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TABLE OF CONTENTS

. Annotations

I. Geothermal Cost Functions — **Pages**

II. Nonelectrical Geothermal Utilization

III. Geothermal Developments in the Western United States

IV. Legal and Environmental Aspects

V. Energy Demand/Supply   Pages

Dof

Armstead, H. C. H., "Geothermal Power for Non-Base Load Purposes," *Geothermics*, Special Issue 2, Vol. 2, Part 1 (1970), 936-949.

1. Areas/places discussed ___
2. Byproducts ___
3. Costs x
4. Depletion x
5. Economies of scale x
6. Energy demand/supply ___
7. Environmental aspects ___
8. Historical aspects ___
9. Legal aspects ___
10. Well data ___

Author's Abstract:

Contrary to the popular belief that geothermal power can be economic only for supplying pure base load, there is no doubt that it can sometimes be attractive even when used for non-base load purposes. Where available geothermal resources are more than sufficient to carry the minimum system load, they could generally be used to economic advantage for supplying substantially more than the pure base load--sometimes even the *whole* load--owing to the phenomenon of "scale effect". Even greater economies can sometimes be derived from the joint use of geothermal power with special plants for carrying the peak loads of short duration. Such special plants could take the form of gas turbines or even diesels or free piston plants. Geothermal steam plants exhausting to atmosphere can also sometimes serve as peaking plants, especially where alternative sources of energy are scarce or costly. As a variant to the installation of separate peaking plants a geothermal steam plant may itself be made capable of carrying short time peak loads by means of fuel fired superheaters. One theoretical way of using at least the bores and a large part of the plant at high plant factor even though the plant as a whole may be supplying non-base load is to introduce thermal storage. The implications of doing this are discussed in the paper, and the order of magnitude of the required storage space is assessed. The practical problems of providing the storage are admittedly formidable and the economics very uncertain, but these questions too are broadly discussed.

All these problems are examined in the paper and are illustrated by means of hypothetical examples.

Capital costs for a geothermal project are classified into

1. Exploration costs

2. Production bore drilling costs

3. Plant and equipment costs.

Production bore drilling costs--a cost analogous to that of boiler plant costs in conventional steam systems--exhibit economies of scale only for very small geothermal installations. Plant and equipment costs are also less likely to exhibit economies of scale because geothermal plant units are limited in size. Items 2 and 3 together are less susceptible to scale effects than is the case with the comparable capital costs of a conventional steam installation.

Exploration costs, on the other hand, being a rather fixed sum, are extremely sensitive to the number of kilowatts installed capacity. Accordingly, the "net result is that geothermal production costs are not very susceptible to scale effect in the larger ranges of capacity, but [are] very susceptible in the smaller ranges."

An abridged version of the author's Table 1 follows.

Table 1

Capital Costs of Geothermal Power Installations
(Dollars per kilowatt installed)

	Installed Capacity (MW):						
Capital Costs:	5	10	20	40	75	150	200
1. Exploration costs[1]	600	300	150	75	40	20	15
2. Drilling costs[2]	35	30	30	30	30	30	30
3. Plant and Equipment[3]	311	283	255	230	208	188	179
Total	946	613	435	335	278	238	224

Notes:

1. Assumed to be a fixed amount ($3 million)
2. $60,000 per effective bore (one out of every three bores is unsuccessful), 2,440 kW per bore, and a spare steam margin of 20%.
3. Cost = $1,125 x (kilowatt installed)$^{0.85}$.

Conclusions drawn by the author are:

"The following considerations suggest that geothermal power may sometimes be economic even when not supplying pure base load only:

1) *Scale effect.* The advantages of scale effect, particularly with small systems, may so mitigate the disadvantages of operating at reduced plant factor that it becomes more economic to supply from geothermal energy a considerably larger share of a system load than the pure base load: sometimes even the *whole* of the load.

2) *Combination of geothermal power with special peaking plants.* By combining the use of special Peaking plants (such as gas turbines, non-condensing geothermal plants or even diesels or free piston Plants) with geothermal power, substantial economies can be effected; even though the load carried by the geothermal plant would still have a load factor well below 100%.

3) *Superheating.* As an alternative to special Peaking plants it may sometimes be economic to provide fuel-fired superheaters to boost the capacity of a geothermal power plant during times of peak load, while still using un-superheated steam to carry the bulk of the load at load factors well below 100%.

4) *Heat storage.* Without discounting the practical and economic difficulties of providing adequate and suitable storage space, it can be shown that the use of heat storage, especially with wet bores, could effect a very substantial saving in drilling costs, and (in the case of wet bores) at the same time would reduce the rate at which heat reserves are squandered. Whether the difficulties can be overcome, practically and economically, is left open to question."

James, R., "Power Station Strategy," Geothermics, Special Issue 2, Vol. 2, Part 2 (1970), 1676-1687.

1. Areas/places discussed	x	6. Energy demand/supply	
2. Byproducts		7. Environmental aspects	
3. Costs	x	8. Historical aspects	
4. Depletion	x	9. Legal aspects	
5. Economies of scale	x	10. Well data	

Author's Abstract:

This paper describes various factors involved when exploitation of a geothermal field for electric power is being considered.

Studies have been made which indicate that for condensing sets, steam turbine inlet pressures optimize at about 50 psig for the longest field life during which the reservoir is drawn down to the lowest usable pressure. This figure applies both for superheated steam reservoir and to pressurized hot water aquifers, and hence appears to be universally applicable, leading to the possibility of plant standardization with resultant lower costs and ease of maintenance.

The feasibility of transmitting steam/water mixtures within long horizontal pipelines has been tested and found to have many advantages compared with the case where the water is first separated and then rejected at the wellheads, with the steam fraction only being transmitted over the same distance. In regions where the hot water contains very high amounts of dissolved chemicals, the possibility of deposition in such lines would have to be investigated--although any tendency is usually predictable from observation of the characteristics of the local boreholes.

The non-condensable gas content of geothermal steam can be used to determine the optimum condenser pressure; the larger the gas concentration, the greater the specific steam rate required and the higher the pipeline cost, but the less the capital cost of the station equipment, hence high gas content inclines the design of the system towards small stations erected at boreholes sites instead of central stations supplied by long pipelines.

The economics of such small stations is very favourable; for instance, a powerful steam/water bore supplying a condenser-set, can generate electricity at as low as 0.2 cents/kWh which the sale of the rejected hot water could reduce to a mere fraction of this figure. The greatest potential for development with regard to hot water fields is in employing this rejected hot water for industrial processes or space heating; every effort should now be directed towards attracting industries to utilise these wasted assets.

The author indicates that if exploratory drillholes yield satisfactory results with regard to flowrate, wellhead pressure, enthalpy, bottom hole pressure, temperature, and draw-down, then a small scale geothermal power station can be built which will provide the information needed to assess the capacity and life of the reservoir:

> "In fact, if a first power station has little effect on the reservoir's performance, it is almost certain to be continuously expanded in scope until changes within the reservoir indicate it would be prudent to call a halt on further exploitation. At this point, the subterranean reservoir has been tacitly accepted as one of quasi-finite capacity and limited life."

