of 65 dB(A) at the property lines of geothermal facilities is suggested for noise control. Under air pollution, discharge during shutdowns should be discouraged. Cleaning of wells should be coordinated with weather and seasons, if possible, and attention be given to condenser design.

Dr. Pasqualetti recommends that a panel of individuals be assembled who can judge the environmental effects of the initial geothermal operations. Later, as impacts and more empirical data are accumulated, this panel should formulate firmer environmental regulations, but at first the regulations

should be relatively liberal and in fact, more stringent ones would be based almost entirely on speculation. In addition, he recommends that the County encourage initial operation so tests may be made for such things as subsidence and the workability of reinjection. This should be done even at the minor cost of some land, water and pollution. He also recommends a study of the possibility of retaining a right to greater control the electricity generated. Current estimates of the benefits from the amount of electricity which would remain within the County indicate that they would not even cover the cost to the County for services. Nonelectrical utilization should be encouraged for the following reasons:

1. Most electricity will be exported.
2. Employment levels will be higher from nonelectrical uses.
3. Lack of water could stop electrical programs entirely, as could many other problems.
4. Nonelectrical potential could not be used outside the Valley.
5. Such utilization does not require cooling water in great quantity.
6. It is a more efficient use of the resource.
7. It would require no large generating facilities or power lines.
8. It can be combined with the other benefits of the Valley, such as people, sun, markets, transportation, etc.
9. It can be made compatible with the existing economy.
10. It can be used in concert with electrical generation or separately.

He also recommends that local people become more expert than outsiders to encourage a reduced emigration and discourage immigration. Consideration should be given constantly to phasing. Each phase of development has

its attendant pollution and nuisance problems. Different areas must be considered differently. The outfall of water for example would have different consequences in Heber than at the Salton Sea.

Regulations adopted to control geothermal plants should consider the seasonality of the crops. The fewer crops on the ground, the less is potential damage from air pollution and water pollution. Regulations should consider that there are fewer people during portions of the year, and thus odors and noise, etc. are potentially less of a problem. These regulations should be considered useful during the initial stages only, assuming evidence of relatively benign operation. Land uses in regards to the crops themselves should be carefully considered. Certain crops will have different tolerances to the constituents of geothermal plants and they can be moved so as not to be downwind or downslope of operating plants.

Plans should be generated to specifically tie together the development of agriculture and geothermal development. Nonelectric application are an example. This will fit in with policy, and encourage more cooperation, speed development, avoid lawsuits and bad feelings, and generally benefit all.

Under the title "The Transferability of Findings" the report notes that some of the information generated in this project should be useful elsewhere, although geothermal resources of size are not recognized beneath any other substantial areas of irrigated desert agriculture. The accumulation of information regarding the environmental experiences of foreign geothermal operations could be applied to any geothermal area and developers at some other area should be aware of the broad range of environmental matters which must be given attention. Some guidelines which seem appropriate to development of geothermal energy in the Imperial Valley should be applicable elsewhere. One is a basic standard of nondegradation. A central

clearinghouse for information on environmental efforts and studies would be beneficial in avoiding overlap and wasted efforts. It is clear from the experience in the Imperial Valley that little attention or money should be expended on the possibility of recovering brine constituents or desalting water. The economics of such endeavors do not permit their present consideration in the Imperial Valley where conditions for their recovery are more favorable than in most other possible areas of the west.

EFFECTS OF GEOTHERMAL DEVELOPMENT ON THE AGRICULTURAL
RESOURCES OF THE IMPERIAL VALLEY

by

Claude Johnson

The Imperial Valley is one of the most productive agricultural regions in the world. It provides the United States with a large percentage of winter vegetables. Other agricultural production includes sugar beets, cotton, and field grains. A third enterprise is devoted to raising forage and feed for local feedlots and the dairy industry throughout the Southern California market. The main reason for the high productivity of the region is the long growing season (365 days) with almost all cloud-free days. The agricultural production capabilities of the Imperial Valley are essential for continued food production in the United States.

The geothermal resources discovered in the Imperial Valley are unique in that the resources lie mostly under highly developed cultivated lands. Most other geothermal resource areas have been discovered in undeveloped land areas which have not posed such a potential economic impact as is faced in the Imperial Valley.

Culturally, the Imperial Valley is devoted to agribusiness and the desire of the elected officials and perhaps most of the population is to continue the agribusiness and at the same time enjoy the fruits of

geothermal production. It has been the stated objective of the elected county officials that the two dissimilar businesses can coexist with minimal impact on one another and perhaps even provide symbiotic effects.

Agricultural Impact

The impact that geothermal energy development may have on the agricultural resources of the Imperial Valley appears to be insignificant. Results of the study discussed in this report show that full development of the presently known geothermal resources for the production of power in the Imperial Valley would displace at the very most only 1 percent of the present agricultural land under production. The report describes an agricultural data base which can be used to estimate the effects (both physical and economic) of geothermal energy development on the agricultural environment. A data base is provided for only four selected Known Geothermal Resource Areas (KGRA's), but the regionalization effects of agricultural practices enable the data for a given KGRA to be extrapolated to the surrounding areas in which it is located. The Salton Sea KGRA agricultural resource data is representative of the northern valley region. The Brawley KGRA agricultural resource data applies throughout the central valley area, and the Heber KGRA agricultural resource data applies equally to the southern valley area.

Four illustrative maps were prepared for each of the four KGRA's, indicating

- A. Parcel Indexes,
- B. Agricultural Resources,
- C. Land Ownership,
- D. Irrigation Canals.

The four maps for the Heber KGRA are included in this summary on the following pages. Data was also collected concerning Assessed Valuation but has not been published as a map display.

Ninety percent of the agricultural fields in the valley have drain tile networks of some type to allow agricultural water to be used more effectively and drained to the Salton Sea. If subsidence occurs in the valley it may affect the drainage tile system as well as irrigation canals. This should be monitored to assure that agricultural land is not affected detrimentally.

Crop Patterns

Fields were difficult to generalize into crop classifications because many fields are in production for the entire year with different crop types. The table below shows the major vegetable and field crops have different seasons.

Table 1		
<u>Fall/Winter/Spring</u> <u>Major Vegetable</u>	<u>Spring/Summer/Fall</u> <u>Field Crops</u>	<u>Permanent Crops</u>
Broccoli	Alfalfa	Asparagus
Carrots	Alice Grass	Citrus
Lettuce	Barley	Pastures
Cantaloupes	Bermuda Grass	
Watermelons	Cotton	
Onions	Rye Grass	
Squash	Grain Sorghum	
Tomatoes	Sudan Grass	
	Sugar Beets	
	Wheat	

IMPERIAL VALLEY - HEBER KGRA PARCEL INDEX

Figure 1a.

IMPERIAL VALLEY - HEBER KGRA AGRICULTURAL RESOURCES

Figure 1b.

IMPERIAL VALLEY - HEBER KGRA LAND OWNERSHIP

Figure 1c.

IMPERIAL VALLEY - HEBER KGRA IRRIGATION CANALS

Figure 1d.

Data was obtained from aircraft and satellite platforms for four dates: June, 1968; March, 1969; December, 1972; and January, 1976.