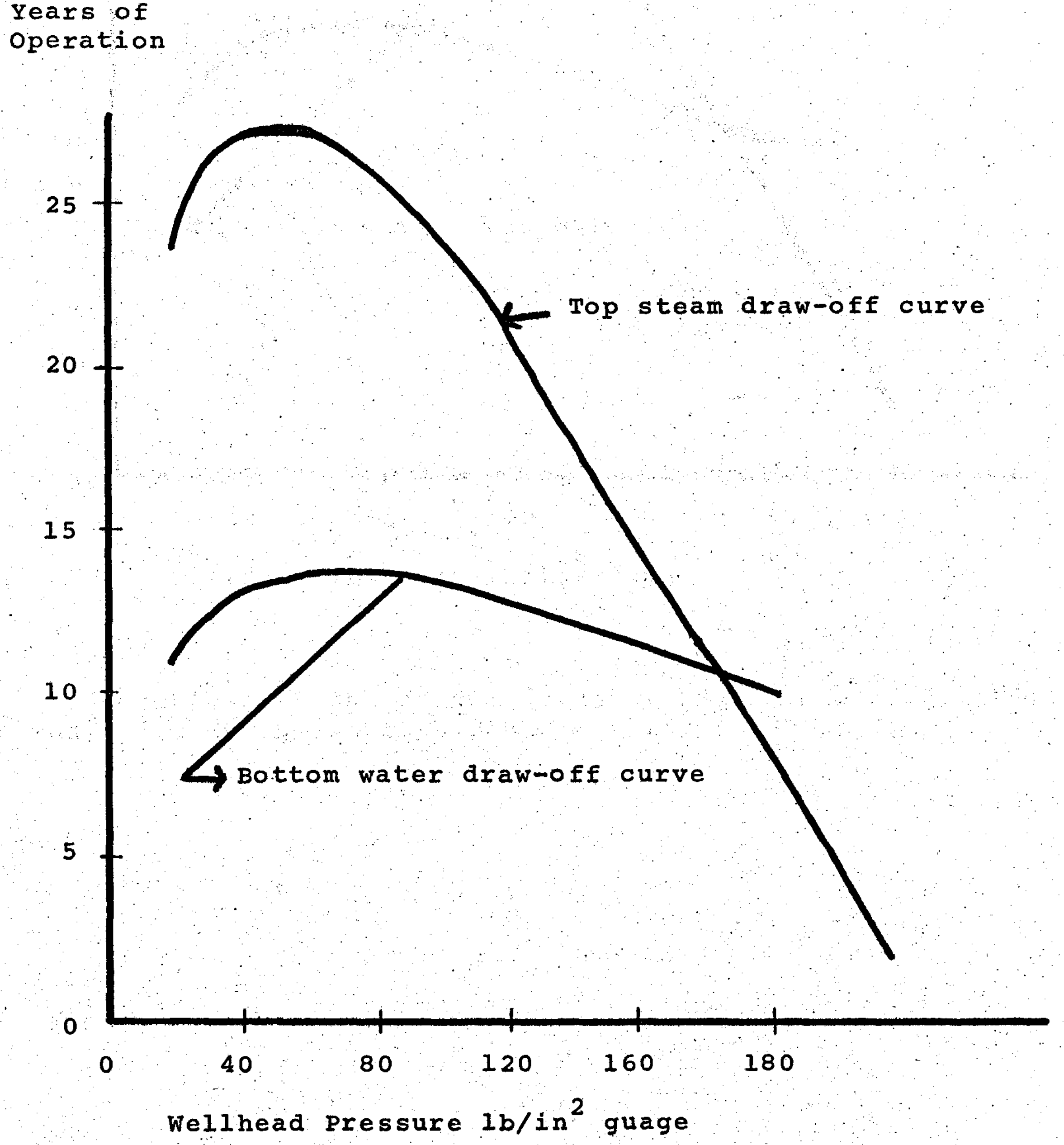
In the Wairakei field, steam is produced from a hot water aquifer by both (1) underground phase separation and dry steam boreholes and (2) separation of the flashed steam-water mixtures at the wellhead. James has made some calculations based on a theoretical model (see Figure 1) with the following assumptions:

1. 150 MW installed capacity.
2. Turbine condenser pressure of 1 lb/in^2 absolute.
3. A pressure-drop between the wellhead and the turbine of 25 lb/in^2.
4. A condensation loss between wellhead and turbine of 5 percent.
5. An aquifer of approximately one cubic kilometer of hot water (410° - 482°F) associated with volcanic rock of 20% porosity.

Figure 1 indicates the advantages, in terms of field life, of low wellhead pressures and of the drawing of top steam as compared with the more usual method of tapping the deep pressurized hot water and separating the flashed steam-water mixture at the wellhead. The maximum field life for top water draw-off is 26 years at 50 psig and is 13 years at 70 psig for the bottom water mode of draw-off.

FIGURE 1

FIELD LIFE AS A FUNCTION OF WELLHEAD PRESSURE AND MODE OF DRAW-OFF



In conclusion, the author suggests the economic feasibility of small (10 MW) geothermal power stations:

"Very high gas content is linked with high condenser pressures which leads to increased transmission costs and comparatively reduced power house costs, hence economics are inclined towards small stations built at borehole sites instead of large central stations supplied from a distance with the discharges from many bores. A study of a particular scheme where a single bore supplies a station *in situ* shows, in fact, that the economics are very favourable and that geothermal stations are not related to a scale effect in which the specific costs are inversely proportional to the size of the station, as in conventional fuel-fired and nuclear stations. Hence even fields which have been investigated and found to be small, may be worth exploiting and not just discarded because they are unable to support a large sized project."

James, R., "The Economics of the Small Geothermal Power Station," *Geothermics*, Special Issue 2, Vol. 2, Part 1 (1970), 1697-1704.

1. Areas/places discussed x
2. Byproducts x
3. Costs x
4. Depletion x
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8. Historical aspects ___
9. Legal aspects ___
10. Well data ___

Author's Abstract:

In this paper the use of a particular geothermal borehole, Tauhara No. 1, near Taupo, is investigated for the generation of electrical energy and for the industrial application of the large amount of heat energy usually wasted in the rejected bore water.

On the electrical side alone, a tentative estimate of costs indicate that a power plant of 10 MW(e) could be erected for about 1.14 million dollars (N.Z.) (i.e. capital costs of 114 dollars/kW(e)) at a generating cost of about 0.2 cents/kWh(e), which is a very attractive figure. This indicates that the specific cost per kilowatt of small plants could be as cheap as that of a very large plants, in other words, the 'scale effect' does not apply for geothermal power in New Zealand.

In order to make use of the large quantity of boiling water discharged by the bore--about a million gallons per day--it is recommended that a government assisted pilot plant be set up with a view to attracting private industries into this field and to assist them in solving any technical problems which arise. The plant could be operated by the municipality of Taupo with various industries grouped around the bore site. The long term purpose is to promote industrial demand for this cheap source of power in order that eventually those interested may absorb part of the enormous volume of hot fluids rejected at large geothermal projects such as that at Wairakei, the heat energy from which if sold at even half the price of that produced by coal-fired boilers, would realise about 6 million dollars per year. This is too

inviting a figure to be lightly disregarded without making a serious effort to induce wide business awareness of the existence of this hitherto largely wasted but unusual resource.

The author points out that, although the Tauhara, Waiotapu, and Reporoa areas in New Zealand have been drilled, further development has not taken place for several reasons. These include (1) lack of confidence in reservoir size; (2) chemical deposition in pipes; and (3) too high a ratio of nonproductive holes. However, there are now (1970) three good bores in the Tauhara area and the author asks "Is it worthwhile to build a small power scheme merely to develop these few holes or do the economics weigh heavily against such an undertaking?"

His data are based on the Tauhara No. 1 borehole which was drilled in 1964 to a depth of 3,953 ft. Testing in 1967 indicated a constant enthalpy of 483 BTU/lb over the flow range tested and a 496° F hot water source. Assuming a 10% capital cost, an 85% load factor, and a 20-year bore life, James' estimated costs, in U. S. dollars, are as follows:

CAPITAL COSTS

	Thousands of U.S. Dollars
Borehole (existing)	$ 111
2 Steam separators of 72" diameter	17
Turbo-alternator-condenser set	556
Twin tower concrete silencer (existing)	11
Cooling tower, natural draught	167
Buildings, foundations (road existing)	111
Electrical equipment	44
C. W. pumps, valves, pipes	22
Water gas ejector, valves, pipes	22
Other mechanical plant	44
	1105
Substation and connnection to Taupo	50
	1155
Engineering and contingencies, 10%	116
	$1271

Cost per kW on 10 MW(e) gross installed = $127.11/kW(e)

ESTIMATED COST OF ENERGY

	Thousands of U.S. Dollars
Capital charges at 10% of $1.271 million	127
Maintenance, 1%	11
Operating salaries, wages	7
	145
Administration, 10% surcharge	14
Total annual cost	159

	Millions of kWh(e):
Annual energy generated at 0.85 load factor on 10 MW(e) installed	74.5
Less 4% auxiliary power	3
	71.5

$$\text{Cost per kWh(e) sent out} = \frac{159{,}000(100)}{(71.5)10^6}$$

$$= .22 \text{ cents/kWh(e)}$$

The author concludes that this figure of .22 cents/kWh(e) for a small geothermal plant is very attractive when compared to nuclear and fossil fired alternatives.

James further suggests that "It is evident that geothermal power stations are independent of the 'scale effect' and small ones can be erected at a capital cost/kW(e) and at a generating cost/kWh(e) which is at least as attractive as that obtained for large ones, hence isolated bores which are good producers may be exploited even if situated in a field which is not considered large enough for development towards a sizeable station." Furthermore, if industries were encouraged to build plants near the wellhead, these might include the following industrial activities based on the reject geothermal hot waters:

- curing hides
- seasoning timber
- drying milk
- manufacturing paper from wood-pulp

In conclusion, it appears that it may be more economically feasible to build small geothermal stations at the borehole than to build large central installations supplied by many bores.

Komagata, S., H. Iga, H. Nakamura, and Y. Minohara, "The Status of Geothermal Utilization in Japan," Geothermics, Special Issue 2, Vol. 2, Part 1 (1970), 185-196.

1. Areas/places discussed x
2. Byproducts x
3. Costs ___
4. Depletion ___
5. Economies of scale ___
6. Energy demand/supply ___
7. Environmental aspects ___
8. Historical aspects x
9. Legal aspects x
10. Well data ___

Authors' Abstract:

This paper includes the use of geothermal energy for curing sicknesses at hot springs, convalescent and recreational resorts, agriculture and secondary industries in Japan, intentionally excluding the geothermal utilization for electric power generation.

Reference is made to the history of bathing at hot spring sites since ancient times in Japan. Also added are, the distribution of hot springs in Japan, the definition thereof based upon the "Hot Spring Law", and the classification of hot springs according to chemical composition. The rapid increase of the use of geothermal waters for curing, convalescent and recreational purposes by so many people is truly surprising, and probably there is no country other than Japan, where hot springs are in close contact with the people. According to the statistical data, approximately 150 million people visit hot spring sites annually. The utilizations for agriculture, fisheries and secondary industries are as yet few. In particular, there is little utilization of geothermal energy for heating of buildings, cooking, etc. In this paper, we have described the typical examples of use for horticulture, animal breeding and secondary industries, many of which are studied by special research organizations formed by local autonomies, because such utilizations largely depend upon regional characteristics.

The larger the scale of geothermal power generation, the more important the problem of the utilization of hot waste water for the above-mentioned purposes. Since it is expected that the efficiency of such hot waste water utilization should contribute much to regional developments, it is considered necessary to accelerate geothermal electric generation particularly in Japan.

Geothermal utilization in Japan dates back many years. The medicinal hot waters at the Tamazukuri Hot Spring (Shimane Prefecture) were used as long ago as 729 A.S. Many shrines were built around hot springs. In the 8-12th centuries Japanese Buddhist temples provided hot water baths and sudatoria for purification ceremonies as well as for curing illness. In Shimokama thermal 194° F waters were used for heating a greenhouse and growing melons and flowers since 1916. These waters today are also used for

- hatching eggs
- raising poultry
- breeding alligators, eels, and carp
- brewing, distillation, and other processing

In Beppu City 54 of 2132 springs are being used for horticulture and another 254 are being used for tourism and other purposes. In Ibusuki City, 106 of 571 springs are being used for horticulture, 6 for fish breeding, and 1 for brewing and distillation.

Table 1 indicates the extent of hot springs with lodging facilities and the number of visitors. Approximately 100 million visitors utilized these springs in 1968. Not included in this total are an additional 50 million visitors on one-day trips. In addition to the 1,590 hot spring sites (as of 1969), there are 46 sites with 98 hot springs which have been designated, in accordance with the Hot Spring Law, as national recuperating hot spring sites.

Japan's Hot Spring Law was enacted in 1948 for the purpose of protecting and rationally utilizing the thermal natural resources. The Law defines a hot spring as hot water, mineral water, vapor, or nonhydrocarbon gases which issue from underground at 77° F or higher and which contain specified minimum amounts of 19 mineral components.

The authors' Table 6 (not reproduced here) contains 27 examples of the utilization of geothermal energy in Japan for agriculture and industry. Seventeen of these involve greenhouses in various areas which are used for the growing of cucumbers, tomatoes, melons, chrysanthemums, papayas, bananas, crotons, lillies, orchids,rubber trees, cacti, egg plant and carnations. Other locations use geothermal waters for

- poultry raising
- alligator breeding
- saltmaking (150 tons annually)
- sulphur extraction (1,540 tons in 1965)
- rice processing (180 kg daily)
- medicinal herb cultivation
- marine hatching center--breeding of eels and carp

TABLE 1

UTILIZATION OF HOT SPRINGS IN JAPAN

Year	Number of Hot Spring Sites	Number of Lodging Facilities	Annual Total Lodged or Visiting Persons	Number of Facilities for Public Baths
1957		7,556	40,701,812	
1958		7,738	47,519,270	
1959		7,913	49,471,913	
1960		8,276	55,251,803	
1961		8,744	77,551,499	
1962		9,244	86,743,797	
1963	1,207	10,319	85,675,621	1,588
1964		10,427	87,371,026	
1965	1,331	10,904	93,311,028	1,629
1966	1,390	11,411	89,634,687	1,686
1967	1,479	12,586	96,050,339	1,594
1968	1,590	13,553	100,551,422	1,588

The authors have provided an estimate of the revenues and costs for several of these 27 enterprises. In addition, a detailed analysis is provided of the Hokkaido Marine Hatching Center (Hot Water Breeding Experimental Station), the Ikeda Geothermal Saltmaking plant near Hokkaido (which is planning to expand to 100,000 tons annually with a 7 MW geothermal power plant), and the Kokonoeyama Sulphur Mining Plant.

The first utilization of geothermal energy for power generation took place at Beppu in 1924 when H. Tachikawa built a 1 kW facility. After World War II small-scale experimental geothermal stations were attempted at Atagawa, Narugo, Beppu (30 kW in 1956), and Hakone. In 1956 a 20 MW plant was constructed at Matsukawa and in 1967 a 13 MW facility opened at Otake. Exploitation is expected in Hachimantai, Onikobe, and Hatchobaru.

Ludviksson, V. and S. Hermannsson, "Geothermal Energy Resources and Energy Costs for Industrial Uses in Iceland," Geothermal World Directory (Glendora, California: P. O. Box 997, 1972), 125-135.

1. Areas/places discussed	x	6. Energy demand/supply	
2. Byproducts	x	7. Environmental aspects	
3. Costs		8. Historical aspects	
4. Depletion	x	9. Legal aspects	
5. Economies of scale		10. Well data	x

The authors report on three recent geothermal developments in Iceland. The first is the Johns-Manville/Icelandic government venture in a diatomaceous earth processing plant which was completed in 1967 near Namafjall. This plant uses about 20 tons of geothermal steam per hour at 110 psia to dry mud dredged from nearby Lake Myvatn. The government owns the steam producing facilities and, as of 1968, was charging $.39 per ton. This is a relatively high price due to the fact that the total amount of steam consumed is considerably less than the output of one production steam well.