These were treated as random samples of agricultural production for the data base to establish the general crop classifications. Crop classifications were defined as below:

Vegetable crop	All vegetable
Predominately vegetable	3/4 vegetable
Mixed	Equal field and vegetable
Predominately field crop	3/4 field crop
Field crop	All field crop

These classifications indicated three agricultural regions, northern, central, and southern. The central region around Brawley tends to specialize in field crops with some winter crop rotation into vegetable. The southern region is more predominately vegetable crops and the northern region around the Salton Sea indicated a mix of field and vegetable crops. Table 2 displays the agricultural resource characteristics.

Land Use Requirements

Estimates of the land use requirements for 5,000 MW were 16,000 acres. This would amount to 3.3 percent of the total producing agricultural acreage.

Mitigating techniques such as slant drilling, strategic placement of wells, and utilization of nonagricultural land can reduce the amount of land taken out of production. Martin Goldsmith's estimates of land requirements using slant drilling would be about 2,000-4,000 acres. Adam

Table 2
Imperial Valley Agricultural Resource Characteristics (by KGRA)

<u>Crop Classification</u>	<u>Heber</u>	<u>Brawley</u>	<u>Salton Sea</u>	<u>East Mesa</u>	<u>Total</u>
% all field crop	46.0	54.8	37.3	9.9	44.5
% predominately field crop	28.2	29.5	29.8	26.2	28.9
% mixed field and vegetable crops	13.3	10.3	17.6	41.7	14.7
% predominately vegetable crop	4.0	1.4	0.8	3.5	2.6
% all vegetable crop	0.3	0.0	0.0	2.0	0.2
% asparagus	4.5	0.0	0.0	0.0	2.2
% tree crops	0.2	0.3	0.1	11.6	0.6
% abandoned agricultural land	1.2	1.3	13.4	5.1	4.5
% feedlots	1.5	1.9	0.3	0.0	1.2
% pasture land	<u>0.8</u>	<u>0.5</u>	<u>0.7</u>	<u>0.0</u>	<u>0.6</u>
Total agricultural acres	53,153	25,475	28,627	4,094	111,349
Total nonagricultural acres	<u>4,016</u>	<u>4,143</u>	<u>12,244</u>	<u>999</u>	<u>21,402</u>
TOTAL KGRA ACRES	57,169	29,618	40,871	5,093	132,751

Rose's figures are even less, about \$1,575 acres for 4,500 MW. Johnson's figures may be considered the upper boundary of land requirements, including settling ponds, disposal sites, transmission corridors and access roads.

Other impacts on the land include subsidence, possible "blowouts," and drift (fine saline droplets from the cooling towers). The drift problem was found to be insignificant compared with salts already being deposited from irrigation.

Population Analysis Relative to Geothermal Energy Development
Imperial County, California

by

James B. Pick, Tae Hwan Jung and Edgar W. Butler

Imperial County is an agriculturally-oriented rural California county with a 46% Spanish-American population component. The present research identified several features in the county which will be of importance to the geothermal development process. Migration trends have been important because they have been of great significance in determining the current age structure and total population. From 1930 to 1970, Imperial County experienced a net outmigration of about .7% per year. Outmigrants have tended to be young adults, resulting in loss to the county of many potential labor force entrants, some with high skill levels. This steady outmigration is a reflection of a steady-state county economy, as well as a lack of economic diversity, so that many types of occupational careers cannot presently be pursued in the county. Since a substantial number of persons have been recorded as entering the county (14.4% of the total population for the period 1965-70), even larger numbers are leaving, and thus the mobility of individuals is much higher than the net migration indicates, with perhaps 40% of the population involved in intercounty moves from 1960 to 1970.

Three interrelated variables, age structure, percent Spanish-American (SA), and fertility, were critical in nearly all phases of this study. The

interrelationships of these variables are due to the following reasons. A high proportion SA leads to high fertility, since it is known both nationally and in Imperial County that SA's have about 40% higher fertility than anglos. High fertility over an extended period tends to cause a significantly younger age structure through well known demographic principles.

This triad of variables is important for projections of population and of county employment. The combination of high fertility and a young age structure is one which generally leads to rapid population growth, as evidenced presently in many underdeveloped countries. In the case of Imperial County, this potential for rapid increase has been held in check by persistent outmigration.

In this study unemployment is viewed broadly the ratio of unemployed to total population. Broad unemployment is the product of three subcategories: age eligibility (percent aged 16+/ total population), labor force participation (percent in the labor force/percent aged 16+), and unemployment (percent unemployed/percent in the labor force). Age structure defines age eligibility. Therefore, the tendency towards an older age structure which would likely occur in the case of geothermal development would increase age eligibility and hence would also increase broad unemployment.

Another important influence for geothermal development is the skill level of the labor force. For 1970 U.S. Census employment and industrial classifications, Imperial County has lower skill levels than California. The most significant cause of this gap is the larger component of agricultural farm laborers (25.1% for males in the county as compared to 4.2% for males in California). This contrast may be even larger, since there are 6-12,000 border commuters who cross the border daily from Mexico and work nearly entirely as agricultural farm laborers. However, even ignoring farm

categories, Imperial County has only 18.6% of its labor force in the category professional managerial as compared to 22.2% for the nation.

For geothermal construction and operational employment, geothermal companies will likely require relatively few workers, who will possess high skill levels and who likely will be largely brought in from outside the county (see study team report by Rose et al.). However, more jobs will be created if local industrialization is stimulated due to geothermal electrical and/or non-electrical causes. In such a situation of potential plant siting by industry, results of a survey study in Nebraska by Shively are useful in showing a primary basis for decisions on industrial plant siting of labor force quality. (this variable was ranked 1st out of 43 variables). On the other hand, energy variables were ranked 5th, 9th, and 12th as a basis for decisions. Hence, the current low skill levels of the county labor force, which stem in part from outmigration of more highly skilled youth and the rural-agricultural nature of the county, may result either in less industrial development or more utilization of skilled outsiders, induced to migrate into the county. Another unknown in the question of skill levels is the large and rapidly growing Mexican population of the Mexicali urban area, which currently has a population of over 600,000. Border regulations between the U.S. and Mexico have been notably unpredictable and volatile. For example, in the 1960's large numbers of Mexican workers (mostly unskilled farm workers) were allowed to reside and seek employment in the county. Hence, during the geothermal development process, which might run from about 1980 for many decades, such regulations might be altered from their present strictness to allow employment in Imperial County industries of segments of the vast Mexicali labor pool (a pool which might become as large as a half million and include substantial numbers of highly skilled workers).

Since geography is so vital for geothermal energy, a regional study of

population-economic characteristics was performed. This part of the research used enumeration district data available on tapes from the 1970 Census of Population. These data were mapped by computer to outline socioeconomic effects in the central irrigated valley and in enlarged displays of the three major county towns, Brawley, El Centro, and Calexico. Information of potential usefulness to geothermal planners was revealed by these, such as concentration of Spanish language residents in Calexico and concentration of age eligible males in Brawley and in certain central and southern irrigated-valley enumeration districts.