The second development is the recent completion of a 2500 KW geothermal electric power plant in the Namafjall area near the diatomite plant. Again, the government owns the steam facilities and the power plant is owned by the Laxa Power Company. The plant will use approximately 50 tons/hour of steam at 150 psia.

The third development, and the one most extensively discussed by the authors, is a feasibility study of producing sea chemicals, using geothermal steam as an energy source, in the Reykjanes area.

According to the authors, this sea chemicals industry would proceed in three stages:

> "The first step would be the production of common salt and potassium chloride from the brine. Combined with this would be the production of byproducts from the mother liquor after salt and potash crystallization. These byproducts would include bromine, calcium chloride and possibly lithium salts...

> "The second major step could be the production of magnesium chloride from sea water and shells and which could lead to the production of magnesium metal. A process based on the use of geothermal steam as combination with an ionexchange step is being developed under NRC [National Research Council] sponsorship. This process produces soda ash as a byproduct. Other steps are possible, such as the production of chlorine-sodium metal production. Alternately, titanium metal could be produced based on the sodium process.
>
> "In a third group is the production of various electrolytic dissociation products of common salt. Most notable of the products in this category is the production of caustic and chlorine. Salt at favorable prices and low cost power would insure low production costs for these chemicals."

Although the chlorine export market appears weak at the present time, it might be possible to convert the chlorine to more valuable products such as vinyl chloride, ethylene dichloride, polyvinyl chloride, or chlorinated solvents. These products require inexpensive ethylene or acetylene from local refineries, ethylene cracking facilities, or acetylene production centers.

The proposed geothermal area is about 2 miles long and 1 mile wide and has numerous hotspots, steam springs, boiling mudholes, and hot brine springs.

The bottom-hole temperature of a 3609 foot borehole drilled in 1968 was 547° F. Recently the eighth well in the area was drilled to a depth of 5906 feet and had a bottom-hole temperature of 491° F. Wells drilled less than 3,300 feet deep appeared to be affected by cold seawater intrusion. It is anticipated that 40 to 80 tons of 266° F steam per hole can be produced when this most recent hole is opened. It is estimated that with 3-6 such holes there will be enough geothermal brine and steam to supply a 250,000 ton salt plant.

The brine composition, when flashed to 1 atmosphere and 212° F, is reported in Table 1 along with the corresponding values for seawater. In comparing the two fluids, the authors comment that "the potassium, calcium and lithium contents are greatly increased, making an economic extraction of these salts possible while magnesium and sulfate ions have greatly decreased in concentration, which reduces the conventional hardness scaling problems. However, the enormously increased silicate concentration gives rise to another scaling agent which will have to be reckoned with."

Some of the results of an economic feasibility study of the proposed sea chemicals industry are given in Table 2.

TABLE 1

CONSTITUENTS IN SEAWATER AND GEOTHERMAL BRINE ON REYKJANES

Constituent	Quantity in Seawater mg/kg	Quantity in Geothermal Brine mg/kg	Ratio
Cl	18,980	30,800	1.62
Na	10,560	15,800	1.50
SO_4	2,650	76	.029
Mg	1,270	25	.02
Ca	400	2,650	6.6
K	380	2,200	5.8
HCO_3	140	6	.043
Br	65	110	1.7
SiO_2	2.5	600	240.
B	4.6	14.6	3.2
F	1.4	0.8	.57
Al	1.9	.74	.39
Li	.1	8.3	83.
I	.05	.6	12.
NH_4	---	1.6	
Fe	.02	.31	15.
Mn	.01	.06	6.
Cu	.008	.00	
Pb	.005	.00	
Zn	.008	.00	
As	.018	.13	
H_2S		.2	
Total solids	34,500	53,400	1.55
pH		6.7	

TABLE 2

FEASIBILITY STUDY OF 250,000 TON SALT PLANT AND 24,000 TON MAGNESIUM PLANT

Production Unit	Raw Material	Power Requirement kW	Geothermal Steam t/h	Oil t/yr	Personnel	Production t/yr	Capital Cost $Mill	Operating Cost $Mill	Sales Value at Factory $Mill
The Salt Works	270 l/sec brine	2,500	270		124		11.5	3.2	3.6
Salt, fine grained						200,000			
Salt, course grained						50,000			
Potash						25,000			
Calcium chloride						58,000			
Bromine						700			
Lithium compounds						500			
Lime Calcination	160 t shellsand	350		12,600	12	70,000	1.5	.8	
The Magnesium-	1100-1200 l/sec seaw.								
Hydroxide Works	70,000 t CaO	300			6	73,000	1.5	.4	
The Magnesium Chloride	145,000 t salt								
and Soda Ash Works	70,000 t $Mg(OH)_2$	1,800	450	12,000	35		11.0	4.1	
Magnesium chloride						107,000			
Soda ash						120,000			3.36
The Magnesium Works	107,000 $MgCl_2$	60,000			300		23.0	10.00	
Magnesium						24,000			13.0
Chlorine						65,000			2.6

Tikhonov, A. N. and I. M. Dvorov, "Development of Research and Utilization of Geothermal Resources in the USSR," _Geothermics_, Special Issue 2, Vol. 2, Part 2 (1970), 1072-1078.

1. Areas/places discussed	x	6. Energy demand/supply	
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Authors' Abstract:

Practical utilization of geothermal resources in USSR, now under way, is closely related to a large development of scientific research in the field of geothermics. Work concerned with geothermal research and utilization of resources in USSR covers 4 main problems:

(a) - regional distribution and condition of formation of a geothermal field within a zone open to direct measurements;

(b) - devising and improvement of the apparatus and geothermal observation techniques;

(c) - study of deep-tectonic processes;

(d) - practical utilization of geothermal resources.

Prospected reserves of thermal waters over the range of temperatures from 50 to 200° C have been tentatively estimated in USSR as being over 8 million m^3 per day.

Geothermal resources in USSR are being utilized for the purpose of heating, hot water supply of living and industrial buildings; in agriculture--for the heating of hotbeds and greenhouses; for the growing of vegetables and for cattle-breeding needs; in extracting chemical matter from geothermal waters; for their utilization in balneology; for electric power generation.

Approximately 50-60 percent of the USSR contains commercially exploitable thermal waters which could provide sufficient heat to replace dozens of millions of tons of conventional fuel annually.

Among the applications of thermal resources in the USSR are the following:

1. Heating and hot-water supply of industrial buildings and residential dwelling units. For this type of application the water temperatures must be 140-212° F. In a search for oil in Makhach-Kala years ago, 100 boreholes were drilled 3937 to 4921 feet deep and 40 of these yielded 140-158° F water. One of these boreholes has been supplying residential heat and hot water for industry since 1948 and another has been giving 1000 bottles of mineral water monthly since 1956. A heat distribution station near Makhach-Kala provides the 15,000 inhabitants of new homes there with hot water.

2. Agricultural uses. Also in Makhach-Kala the thermal waters have been heating hotbeds and hothouses in a 5000 x 5000m area for several years. A 50,000 m^2 hotbed-hothouse is being built for year-round production and it is anticipated that 2,000 tons of cucumbers, tomatoes, and other vegetables can be grown there.

3. Chemical processes. Application is being made of the heat in thermal waters to produce cold in refrigerating machines: "Refrigerating equipment is increasing every year. A number of chemical plants consume milliards of cold kilocalories refrigeration units. Cold is used for the production of synthetic rubber, ammonia, protein and vitamins preparations, etc. Metallurgical plants also consume enormous quantities of cold. It is interesting that a majority of enterprises are equipped with compressor machines which consume enormous electrical energy.