Another regionally-oriented segment of the research studied the potential farm labor force reduction from geothermal development. Based on the land area study of C. Johnson and M. Sheehan, numbers of farm laborers likely, with present agricultural technology, to be displaced through geothermal development were calculated based on a medium geothermal plant capacity scenario for the county (Davis, 1976) and alternative assumptions of farm laborer income and interstitial land reduction. This latter term is defined as the percentage reduction of land in the entire geothermal well-siting area, not including the land immediately surrounding central power plant and the well sites. Even with the assumptions maximal interstitial land reduction of 35% and farm laborer income of \$4,000 per year, by 2020 only 1.24% of the 1970 county farm labor force would be displaced by geothermal development. Since geothermal development is unlikely to displace established business and governmental offices and factories, the potential geographical labor displacement effect from geothermal energy is assumed to be minimal.

Population projections were performed in order to estimate potentials for growth under varying sets of assumptions. In accordance with standard U.N. and U.S. Census projection methods, these were not intended to say definitely what will happen in the county, but rather to answer the

question, if certain assumptions are made, then what. Four projection series were run, using 1970 and 1975 Census and state vital statistics records as input into modified standard population projection routines. In all four series, fertility and mortality were assumed constant at the rates for the initial year (either 1970 or 1975). Migration was varied by assuming no net migration (series I), historical rates (II), rates linearly scaled up from historical levels in accordance with likely additions to plant capacity to an eventual rate equal to 20% of the rate for fast-growing California counties 1950-70 (III), and a series identical to III, except for a final maximal rate equal to 30% of fast-growing California counties 1950-70 (IV). The latter two projections are not intended to reflect geothermal energy development alone, but rather to roughly reflect a complex of geothermal, geothermal-induced and non-geothermal concurrent trends. Examples of possible concurrent trends are potential large national fertility increase and continuation of a national trend of return to rural areas.

Year 2020 projection totals for series I-IV are 175081, 71195, 231851, and 292570 respectively. Since the assumptions of series I, III, and IV are not extreme, the previously-mentioned large potential for population increase in the county age structure is revealed. County populations of over 175,000 would imply significant changes from the past 40 year demographic totals of 60-70,000. An important population distribution question arises from such increased total population--namely, where such additional population will be located in relation to geothermal fields, since nearly all urban population in the county currently borders KGRA's. Creative planning for location of possible new residents relative to geothermal pollutants and hazards may mitigate adverse development.

A discriminant analysis was conducted to establish what variables distinguished county KGRA regions in 1970 from each other and from non-geothermal areas. The key discriminating variables turned out to be utility gas and percent SA, both closely related to urban-rural gradients. The regression analysis for broadly-defined unemployment revealed the importance of higher fertility (negative effect) and lower density (positive) for age eligibility, of higher income (positive) for participation, and of fertility and economic variables for unemployment. The results of the discriminant and regression analyses may be helpful in indicating KGRA-specific differences in social forces. Whether such differences will persist in a changed future county in the decades after geothermal power comes on-line is certainly questionable.

The population analysis summarized above has suggested the following policy recommendations: (1) a retraining program be established by the county in order that local workers benefit more from a county economy containing a significant geothermal component. (2) Some outmigrants from the county who have developed skills elsewhere be encouraged to return to the more diverse and vital economic setting of geothermal development. (3) Creative regional geothermal planning would be beneficial. Since the present urban population borders KGRA's, new increments of population might be encouraged to locate away from geothermal side-effects, particularly since there is a wealth of site-specific material available to county planners from the present NSF research project and from Lawrence Livermore Laboratory studies.

PUBLIC ATTITUDES REGARDING GEOTHERMAL DEVELOPMENT IN
IMPERIAL COUNTY, CALIFORNIA

by

Edgar Butler and James Pick

A public opinion survey was conducted with the primary tasks of:

A. Investigating community attitudes in order to anticipate any problems that geothermal development might bring about in Imperial County.

B. Determining if there are differences in opinion in regards to geothermal development among different population categories of residents in Imperial County--e.g., citizens as opposed to leaders.

The County of Imperial contains approximately 19,200 households, of which approximately 1,200 were sampled for this survey. A description of the sampling techniques is included in the report. Over 300 surveys have been returned; the response rate has been about 30 percent.

The questionnaire was reviewed and critiqued by the scientists on the project, Imperial County government staff, NSF staff, and several officers of the Sierra Club. The extensive review resulted in changes in the questionnaire to assure the objectivity of the questionnaire's wording.

Major findings of the questionnaire are listed below:

1. The great majority of the population is in favor of geothermal development. About 90 percent reported themselves as being in favor or strongly in favor. This is in contrast to the responses of residents in Lake County (65 percent of Cobb Valley and 75 percent of other Lake County residents supporting geothermal development), where geothermal development is also taking place.

2. A smaller proportion (19 percent) of the population feel that they have a good understanding of geothermal development.

3. About 75 percent of the people agreed/or strong agreed that geothermal development should be strictly regulated.

4. About 75 percent thought preserving the environment was an important issue. Only one in five saw any environmental or social problems arising out of geothermal development. Of the people who thought there would be problems, most thought they would be environmental.

5. Fifteen percent of respondents believe there is opposition to geothermal development in the county.

6. Ten percent reported attending a meeting on potential geothermal development; 25 percent believed there had been meetings held. Of those attending meetings, the vast majority learned of them from the newspapers.

7. One in three respondents had visited a geothermal testing site.

8. Only 5.9 percent of population feel that citizens have been adequately informed about geothermal development.

9. An open-ended question, "What do you expect from geothermal development?" clustered expectations into three different areas:

A. Cheaper source of energy (20 percent).

B. More power availability in Imperial County (a little under 20 percent).

C. A variety of miscellaneous but positive benefits (about 15 percent).

10. There was ambivalence and uncertainty as to three statements:

A. Economic benefits of geothermal development are more important than environmental costs.

B. Most geothermal electricity produced in Imperial County should be used in Imperial County.

C. Geothermal development may cause unusual odor problems.

With the exception of these few questions, all of the rest of the responses were substantially in favor of geothermal development.

11. People in higher educational and income social groups are more likely to report a good understanding of geothermal development. The higher the reported understanding of geothermal development the more likely the respondent is to favor strict regulation. The higher the knowledge about geothermal energy the more positive the attitude about it.

12. Only 8 percent of Imperial County residents agreed with the statement "I like Imperial Valley the way it is, and don't want it to change."

A preliminary analysis of leadership and geothermal development was also made. Some interpretations are:

1. Imperial County's economic, social and political life is strongly influenced by agribusiness. The major decision-making activity

involves those in agricultural activities, related business, and local government.

2. If geothermal development occurs on a large scale, potential conflict over decisions may arise. If a decision has to be made that allocates scarce resources (water, land, services) between agriculture or energy, for example, the two sectors could become competitive influences upon leadership, which could then undergo change.

3. The leaders generally accept the idea that growth is good for the community, as do the residents.

4. There appears to have been little activity on the part of community leaders and county officials in developing citizen participation in major decisions. This could allow for conflict in the future. If environmental problems occur the latent potential for citizen action against geothermal development and those responsible for it may be utilized by those who are in opposition.

5. Large landowners are more likely than others to view geothermal development in a positive manner and are also more likely to view the economic benefits as being more important than environmental costs. Nevertheless, the large landowners, who generally are longer-term residents of Imperial County and who plan on spending their entire lives in the county, do view the environment as possibly becoming an important issue in development.

"THE COSTS OF GEOTHERMAL
ENERGY DEVELOPMENT"

by

Tod Larson

This report is a collection of cost information from many sources. Assumptions were generated and income statements were prepared for the life of a 200 MW field and plant. All cost information was standardized to 1976 dollars. The assumptions used are generalized and may not hold for any given geothermal resource area. For this reason a range of costs is considered. Optimistic cost projections (assuming low costs) and pessimistic projections (assuming high costs) give a range of costs to consider.

The costs of geothermal development are dependent upon many variables. The temperature, salinity, and composition of the brines, flow rate of the wells, well spacing, technology, interest rate, and tax rates are among the many variables which directly affect the cost of geothermal energy. Any given field might have any combination of variables affecting it. This has generated a wide range of cost estimates concerning different geothermal fields developed by different operators.

Comparisons are sometimes made of Imperial Valley with The Geysers, where the fields have been profitable for the operators.

However, The Geysers represent a dry steam geothermal resource whereas Imperial Valley reservoirs are water-dominated. As a result, the technologies for energy conversion, and the costs, differ.

The assumptions used for the paper are outlined on the following page. Industry sources currently indicate that the plant and field costs may total \$1,000 per KW of capacity (instead of falling in the \$500-\$850 range) due to inflation, high design costs, and extensive transmission pipe installations.

Exploration Costs. Bob Greider's (Chevron) figures of \$14.7 million to identify a 200 MW field were cited. New figures from Greider indicate that an exploration project in Imperial County would cost between \$3 and \$4 million. These figures are closer to Holt/Procon's EPRI figures of \$800,000 per 50 MW or \$3.2 million for a 200 MW plant.

Capital Costs. Capital costs for the field ranged from \$103/KW to \$300/KW. Costs for the plant ranged from \$150/KW to around \$750/KW. A feasible range of capital costs is indicated in the table below.

	<u>Optimistic</u>	<u>Pessimistic</u>
Field	\$172/KW	\$300/KW
Plant	<u>300/KW</u>	<u>550/KW</u>
Total	\$472/KW	\$850/KW*

*Cost figures were also cited which would increase the total cost to over \$1,000 KW

Breakdowns of the cost components were cited from different sources.

Assumptions for Development of a 200 MW Field
in Imperial County

	<u>Optimistic</u>	<u>Pessimistic</u>	<u>Alternative Pessimistic</u>
1. Exploration time	2 years	4 years	
2. Field and plant development (1st 50 MW)	3 years	5 years	
3. Operating and maintenance cost (public utility)	1.5 mill/KWH	3 mill/KWH	6-9 mill/KWH
4. Operating and maintenance cost (field)	3 mill/KWH	6 mill/KWH	5-7.5 mill/KWH
5. Royalty payments	10% TR	12% TR	
6. Capital cost (utility) 1976 dollars	\$300/KW	\$550/KW	\$800.KW
7. Capital cost (field) 1976 dollars (less replacement wells)	\$172/KW	\$300/KW	
8. Life of field	30 years	20 years	10-15 years

Assumptions Common to Both Optimistic and
Pessimistic Projections

1. Depreciation (utility)--straight line
2. Depreciation (field)--18% declining balance
3. Intangible drilling costs not allowed
4. Depletion allowance not allowed
5. Average well productivity 5 MW
6. Average well depth 5,000 ft.
7. Average well cost \$400,000 (\$450,000 accounting for nonproducers)
8. County property tax \$5,000/MW
9. State income taxes 9%
10. Federal income taxes 48%
11. Return on equity (utility) 12%
12. Return on equity (field) 16%
13. Capitalization rate (utility) 16%
14. Capitalization rate (field) 20%
15. Financing (utility), 50% borrowed, 10% preferred stock, 40% equity
16. Financing (field), 20% borrowed, 10% preferred stock, 70% equity
17. # kilowatt hours per year = 1,401,600,000 (-365 days x 24 hours x 200 MW x 80% load factor)

Field Operating Costs. Estimates for Imperial County range from 3 to 6 mill/KWH. A breakout of Chevron costs is included.

Plant Operating Costs. Historical costs at The Geysers are very low, around .6 mill/KWH. Optimistic and pessimistic costs used were 1.5 and 3 mill/KWH respectively. San Diego Gas and Electric has cited costs of 6-9 mill/KWH.

Environmental Costs. Environmental problems were mentioned; however, little actual cost information is available at this time.

Income Statements. Income statements were generated using the assumptions described above. Sample statements are shown below displaying the costs in mill/KWH. These are near average income statements.

Costs in Mill/KWH

	<u>Optimistic (Yr. 9)</u>	<u>Pessimistic (Yr. 25)</u>
<u>Geothermal Fields</u>		
Total revenue	12.8 mill/KWH	19.3 mill/KWH
Operating and maintenance	3	6.0
Royalties	1.3	2.3
Property taxes	.5	.5
Insurance	--	--
Interest and preferred stock	.6	.8
Depreciation	1.5	1.8
State taxes	.5	.7
Federal taxes	2.6	3.4
Net income	2.8	3.7
<u>Generating Plant</u>		
Total revenues	19.8 mill/KWH	35.4 mill/KWH
Operating and maintenance	1.5	3.0
Steam expenses	12.8	19.3
Property taxes	.2	.2
Insurance	--	.1
Interest and preferred stock	1.8	4.6
Depreciation	1.4	3.9
State taxes	.2	.4
Federal taxes	.9	1.7
Net income	1.0	1.9

The average cost of power using optimistic assumptions was 18.5 mill/KWH, using pessimistic assumptions was 35.5 mill/KWH, and using higher cost assumptions (\$1,000/KW capital cost) increases the cost to 42.1 mill/KWH. These figures are competitive with alternative sources of power, fossil fuel and nuclear.

Other factors which could have an effect on geothermal costs but were not incorporated in the cost analysis are:

1. Possible depletion allowance
2. Possible intangible drilling cost expensing
3. Investment tax credit.

Risk and Return on Investment

This section discusses how field developers and public utilities may evaluate the risk involved with geothermal development. It concludes that the utilities are taking a greater risk than the field developers.

The table below indicates the increase (or decrease) in return on investment with a 1 mill increment in the price of steam and price of power for the pessimistic and optimistic assumptions.

Increment in Return on Investment with a 1 Mill
Increment in Steam and Power Prices

	<u>Optimistic</u>	<u>Pessimistic</u>
Steam price (field developer)	2.4%	1.7%
Power price (public utility)	7.0%	3.0%

A 1 mill increment (pessimistic) in the price of steam would increase the return on investment from 10 percent to 11.7 percent. A decrease would lower the return to 8.3 percent.

The public utilities are at a disadvantage because they cannot take advantage of possible increases (regulation by PUC); however, they can take the losses.

County Property Taxes. Revenues to the county from geothermal development can be expected to be around \$5,000 MW per year. The revenues from the first 200 MW will increase present county property taxes by 4.4 percent.