"In the USSR, the absorption lithium bromide machine, with a power of 2.5 million kilocalories of cold in an hour, which does not operate with electrical energy but with thermal water, has been examined and is being mass-produced. This refrigerating plant is notable for the fact that it gives not only cold but also transforms heat. It is able to act the whole year round, supplying cold in summer and heat in winter."

4. There has been an experimental 5 MW geothermal plant in Pavjetskaya since 1967. Twenty boreholes have been drilled there which are 722-1575 feet deep and which have temperatures up to 424° F. It is estimated that the Pavjetsk aquifer may be sufficient for the generation of 50-70 MW. Exhaust waters (230° F) are currently discharged into a nearby river but plans are to use these waters for an 80,000 m^2 hothouse center.

An experimental freon geothermal station has been put into operation at Paratunka (Kamchatka). There are plans to build a 6 MW geothermal station at Kunashiry in the Kuril Islands and thermal waters at Big Bath appear sufficient for the generation of 15 MW of electric power.

5. Medicinal uses. Health spas and bottling works make use of 280 water springs. Thermal water bottling takes place in 22 factories. The Telaja sanatorium near Magadan has used thermal waters for many years from a borehole which has a temperature of 185° F. These waters are used not only for treatment but also for the heating of dining rooms, staff and guest residences, and hothouses where their own vegetables are raised.

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El-Ramly, Nabil, R. E. Peterson, and K. K. Seo, "Geothermal Wells in Imperial Valley, California: Desalting Potentials, Historical Development, and a Selected Bibliography," NWSIA (National Water Supply Improvement Association) Journal, 1 (July 1974), 31-38.

1. Areas/places discussed x
2. Byproducts x
3. Costs ___
4. Depletion ___
5. Economies of scale ___
6. Energy demand/supply ___
7. Environmental aspects ___
8. Historical aspects x
9. Legal aspects ___
10. Well data x

Authors' Abstract:

Reclamation, importation, and desalting systems are energy-intensive and energy shortages are at hand. A potentially important source of energy is geothermal brine, a subterranean resource existing in abundance in the Imperial Valley, California which is, in turn, an area in short supply of good quality water. A history of Imperial Valley geothermal well drilling is provided in this paper. Current developments suggest the possibilities of two technological breakthroughs: utilization of 300° to 400° F brines in the world's first binary fluid closed cycle geothermal power plant and the world's first operational geothermal desalting plant.

The authors indicate that the likelihood of future water shortages has become a serious concern in many areas. Possible solutions include wastewater reclamation, importation, and desalting of sea or brackish water, but all of these are energy-intensive, and energy shortages are also present. However, a potentially important source of readily available energy is geothermal brine. Technology is rapidly advancing in geothermal energy production and, at the same time, desalting technology has been improving at a pronounced rate. Consequently, geothermal desalting itself is now very promising and may contribute significantly to future water resource development.

The problem of brine disposal has been an important bottleneck holding back geothermal development in the Imperial Valley. Approximately two pounds of brine are produced for every pound of steam. R. W. Rex, a leader in geothermal exploration and development, has suggested

> "development of a large market for geothermal brine is essential for development of the lower Colorado basin geothermal potential. The only market evident for very large quantities of geothermal brine is for saline water conversion."

Figure 1 shows the location of the seven known geothermal resource areas located within the Imperial Valley of California: the Buttes (which includes the Salton Sea geothermal field), Heber, Mesa, Dunes, Glamis, Border, and North Brawley anomalies. Geothermal wells have been drilled in four of these regions--Buttes (first drilled in 1927) and Heber, Mesa, and Dunes (first drilled in 1972).

Thirty-two geothermal wells have been drilled or are being drilled and these are listed in Table 1. Three periods of activity can be identified: 1927 to 1928--3 wells; 1958 to 1965--11 wells and 1972 to 1973--18 wells. Of the 18 recent wells, 14 have been drilled by Magma Power Company-San Diego Gas and Electric Company, or by Magma Energy, Inc., a subsidiary of Magma Power Company.

Conclusions drawn by the authors are as follows:

Private enterprise has been the pioneer since 1927 in the exploration and development of geothermal energy and mineral recovery within the Imperial Valley. The corrosive and scaling nature of the geothermal brines have stymied large scale commercial development thus far, especially near the Salton Sea where salinities are close to 30 percent. In the past two years, however, drilling interest by both private and public organizations has been rekindled and, for the first time, wells have been drilled in the Dunes, Heber, and East Mesa geothermal areas.

A joint venture between Magma Energy, Chevron Oil, and San Diego Gas and Electric at the Heber anomaly appears to offer great promise for future developments. Although the temperatures of the geothermal fluids appear to be on the low side (under 400° F), both at Heber and East Mesa, the salinities are much less (close to 2 to 3 percent) than they were near the Salton Sea, and the Magmamax process which utilizes a binary fluid closed cycle power Plant could conceivably represent the technological breakthrough that will open up the southern end of the Imperial Valley for geothermal power. The establishment of the feasibility of geothermal power will not only provide electrical energy for the Valley but will also enhance the prospects of the Bureau of Reclamation dual purpose geothermal power-desalting project at the East Mesa geothermal area.

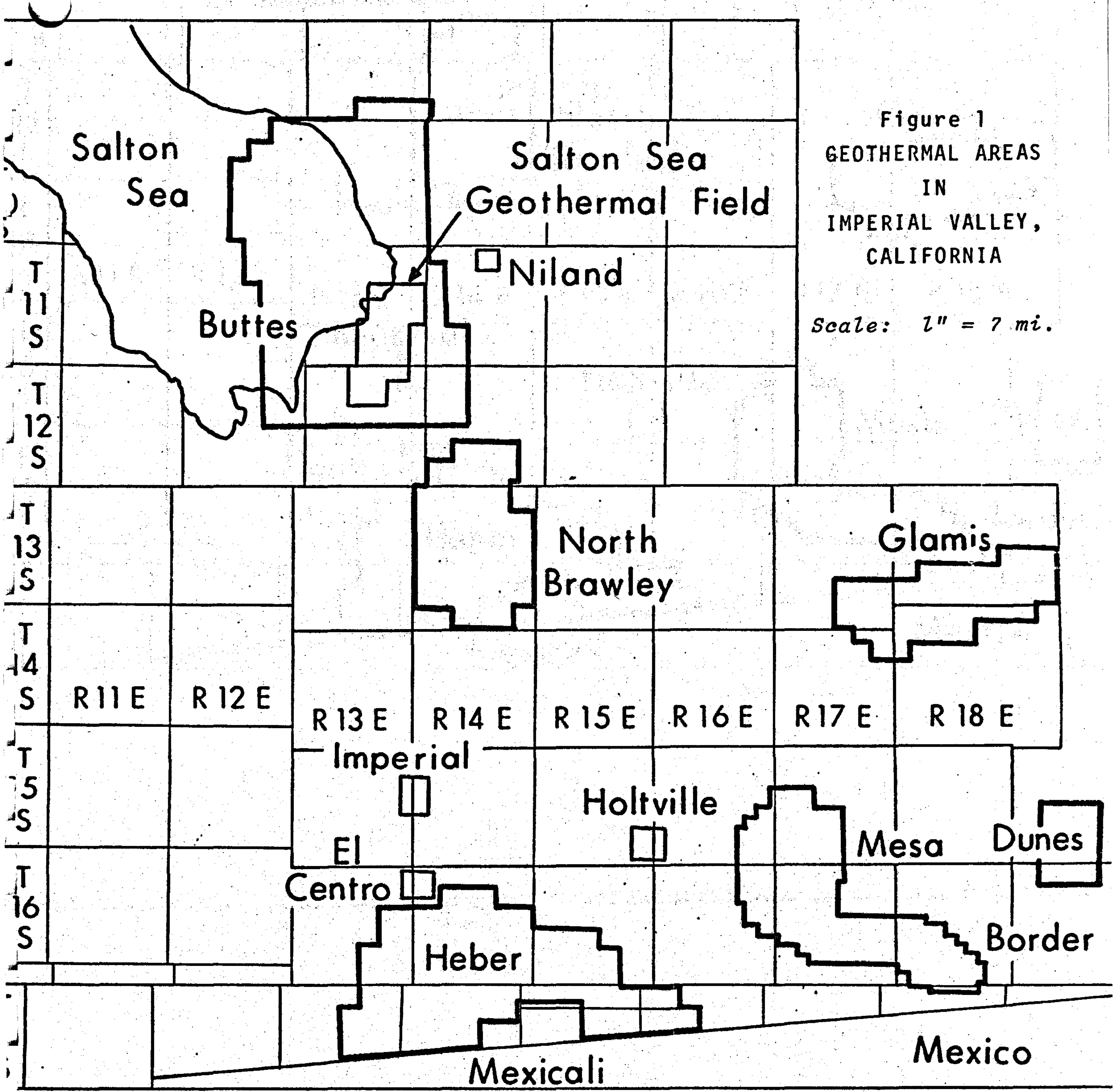

Figure 1
GEOTHERMAL AREAS
IN
IMPERIAL VALLEY,
CALIFORNIA

Scale: 1" = 7 mi.

Table 1
GEOTHERMAL WELLS IN IMPERIAL VALLEY, CALIFORNIA

Well	Location/Anomaly	Date Completed (mo./yr.)	Depth (feet)	Maximum Temperature (°F)	Operator
P.D. #1	11S/13E/Buttes	6/27	728	244	Pioneer Development
P.D. #2	11S/13#/Buttes	10/27	1263	?	Pioneer Development
P.D. #3	11S/13E/Buttes	2/28	1473	?	Pioneer Development
Sinclair #1	"	2/58	4723	561	Kent Imperial Oil Co.
Sportsman #1	"	3/61	4730	590	O'Neill Geothermal
I.I.D. #1	"	3/62	5232	622	O'Neill Geothermal
Sinclair #3	"	4/63	6921	536	Western Geothermal
I.I.D. #2	"	12/63	5802	626	Shell Development
River Ranch #1	"	1/64	8098	653-800	Earth Energy, Inc.
State of Calif. #1	"	5/64	4838	590	Shell Development
Elmore #1	"	5/64	7118	770	Earth Energy, Inc.
Sinclair #4	"	6/64	5304	428	Western Geothermal
Hudson #1	"	7/64	6114	500	Earth Energy, Inc.
I.I.D. #3	"	3/65	1696	392	Imperial Thermal Products
Magmamax #1	11S/13E/Buttes	1/72	2804	509	MPC/SDGE
Dearborn #1	12S/13E/none	abandoned			MPC/SDGE
Sharp #1	15S/16E/Mesa	abandoned			MPC/SDGE
Woolsey #1	11S/13E/Buttes	3/72	2401	460	MPC/SDGE
Holtz #1	16S/14E/Heber	3/72	?	>320	MPC/SDGE
Holtz #2	16S/14E/Heber	7/72	?	>320	MPC/SDGE
Dunes #1	15S/19E/Dunes	8/72	2007	270	DWR/UCR
Mesa 6-1	16S/17E/Mesa	8/72	8030	392	Bureau of Reclamation
Magmamax #2	11S/13E/Buttes	11/72	4303	532	MPC/SDGE
Magmamax #3	11S/13E/Buttes	11/72	4003	610	MPC/SDGE
Nowlin Partnership #1	16S/14E/Heber	11/72	5030	>320	Chevron Oil Co.
Magmamax #4	11S/13E/Buttes	12/72	2558	464	MPC/SDGE
Bonanza #1	15S/14E/Heber	3/73	5024	?	Magma Energy, Inc.
Sharp #2	16S/16E/Mesa	3/73	6493	?	Magma Energy, Inc.
Fed-Rite #1	17S/16E/Heber	4/73	5380	?	Magma Energy, Inc.
Mesa 6-2	16S/17E/Mesa	8/73	6006	369	Bureau of Reclamation
Sharp #3	16S/16E/Mesa	pending			Magma Energy, Inc.
Bonanza #2	15S/14E/Heber	pending			Magma Energy, Inc.

Notes: MPC is Magma Power Co.; SDGE is San Diego Gas and Electric; DWR is California Dept. of Water Resources; UCR is Univ. of California, Riverside; Chevron Oil Co. is a subsidiary of Standard Oil Co. of Calif.; Imperial Thermal Products is a subsidiary of Morton International; Earth Energy is a subsidiary of Union Oil Co.; Magma Energy is a subsidiary of Magma Power Co. ; I.I.D. is Imperial Irrigation District.

Garside, Larry J., "Geothermal Exploration and Development in Nevada Through 1973," Nevada Bureau of Mines and Geology (Reno, Nevada 89507), Report 21, 1974, 12 pp.

1. Areas/places discussed	x	6. Energy demand/supply	
2. Byproducts	x	7. Environmental aspects	
3. Costs		8. Historical aspects	x
4. Depletion		9. Legal aspects	x
5. Economies of scale		10. Well data	x

Author's Abstract:

A brief description of Nevada's geothermal resources, and exploration activity for geothermal power through 1973. The use, geology, exploration, and regulation of the State's geothermal energy resources are discussed.

The author's Table 1, "Exploratory geothermal drilling in Nevada through 1973," reveals that 48 geothermal wells have been drilled over the period 1954-1965. Exploratory drilling ceased after 1965 due to the problems of leasing on Federal land. Just recently (January 1974), however, Standard Oil Co. of California and American Thermal Resources started a well in the Beowawe geothermal area.

Use of hot springs in Nevada goes back to prehistoric time when Indians used the thermal waters to

- scald ducks and geese
- bathe
- remove pitch from pine cones and seeds.

The 49'ers used these waters for watering stock as well as for bathing and drinking. At the Tonopah mines hot waters were pumped out and used to heat greenhouses. Many early-day spas were located by hot springs and of those surviving at present are Steamboat Hot Springs and Lawton's Hot Springs, both near Reno. Besides being used balneologically at Steamboat Hot Springs, the thermal waters have been used in the processing of asphalt emulsions and in the melting and casting of plastic explosives. Farm dwellings have been heated from wells encountering hot

TABLE 1
Exploratory geothermal drilling in Nevada through 1973[1]