THE ECONOMIC IMPACT OF GEOTHERMAL ENERGY DEVELOPMENT
IN IMPERIAL COUNTY, CALIFORNIA*

by Adam Rose

A. Introduction

This report examines the economic impact of alternative geothermal development scenarios on the Imperial County Economy. The results indicate that any large scale development effort of, say, 2,000 to 9,000 megawatt hours of installed capacity will have a moderate to strong positive economic impact. County government policies will determine which end of this range is achieved.

B. The Impact of the Primary Development Scenario

A breakdown of the economic research findings pertaining to the primary development scenario (4500 MW by the year 2020) is presented in Table 1. Thirteen major economic indicators are listed. The overall impact on each indicator is given in column (3) labelled "direct + secondary economic + demographic effects." This refers to the summation of the primary effects of the installation and operation of geothermal facilities themselves + the indirect and induced multiplier effects + the interaction between economic and demographic factors such as changes in migration and age composition. Where relevant, a disaggregation of this overall impact is given in columns (1) and (2). Otherwise the components are assumed to lean in the direction of the overall effect though,

* This report represents a component of the economic research fulfilling NSF RANN contract CI 75/76-1: Imperial County Geothermal Element Project. Related investigations have been carried out by Lofting and Larson and have been submitted separately. The author wishes to thank Ben Nakayama, Michael Sheehan, Dale Hurd and Abdollah Soofi for their assistance and Everard Lofting for developing an input-output table of the Imperial County economy which served as the basis for much of this research.

TABLE 1. ECONOMIC IMPACT OF GEOTHERMAL DEVELOPMENT (4500 MW SCENARIO) IN IMPERIAL COUNTY, CALIFORNIA, 2020
(In 1976 dollars)

	Direct Effect (change over baseline)	Direct + Secondary Effects ^a (change over baseline)	Direct + Secondary + Demographic Effects ^b (change over baseline)
1. OUTPUT			
Construction ^c	+\$ 3.1 million	+\$ 4.0 million	+\$ 8.4 million
Operation ^d	+\$969.4 million	+\$1672.2 million	+\$2034.3 million
2. INCOME			
Construction ^c	+\$ 1.8 million	+\$ 2.4 million	+\$ 4.4 million
Operation ^d	+\$ 20.3 million	+\$ 92.2 million	+\$ 250.1 million
3. EMPLOYMENT			
Construction ^c	+ 131 man-years	+ 158 man-years	+ 251 man-years
Operation ^d	+ 467 man-years	+ 4849 man-years	+14749 man-years
4. STRUCTURE OF THE ECONOMY	e	e	Major shift to industrialization
5. VIABILITY OF AGRICULTURE	0	0	0 ^f
6. STRUCTURE OF THE LABOR FORCE	e	e	Moderate shift toward higher skilled occupations
7. INCOME DISTRIBUTION			
Wage (Gini)	e	e	-3.75% to +19.80% ^g
Profit and Interest	0	e	--
Rent and Royalty	e	e	--
8. UNEMPLOYMENT	e	e	+8.30% to +41.50% ^h (improvement)

TABLE 1. Continued

	Direct Effect (change over baseline)	Direct + Secondary Effects ^a (change over baseline)	Direct + Secondary + Demographic Effects ^b (change over baseline)
9. ECONOMIC GROWTH (PCI) ⁱ	e	e	+ 49.9%
10. ECONOMIC STABILITY	e	e	++
11. INFLATION			
Energy	0	0	+ (improvement)
Land (surface)	0	0	-
Land (subsurface)	---	---	---
Other	?	?	?
12. FISCAL STRUCTURE			
Tax base (assessed value)	+\$703.1 million	e	+\$1396.8 million
Tax rev./Total exp.	e	e	+ 162.6%
Total exp. - Tax rev.	e	e	+ 2.4% (worsening)
Potential surplus ^j	e	e	+\$ 31.8 million
13. ENVIRONMENT			
Amenities (uncontr./contr.)	-/0	-/0	--/0
Health (uncontr./contr.)	-/0	-/0	-/0
Property (uncontr./contr.)	-/0	-/0	--/0
Catastrophic events	?	?	?

a) Includes indirect (TypeI) and induced (TypeII) multiplier effects.

b) Includes interaction of economic and demographic variables.

c) Represents construction of three 200MW facilities at average annual expenditure of seven year phase.

d) Does not include decrease in agricultural activity due to land displacement; less than 1.0% in all cases except direct employment (5.0%).

e) Value in the direction of but less than overall impact; separate calculation not warranted.

f) Assumes additional residents will reside in non-agricultural areas. Range for order of magnitude estimates:
-/+ small, --/++ moderate, ---/+++ large.

g) Result depends on County employment policies.

h) Assumes baseline unemployment rate of 16.8% (1976 average). Also result depends upon employment policies.

i) Refers to income generated but not necessarily retained in the County.

j) Calculated at 3.0% County property tax rate.

of course, they are of a smaller magnitude. A short summary discussion of each of these indicators follows. Policy implications will also be noted in passing.

1a.-3a. Output, Income and Employment Effects: Construction

The impact of resource exploration, well drilling and power plant construction are rather small. In the year 2020, the simulated results represent the formation of three 200MW installations both to complete the scenario and to replace depreciated installations. Though the total investment expenditure is \$375 million (or an average of \$53.6 million per year of the seven year construction cycle) only \$3.1 million is spent directly in the County, with direct and indirect effects being less than \$4.0 million. The reasons for these results are the specialization of geothermal development activities which cannot be supported by the County and the low (Type II) output multipliers averaging about 1.3. The effects on income are similarly small.

Employment effects are somewhat ambiguous. While an average of 329 jobs are created per year, only 131 are likely to go to permanent County residents. For example, power plant designers will reside outside the County while workers such as drill crews are likely to be only temporary residents. In any case, the inclusion of the local spending of these temporary residents increases the impact.

Note that this analysis assumes that no new industry categories will locate in the County between now and 2020. However various agglomeration effects may serve to attract geothermal support industries and thus increase the direct and secondary effects of both construction and operation. These potential new industries will be encouraged by a healthy economic outlook for their product.

Policy Recommendation: If the attraction of support industries is deemed desirable, the County should pursue a steady geothermal development plan which minimizes uncertainties.

1b.-3b. Output, Income and Employment Effects: Operation

The operation of geothermal steam fields and power plants will provide an enormous stimulus to the County Economy in terms of output and employment and a moderate increase in income. For example the overall output effect of \$2,034 million represents 59% of total gross output in the County in 2020. The impacts are much greater than those associated with construction effects because they represent 22 power plants. Furthermore, much more of the total direct effect is captured by the County. The exception is income, which excludes direct interest and dividend payments since these are likely to accrue completely to non-residents. Multiplier effects still remain low, as in the construction phase.

4. Economic Structure

The structure of the Imperial County economy should change considerably due to geothermal development. There will be a major shift toward industrialization with the majority of this result attributable to the direct operation of geothermal facilities themselves. By 2020 gross output of the geothermal sector will be \$1,454.1 million as compared with \$1,086.1 million in agriculture.

5. The Viability of Agriculture

The viability of agriculture will not be threatened by geothermal development. In fact, the two sectors should be able to share a harmonious relationship.

The possibility of adverse effects stemming from land displacement and environmental degradation were examined. It was determined that planning can reduce land requirements for a 200MW operation to 70 acres. The reduction in agricultural output need not be commensurate, however, since non-agricultural land can be used, previously fallow land can be brought under cultivation and (land) productivity increases may be inspired. A total of 35 acres per 200MW unit (788

total or 0.12% of the County's total irrigable land) was deemed a more realistic figure. This would mean a direct decrease in agricultural output of \$1.0 million and a decrease in employment amounting to 25 man-years. The positive stimulus to agriculture through multiplier and demographic effects of geothermal development will more than compensate for the reduction.

A reduction in agricultural productivity as a result of air and water pollution from geothermal operations can be a significant problem if not controlled. However, inexpensive control technologies do exist for the major pollutants.

Policy Recommendation: If the minimization of agricultural displacement is deemed desirable, the County should monitor development and remedy any deficiencies in the market by zoning ordinances or fiscal inducements.

Policy Recommendation: If potential productivity losses in agriculture are deemed objectionable, the County should require environmental controls on geothermal facilities.

6. Structure of the Labor Force

There will be a significant shift to relatively higher skilled occupations as a result of geothermal development. A large portion of these will be the operatives and managers employed in the new power plants. However, additional skilled workers will be required in various geothermal support industries. At the present time, training for these positions is not available in the County.

Policy Recommendation: If it is deemed desirable to enable County residents to compete for geothermal-related job openings, the County should establish training facilities for newly demanded skills (preferably with industry cooperation).

7. Income Distribution

The relative shift in skill levels can have various effects on the salary income distribution of the County. If all new jobs go to outsiders there will be a 3.75% increase in inequality. This can be countered by giving jobs to County

residents, hence raising the lower end of the scale. A net improvement of 19.8% can be effected in this manner.

Unfortunately, much of the potential gain in salary distribution will be eroded by proprietary income. Even though no interest or dividend payments from geothermal production will be retained in the County, indirect sources of these income payments will be distributed in favor of upper income classes. This will also be the case for rent and royalty payments. Given the large size of proprietary income stemming from geothermal development, the overall pre-tax distribution in the County should show no marked improvement at best.

Policy Recommendation: If adverse income distribution effects are deemed objectionable, the County should encourage the absorption of its residents into job openings created by the geothermal sector. The County can also achieve this goal through fiscal policy such as property tax relief or selective spending on services.

8. Unemployment

The 4,849 jobs related to operations and 251 to construction can potentially reduce the unemployment rate by 41.5%, i.e. from 16.8% to 10.0%, if all new jobs are filled by County residents. If residents are absorbed only in unskilled and semi-skilled slots, the improvement will be only 8.3%.

Policy Recommendation: If a decrease in unemployment is deemed desirable, the County should encourage the geothermal sector to hire local residents.

9. Economic Growth

Per capita income (in 1976 dollars) will increase from a baseline level of \$4,934 to \$7,150 or an increase of 44.9%. The magnitude of the increase, however, is misleading since it represents income generated but not necessarily retained in the County. As noted earlier a major proportion of proprietary income will go

to non-residents. An adjustment for this factor reduces the improvement to approximately 10%.

10. Economic Stability

The development of the geothermal sector will help rid the County of its monoculture character. The local economy will be less susceptible to climatic factors and the agricultural business cycle. By 2020 a large portion of the County product will emanate from a second major sector with a steady demand for its product. The eventual exhaustion of the resource, however, may pose a long-run threat to stability. The spectre of the mining town boom and bust is a distant but important consideration.

11. Inflation

It is assumed that the price of electricity in the County will not be directly affected by geothermal development due to the competitive edge of the low cost product generated by the IID. The projected large influx of people may, however, cause the demand to exceed total IID capacity. Some welfare gain might accrue to the residents if geothermal power is cheaper than that produced by increases in capacity in the form of fossil fuel installations.

In light of the negligible surface requirements, there should not be any direct increase in surface land values. However, the 40% increase in population which will accompany geothermal development by the year 2020 should put substantial pressure on land values in urban areas. Geothermal development makes all the difference in sub-surface land values. Also, there is a possibility of neighborhood effects between and across land strata.

It is virtually impossible to predict the effects on other prices.

12. Fiscal Structure

The tax base will be increased substantially. Geothermal facilities will represent approximately 36.9% of the total assessed value in the County by 2020 and will be responsible for inducing another 36.4%. The added revenues will increase the projected property tax share of expenditures by 163%, thus lessening the relative reliance on outside funds. However, the additional growth in the County population and economy will increase the gap between total expenditures and tax revenues by 2.4%. The gap will more than be made up by automatic transfers from the State and Federal governments and conventional local revenue sources. On net, geothermal development should yield a considerable fiscal boon equal to \$31.8 million dollars in potential surplus revenue.

Policy Recommendation: If an active role in geothermal development is to be assumed by the County, the surplus tax revenue can be useful in such ways as inducement rebates or discounts, liability bonds against environmental damage, etc.

13. Environment

Power generation from geothermal resources is not a perfectly clean process. Major air pollutants such as hydrogen sulfide (H_2S) and water pollutants such as cooling tower blowdown pose a threat to the quality of life.

A significant number of amenities exist in Imperial County. They range from hunting to scenery to recreational vehicle use. An evaluation has shown that the Niland KGRA is far superior to the others owing mainly to its wildlife refuge. If uncontrolled, geothermal operations could have a significant impact on amenities in all areas of the County. Environmental controls should nullify many of the adverse effects, though it will be virtually impossible to avoid intruding upon features such as "primitive values." Assuming population settles in existing urban areas, indirect adverse effects are likely to be small and localized to the Brawley and Heber KGRA's.

Uncontrolled emissions of hydrogen sulfide (H_2S) from power plants in the Brawley and Niland areas are near lethal levels at the stack but pose a threat to health only within the immediate plant vicinity. These emissions can also have an adverse effect on property, especially crops, for a significant radius. Conventional control technologies can reduce these pollutants to negligible levels though some detectable sulfur odor may still persist. It should be noted that the costs of air and water pollution control are minor, amounting to less than 1.0 mill per kwh. It is unlikely that these costs can be passed on to local residents nor are they likely to slow or discourage development.

Finally, there is little that can be said about catastrophic side-effects such as induced seismicity, subsidence and blowouts, other than they still remain a mystery. This is unfortunate as it injects a great deal of uncertainty into the overall evaluation. Even though the probabilities of occurrence are low on all three counts, a major version of any of these phenomena could offset a significant portion of the gains accruing from geothermal development.

Policy Recommendation: If it is deemed desirable to protect the quality of life, the County should require extreme environmental controls in the geothermal sector.

Policy Recommendation: If it is deemed desirable to protect its citizens against risks, the County should create a catastrophe insurance fund. This can be paid for out of additional tax revenues and/or industry contributions.

C. Alternative Scenarios and Constraints

The analysis was performed in such a manner as to facilitate the consideration of alternative development scenarios. Major investigations were performed for a basic 200MW unit of analysis with the intention of scaling them upward to any desired level. This task was simplified by the prevalence of linear relationships. For example, the engineering investigation revealed no significant

economies of scale in power plant construction or well drilling. Thus the result of altering the development target would be proportional for cases such as output employment and fiscal effects. For others, especially those for which a crude quantitative or qualitative assessment was used, reasonable scenarios (2,000-9,000 MW) are within thresholds, so there is no perceptible change. Examples are, economic structure, economic stability and environmental effects. Impacts of alternative phasing or target dates can be evaluated similarly. The only modification that must be made is in measuring percentage changes. Here they are likely to increase with the pace of development because of the relatively smaller base.