Operator	Name	API No.[2]	Location	Depth	Maximum Spring Temp. (°F)	Maximum Well Temp. (°F)	Completion Date	Remarks
1. Steamboat Hot Springs					203	369		
Nevada Thermal Power Co.	Steamboat No. 1[3]	27-031-90000	NW/4,NE/4,S28,T18N,R20E	1830			1954	Hot water present with 5-10% steam flashover. Eight core holes drilled by the U. S. Geological Survey (1950), for a total footage of 3316 feet. Also several wells for hot water baths, etc. Numerous homes are heated from warm water wells in the Reno area. For more information see White (1968).
Nevada Thermal Power Co.	Steamboat No. 2[3]	27-031-90001	SE/4,SW/4,S28,T18N,R20E	964			1959	
Nevada Thermal Power Co.	Steamboat No. 3[3]	27-031-90002	NW/4,NE/4,S32,T18N,R20E	1263			1960?	
Nevada Thermal Power Co.	Steamboat No. 4[3]	27-031-90003	NE/4,NW/4,S32,T18N,R20E	520?			1960	
Nevada Thermal Power Co.	Steamboat No. 5[3]	27-031-90004	NW/4,NW/4,S32,T18N,R20E	826			1961	
Nevada Thermal Power Co.	Steamboat No. 6[3]	27-031-90005	NW/4,NW/4,S32,T18N,R20E	716			1961	
2. The Needles (Pyramid Lake)					208	240		
Western Geothermal Inc.	Needles No. 1	27-031-90006	NW/4,SW/4,SW/4,S6,T26N,R21E	5888			1965	Large flow of hot water.
Western Geothermal Inc.	Needles No. 2(?)[3]	27-031-90007	C,W/2,NE/4,S12,T26N,R21E	~4000?			1964	
Western Geothermal Inc.	Needles No. 3(?)[3]	27-031-90008	NW/4,SW/4,SW/4,S6,T26N,R21E	?			1964	
3. Wards Hot Springs (Fly Ranch)					203	>220		
Western Geothermal Inc.	Fly Ranch No. 1(?)[3]	27-031-90009	SW/4,S2,T34N,R23E	1000+			1964	Largest hot springs in northwestern Nevada.
Western Geothermal Inc.	Granite Creek Ranch No. 1(?)[3]	27-031-90010	S35(?),T34N,R23E	800			1965?	
4. Monte Neva Hot Springs					193	190		
Magma Power Co.	Monte Neva No. 1(?)[3]	27-033-90000	S24(?),T21N,R63E	402			1965	Melvin (Goodrich) Hot Springs
5. Beowawe Geysers					205	414		
Magma Power Co.	Beowawe No. 1	27-011-90000	NE/4,SE/4,NW/4,S17,T32N,R48E	1918			1959?	Hot water with 5-10% steam flashover. Problems of scaling and cold water inflow.
Magma Power Co.	Beowawe No. 2	27-011-90001	SE/4,SW/4,NW/4,S17,T32N,R48E	715			1959?	
Vulcan Thermal Power Co.	Vulcan No. 1	27-011-90002	NW/4,SW/4,NW/4,S17,T32N,R48E	715?			1961	
Vulcan Thermal Power Co.	Vulcan No. 2	27-011-90003	C,SE/4,NW/4,S17,T32N,R48E	655?			1961	
Vulcan Thermal Power Co.	Vulcan No. 3	27-011-90004	NE/4,SW/4,NW/4,S17,T32N,R48E	795 or 715			1961	
Vulcan Thermal Power Co.	Vulcan No. 4	27-011-90005	S17?,T32N,R48E	767			1961	
Vulcan Thermal Power Co.	Vulcan No. 5	27-011-90006	S17?,T32N,R48E	237			1963?	
Vulcan Thermal Power Co.	Vulcan No. 6	27-011-90007	NW/4,SW/4,NE/4,S17,T32N,R48E	478			1963	
Sierra Pacific Power Co.(?)[3]	Sierra No. 1	27-011-90008	S17?,T32N,R48E	927			1964?	
Sierra Pacific Power Co.(?)[3]	Sierra No. 2	27-011-90009	S17?,T32N,R48E	397			1964?	
Sierra Pacific Power Co.(?)[3]	Sierra No. 3	27-011-90010	NW/4,SE/4,NW/4,S17,T32N,R48E	2052			1964?	
Sierra Pacific Power Co.(?)[3]	Sierra No. 4	27-011-90011	NW/4,NE/4,NW/4,S17,T32N,R48E	1005			1964?	
Chervon-American Thermal Res.	Ginn No. 1-13	27-015-90000	C,SE/4,SE/4,S13,T31N,R47E	–			–	
6. Hot Springs Point (Crescent Valley)					122	166		
Magma Power Co.	Hot Springs Point No. 1(?)[3]	27-011-90012	S1,2, or 11,T29N,R48E	410			1965	Hot water.

TABLE 1 (Continued)
Exploratory geothermal drilling in Nevada through 1973[1]

Operator	Name	API No.[2]	Location	Depth	Maximum Spring Temp. (°F)	Maximum Well Temp. (°F)	Completion Date	Remarks
7. Wabuska Hot Springs					162	222		
Magma Power Co.	Wabuska No. 1	27-019-90000	S16?,T15N,R25E	488			1959	Hot water used for greenhouse heating.
Magma Power Co.	Wabuska No. 2	27-019-90001	SE/4,NE/4,SW/4,S16,T15N,R25E	532?			1959	
Magma Power Co.	Wabuska No. 3	27-019-90002	NE/4,SE/4,SE/4,S16,T15N,R25E	2223			1959	
8. Fernley (Hazen)					?	270		
Magma Power Co.	Hazen No. 1(?)[3]	27-019-90003	SW/4,S18?,T20N,R26E	750			1962	Patua Hot Springs.
Magma Power Co.	Hazen No. 2(?)[3]	27-019-90004	S18?,T20N,R26E	∿300?			1962	
Magma Power Co.	Hazen No. 3(?)[3]	27-019-90005	S18?,T20N,R26E	∿300?			1962	
9. Hind's Hot Springs					144	?		
U. S. Steel Corp.	Hind's No. 1(?)[3]	27-019-90006	SW/4,SE/4,S16,T12N,R23E	?			1962?	Hot water in wells cooler than springs at surface.
U. S. Steel Corp.	Hind's No. 2(?)[3]	27-019-90007	SW/4,SE/4,S16,T12N,R23E	?			1962?	
U. S. Steel Corp.	Hind's No. 3(?)[3]	27-019-90008	SW/4,SE/4,S16,T12N,R23E	?			1962?	
10. Darrough Hot Springs					207?	265		
Magma Power Co.	Darrough No. 1(?)[3]	27-023-90000	S17?,T11N,R43E	812			1962	Very large flow of hot water, little steam.
11. Brady's Hot Springs					194	418		
Magma Power Co.	Brady No. 1	27-001-90000	NE/4,NE/4,SW/4,S12,T22N,R26E	700?			1959?	Hot water with 5% steam flashover. Problem of scaling.
Magma Power Co.	Brady No. 2	27-001-90001	NE/4,NE/4,SW/4,S12,T22N,R26E	241			1959?	
Magma Power Co.	Brady No. 3	27-001-90002	SE/4,SE/4,NW/4,S12,T22N,R26E	610			1961?	
Magma Power Co.	Brady No. 4	27-001-90003	SE/4,SE/4,NW/4,S12,T22N,R26E	723			1961?	
Magma Power Co.	Brady No. 5	27-001-90004	NW/4,SW/4,NE/4,S12,T22N,R26E	593			1961?	
Magma Power Co.	Brady No. 6	27-001-90005	NW/4,SW/4,NE/4,S12,T22N,R26E	770			?	
Magma Power Co.	Brady No. 7	27-001-90006	NW/4,SW/4,NE/4,S12,T22N,R26E	250			?	
Earth Energy Inc.	R. Brady EE No. 1	27-001-90007	S12?,T22N,R26E	5062?			1964	
Earth Energy Inc.	Brady Pros. No. 1	27-001-90008	S12?,T22N,R26E	1758?			1965?	
12. Stillwater					–	240		
O'Neill Geothermal, Inc.	Joseph I. O'Neill, Jr. Reynolds No. 1	27-001-90009	NE/4,SW/4,SW/4,S6,T19N,R31E	∿4200?			1964	Some water wells drilled in this area encountered hot water and steam which have been used for space heating. No springs or other surface features.
13. Wally's Hot Springs					160	181		
U. S. Steel Corp.	Wally's No. 1	27-005-90000	SE/4,NW/4,NW/4,S22,T13N,R19E	1268			1962	Twenty-six shallow holes were also drilled to measure the temperature gradient.
U. S. Steel Corp.	Wally's No. 1	27-005-90001	SW/4,SW/4,NW/4,S22,T13N,R19E	499			1962	

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[1] Listing does not include thermal water wells or wells drilled to exploit thermal waters for spas, swimming pools, space heating, etc.