The impact of alternative uses of the resource are more difficult to ascertain and time did not allow for a formal analysis. Inspection of basic data, however, indicates that most of the effects would be similar to those presented above with two major exceptions. Employment effects would be much greater and fiscal effects moderately smaller. If the alternative uses were agriculture-related, multiplier effects might be significantly larger as well.

Alternative constraints were found to have no perceptible effect on the results. For example, the costs of state-of-the-art environmental control are so minor as to pose no threat to development incentives. Additional means of extracting revenue are unnecessary because of the large budget surplus geothermal development will yield under normal means. On the other hand, tax rebates to developers are also not likely to have much effect because a strong competitive advantage for geothermal energy already exists. Land requirements are so miniscule that they do not warrant consideration as a limiting factor. Water, however, can be a constraint, but any adverse effects can be reduced to minor significance with careful planning.

D. Summary

Geothermal development should provide a strong stimulus and stabilizing influence on both the public and private sectors of the Imperial County economy. Furthermore, there should be no distinct advantage to any group except landowners and employees of geothermal related industries who might otherwise be out of work. With some control and planning, development can be realized without any injury to the agricultural sector or the environment.

A Multisector Analysis of the Impact of Geothermal
Development on the Economy of Imperial County, California

E.M. Lofting

Imperial County is situated in the extreme south-east corner of the State of California and consists of approximately 4,000 square miles of Colorado desert. The county derives its name from the Imperial Valley Land Company which at the turn of the last century reclaimed the southern portions of the desert for agriculture. Agriculture has been the leading economic sector in the county economy, although there has been some modest diversification. Attention has recently been focussed on the potential development of geothermal energy within the valley, and the need for determining the county-wide impact of this in terms of income, employment, and production levels became evident. The present analysis is aimed at assessing the overall effects that the development of geothermal resources will have.

In order to understand in relative terms the impact of certain major developments in Imperial County, it is important to know what sectors are in the economy and how they are interrelated. At the national level income and product accounts are prepared annually in detail. Below the national level population, personal income by major source, employment and payrolls are the only standard socio-economic variables that can be assembled for analytical purposes. In most instances, for small geographical areas, the economic data that are readily available are generally insufficient to permit a thorough analysis to be carried out. It is usually necessary to resort to various estimating techniques to develop measures that permit a more complete analysis to be undertaken. One of the most satisfactory techniques

that has been developed in recent years is known as regional or "small area" input-output analysis. This technique can be implemented empirically in cases where severe data shortages and poorly developed theoretical constructs restrict the opportunities for intensive quantitative research. The increasing need for analyses which require an understanding of the economic structures of regions and small localities in terms of planning alternatives and benefit-cost considerations makes input-output an almost indispensable tool. This method can be used with primary data, although in the present instance only secondary data sources were used. No primary data gathering efforts were undertaken. Census data on employment and payrolls, and Department of Commerce data on personal income by source were augmented with business directory information giving plant locations and numbers of employees. These data were used to prorate national and state production estimates to the county level. These estimates were then benchmarked to published data and used to structure a set of regional economic accounts for the county economy. There are essentially eighty-five discrete industrial sectors present in the county economy. Together these generated a gross county product of approximately 447 million dollars in 1972. Total final demand amounted to 964 million dollars with 517 million dollars of this being satisfied by imports. The largest producing sector is agriculture with 454 million dollars of output; transportation, communications and public utilities produces 116 million dollars of output; wholesale and retail trade, 89 million dollars; services, 45 million dollars; food and kindred products, 40 million; finance, insurance, and real estate, 26 million; and miscellaneous manufacturing, 20 million. The largest single import appears as food and feed grains at 118 million dollars. The population of the county was 76,300 in 1972, and without geothermal development is forecast to grow to 134,000 by

the year 2020. Under the stimulus of geothermal development it is anticipated that by 2020 the population will reach 193,000. Total employment was approximately 24,000 in 1972, and 30,000 in 1975. A breakdown of the 1975 employment into major categories shows that agriculture employed approximately 13,000; wholesale and retail trade 7,500; services 2,500; manufacturing 2,000; government and other, 1,600; communication and utilities 1,200; construction 700; and finance, insurance, and real estate 600. The employment to population ratio was approximately .34 in 1975, indicating that one out of every three persons in the county was employed.

Projections of output and employment were made to 2020 assuming no geothermal development in the first instance, and full geothermal development in the second. Department of Agriculture forecasts of county agricultural production were used to project agricultural growth, and the Industrial Council estimates of geothermal development were used to project the growth of the energy sector. The increases in population were used to project the growth in the other sectors of the county economy. With no geothermal development, the level of employment was estimated to be 48,000 by 2020. With geothermal development, employment would be 62,000 by 2020. Value added was estimated to be 711 million in 1972 dollars by 2020 without geothermal development; with geothermal development it would reach 1425 million (\$ '72). County personal income is estimated to be 676 million (\$ '72) without geothermal, and 1377 million (\$ '72) with geothermal-- a difference of 701 million.

To verify that the projected growth rates were consistent with county resource availabilities, a linear programming model was set up and employment and water use coefficients developed for each of the 85 producing sectors. Five different objective functions were maximized subject to certain constraints. The model indicates that in order to achieve the forecast level

of agricultural development, water use rates in agriculture would have to be improved by some 35%; i.e., the efficiency of water use in agriculture must improve by approximately one-third.

Policy implications which stem from the analysis are as follows:

- (1) Geothermal development should be fostered.
- (2) Agricultural development should be expanded.
- (3) More efficient methods of using water should be encouraged.
- (4) Local industries with an export base should be encouraged.
- (5) Recreation and tourism should be promoted.

REGULATORY, PLANNING AND POLICY ASPECTS OF GEOTHERMAL ENERGY
DEVELOPMENT IN IMPERIAL COUNTY, CALIFORNIA

by

Vince Buck

Geothermal energy development in Imperial County contains within it the possibility of negative environmental, economic and social impacts. To reduce the possibilities of those impacts, this development will have to be carefully regulated. Part of this regulation can be through the county plan, but other agencies such as the APCD and state agencies will have to be involved as well. Regulation should take note of other county goals, such as maintaining the predominance of agriculture, encouraging local economic development, and developing fair taxation and spending policies. Failure to effectively regulate geothermal development could result in political dissatisfaction.

The political environment of Imperial County differs from that of the state in degree, not in kind. The county registration and voting patterns are increasingly reflecting statewide trends. The county is undergoing slow political change with a new element, primarily composed of lower income and Chicano voters, becoming more active. The principal political issue facing the county seems to be unemployment. Environmental ballot propositions appear to have strong, but generally not majority, support in the county. Most county residents seem to favor

geothermal development, but they do not seem to be especially well informed about this development. Should it not live up to their expectations, political dissatisfaction may occur. Most county department heads feel that increased resources in some areas of county government will be necessary to meet the demands for increased services brought on by geothermal development.

Experiences with energy development elsewhere suggest that government authorities should carefully consider who benefits and who pays for development. Authorities will have to engage in careful planning, determine how much development is acceptable, and what will happen when the resource is exhausted. Also, they need to consider the impact of development on other local governments who may not receive as much in the way of revenues, but will have to bear much of the cost.

The experience of geothermal energy development in Lake County is of particular interest. Lake County voters respond similarly to Imperial County voters on environmental issues. Yet strong opposition has developed there to geothermal development. This experience suggests that opposition is more the result of directly felt impacts (in this case, hydrogen sulfide in the air) rather than general environmental attitudes. When the residents of Lake County experienced this negative impact they reacted strongly, not only against the development, but against county officials who, they felt, were not effectively regulating geothermal development, and were not listening to the complaints of local residents.

Imperial County does have the authority and power to regulate geothermal development. It shares many of these powers with other agencies and in many cases exact regulatory authority is not clear.

However, in all probability, once the county decides what it wants to do, a means--perhaps not the most direct means--can be found to do it. In attempting to regulate geothermal development the county should consider developing a well-articulated plan utilizing the special zoning techniques of floating zoning (standards for a zone are designated but the zone is not located geographically until a request for rezoning is made) and performance standards (use is permitted so long as it does not exceed a number of precisely stated standards). The county might also want to attempt to get legislation passed establishing a joint state-county geothermal development commission that would oversee all geothermal development in the county and on which it would have equal representation. In addition to that, careful attention should be given to developing working procedures with the State Energy Commission, an agency in which matters are still very much in flux. The county might take advantage of this fluid situation to suggest effective regulatory procedures to the Commission which maintains the county's jurisdiction.

It was suggested that the county might want to consider pursuing six general objectives and 15 policy choices directed toward those objectives advanced.

Policy Choices Related to the Regulation of Geothermal Development

1. Develop a well-articulated plan using the special planning techniques of floating zoning and performance standards.

2. In order to make informed decisions more detailed, environmental impact reports will be required with the costs passed on to the developer in conjunction with rezoning requests.

Policy Choices Related to Increasing the Benefits
of Geothermal Development for Local Residents

3. To reduce the burden on county government and county residents, the developer should be assessed for direct developmental costs.

4. To increase employment of local residents, the county could encourage the development of nonelectrical use of geothermal resources.

5. To reduce economic dislocations, development of the geothermal field in a manner that will prolong the resource could be encouraged.

Policy Choices Related to Maintaining County Influence
Over Regulatory Decisions Affecting Local Development

6. To regulate geothermal development in a comprehensive manner, legislation creating a joint county-state geothermal energy development commission would be effective.

7. To maintain its regulatory influence, the county should pursue all opportunities for cooperation with the energy commission, proposing an active role for county agencies.

8. Other regulatory agencies can provide alternative means for controlling the impacts of geothermal development.

Policy Choices Related to Simplifying the Regulatory
Process and Making It More Efficient

9. To facilitate geothermal development the county should develop a generic environmental impact report.

10. Creating an office of geothermal development would facilitate development.

Policy Choices Related to Maintaining
an Efficient County Government

11. To effectively meet new demands with new revenues, the county should consider developing a long-range monetary policy office with the responsibility of developing long-range monetary policy.

12. A method of keeping current with developments in both technical and regulatory fields should be implemented.

13. Continued efforts to obtain external funding to meet needs associated with geothermal development will prove valuable.

Policy Choices Related to Increasing Interactions
with Local Citizens and Local Governments

14. Dissatisfaction with municipal governments toward geothermal developments might be averted if the county were to follow a course that would lessen the impact of this development on these governments.

15. To provide a greater citizen role in geothermal development policy, a citizens' advisory group on geothermal energy development should be formed, given the responsibility of holding hearings on all aspects of geothermal development.

Summary of Policy Implications

1. Reservoir levels and draw-down should be monitored to avoid subsidence, and background seismic activity should be measured to distinguish natural earth movement from thermal strain release due to reservoir operation.
2. Provision should be made for the disposal of drilling mud, blow-down residue, and detrimental waters.
3. Monitoring should be provided to avoid the possibility of organic growth being introduced in reservoirs by make-up reinjection water.
4. Transmission pipes are hazardous and consideration should be given to their installation in open trenches.
5. While the utilization of agricultural land by geothermal sites will be small (1% or less), provision should be made to reallocate irrigation water to other arable land in the district to maintain agricultural production.
6. Imperial County should encourage construction of geothermal pilot plants of about 50 megawatts for each of the four KGRAs with flexible environmental standards, in order to obtain operating data, but advise operators that minimal environmental impacts are an ultimate goal.
7. Planning for electrical transmission lines should seek to consolidate corridors along existing road and canals with height provisions for aircraft safety.

8. Environmental standards compatible with State regulations should be adopted for subsidence, seismic effects, water quality, and air quality. An ambient standard of 0.03 ppm of hydrogen sulfide within one mile of a geothermal plant is recommended.
9. Plans for the non-electric uses of geothermal energy should be undertaken because the benefits to the county from non-electric development are likely to be greater than from electric conversion.
10. Creative planning should be undertaken for the location of new residents and an expanded population which may be expected to accompany geothermal and general economic development.
11. Consideration should be given to informing citizens broadly on the policy implications of geothermal development and to encourage citizen participation in planning or issue resolution.
12. The County should encourage and assist geothermal test installations by cooperative administrative procedures, so that industry can ascertain its costs and risks, by experience, more accurately than at present.
13. If the attraction of support industries is deemed desirable, the County should pursue a steady geothermal development plan which minimizes uncertainties.
14. If it is deemed desirable to enable County residents to compete for geothermal-related job openings, the County should establish training facilities for newly demanded skills (preferable with industry cooperation).

15. If adverse income distribution effects are deemed objectionable, the County should encourage the absorption of its residents into job openings created by the geothermal sector. The County can also achieve this goal through fiscal policy such as property tax relief or selective spending on services.
16. If a decrease in unemployment is deemed desirable, the County should encourage the geothermal sector to hire local residents.
17. If an active role in geothermal development is to be assumed by the County, the surplus tax revenue can be useful in such ways as inducement rebates or discounts, liability bonds against environmental damage, etc.
18. If it is deemed desirable to protect its citizens against risks, the County should create a catastrophe insurance fund. This can be paid for out of additional tax revenues and/or industry contributions.
19. Water conservation should be encouraged to optimize the long run development of both agriculture and industry in the valley.
20. Industrial development should encourage: support services to the geothermal industry, non-electric uses of geothermal energy, local industries with export potential, recreation, tourism, and services.
21. The County should develop a well articulated plan using the special planning techniques of floating zoning and performance standards.
22. In order to make informed decisions, detailed Environmental Impact reports should be required with the costs passed on to the developer in conjunction with rezoning requests.

23. To reduce the burden on County government and County residents, the developer should be assessed for direct development costs.
24. To reduce economic dislocations, development of the geothermal field in a manner that will prolong the resource could be encouraged.
25. To maintain its regulatory influence, the County should pursue all opportunities for cooperation with the energy commission, proposing an active role for County agencies.