[2] The American Petroleum Institute Unique well number system has been applied to geothermal wells as well as oil and gas wells, and is recommended for the unique identification of wells by all agencies of industry and government.

[3] Name assigned by Nevada Bureau of Mines and Geology; original name unknown.

water in an area devoid of thermal manifestations (Stillwater, in west-central Nevada, near Fallon). Geothermically heated greenhouses at Wabuska near Yerington, Wally's Hot Springs near Minden, and Werdel Hot Springs have been used for growing vegetables, especially tomatoes.

In 1965 the Deputy Attorney General of Nevada ruled that geothermal resources are water resources which come under the jurisdiction of the Division of Water Resources in the Department of Conservation and Natural Resources. No state geothermal leasing regulations have been issued in Nevada. Approximately one percent of Nevada land is state-owned, whereas 86 percent is under the jurisdiction of the Federal Government. The final regulations arising out of the Geothermal Steam Act became effective January 1, 1974. Twelve areas (343,996 acres) have been designated as known Geothermal Resource Areas. These are Beowawe (12,712 acres), Brady Hot Springs (19,020 acres), Darrough Hot Springs (8,398 acres), Double Hot Springs (10,816 acres), Elko Hot Springs (8,960 acres), Fly Ranch (5,125 acres), Gerlach (8,972 acres), Leach Hot Springs (8,926 acres), Moana Springs (5,120 acres), Monte Neva (10,302 acres), Steamboat Springs (8,914 acres), Stillwater-Soda Lake (225,211 acres), and Wabuska (11,520 acres).

Nineteen percent of the State lands (13,458,000 acres) are classified as having prospective geothermal value.

It is uncertain whether or not geothermal resources belong to the owners of the surface rights or to the mineral rights owners. In *The United States* v. *Union Oil Co., Magma Power Co., et al.*, it was ruled that geothermal resources belong with homestead water rights rather than with the mineral rights reserved to the Federal Government.

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White, D. E. and J. R. McNitt, "Geothermal Energy," in Mineral Energy," in Mineral Resources of California (Ferry Building, San Francisco, CA 94111: California Division of Mines and Geology, Bulletin 191, 1966), 174-179.

1. Areas/places discussed x
2. Byproducts ___
3. Costs ___
4. Depletion ___
5. Economies of scale ___
6. Energy demand/supply ___
7. Environmental aspects ___
8. Historical aspects ___
9. Legal aspects ___
10. Well data x

Fifteen areas in California have been explored for geothermal energy (see Table 1).

Three areas of particular interest have been The Geysers in Sonoma County, the Salton Sea area in Imperial County, and the Casa Diablo area (Mono County) which is part of Long Valley. The ten wells drilled in Casa Diablo have been located in a 2 square mile area and most of them have produced satisfactorily.

Of the approximately 30 areas in the United States which have been explored for geothermal resources, 15 have been in California.

TABLE 1

GEOTHERMAL EXPLORATION IN CALIFORNIA, 1955-1965

Thermal Area	No. of Wells Drilled	Max. Depth	Max. Temp. (°F)	Dates Drilled	Remarks
1. Lake City, Modoc County	4	2,150	320	1959-62	Magma Power Co.
2. Cedarville (Surprise Valley), Modoc County	1	734	130	1962	"
3. Terminal Geyser, Plumas County	1	1,270	264	1962	Geysers Steam Co.
4. Wendel, Lassen County	1	630	174	1962	Magma Power Co.
5. Amedee, Lassen County	3	1,116	225	1962	"
6. Sulphur Bank, Lake County	4	5,000	>356	1961-64	Earth Energy Inc. , Magma Power Co.
7. The Geysers, Sonoma County:					
(a) The Big Geysers	23	5,036	475	1955-62	Magma & Thermal Power Cos.
(b) Sulphur Bank	16	5,127	437	1962-65	"
(c) The Little Geysers	2	3,476	---	1964-65	"
8. Calistoga, Napa County	3	2,000	279	1960-61	Magma & Calistoga Power Cos.
9. Fales Hot Springs, Mono County	1	413	<100	1962	Magma Power Co.
10. Bridgeport, Mono County	1	982	124	1962	"
11. Casa Diablo - Mammoth, Mono County	10	1,063	352	1959-62	"
12. Tecopa, Inyo County	1	422	low	1962	"
13. Randsburg, San Bernadino County	1	722	240	1960	"
14. Arrowhead, San Bernadino County	2	571	234	1963	R. A. Rowan & Co.
15. Salton Sea (Niland), Imperial County	10	8,100	>572	1961-65	O'Neil Geothermal (2), Earth Energy (3), Western Geothermal (2), Shell Oil (2), Imperial Thermal Products (1)

"The Majority Opinion in the *Reich* Case: The Question of Depletion," (Arthur E. Reich and Carolyn G. Reich, et al., Petitioners v. Commissioner of Internal Revenue, Respondent, 52 Tax Court of the United States Reports, July 31, 1969), in *Proceedings: National Conference on Geothermal Energy* (Palm Springs, California, May 10-11, 1973), Volume II, University of California at Riverside, 1973, 283-301.

1. Areas/places discussed x
2. Byproducts ___
3. Costs ___
4. Depletion x
5. Economies of scale ___
6. Energy demand/supply ___
7. Environmental aspects ___
8. Historical aspects ___
9. Legal aspects x
10. Well data ___

Judge Fay's summary:

The petitioners participated in ventures to drill for and exploit geothermal steam. One of these ventures was successful and the resulting wells produced sufficient steam to supply electrical generating plants. One of the petitioners claimed percentage depletion against the gross income it received from steam production in the successful venture. All the petitioners expensed the intangible costs of drilling and developing geothermal steam wells. *Held*, the petitioner which participated in the successful venture is entitled to deduct percentage depletion at the rate of 27 1/2 percent against gross income it received from steam production. *Held*, *further*, all petitioners are entitled to expense the intangible costs of drilling and developing geothermal steam wells.

The Judge's "Ultimate Findings of Fact" were as follows:

The commercial product of the geothermal wells at The Geysers is steam.

Geothermal steam is a gas.

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

In backing up his opinion that geothermal steam is a gas, Judge Fay indicated that,

> "On the basis of the record as a whole, we conclude that in the common parlance of the industries involved herein the term 'gas' includes steam. The testimony of every expert witness in the trial of this case, except Joseph Berman who is an employee of respondent, included references to steam as a 'gas'. Even Berman conceded that other people disagree with his limited use of the term 'gas'. Morever, the tenor of the record as a whole convinces us that people involved on a daily basis in the industries in question think of steam as a 'gas'."

According to the tax laws (Sec. 613), "all other minerals" (but with the exclusion of "water") are entitled to a 15 rather than a 27 1/2 percent depletion allowance. The respondent argued that

> "Since Congress in Section 613(b)(7) specifically denied a depletion allowance of 15 percent to water and did not include it in any other percentage depletion of Section 613 of the Code, it is obvious that Congress did not intend that water existing in the form of steam should be granted the even larger depletion rate of 27 1/2 percent for 'gas wells' by Section 613(b)(1) of the Code."

The Judge's response to this argument was as follows:

We do not agree. We think respondent's argument is based upon a confusion of two ways in which the word 'water' is used. In a chemical sense, 'water' is any substance with the chemical composition of H_2O. Chemically speaking, H_2O has three forms--gaseous, liquid, and solid. Again, speaking chemically, any of these three forms of H_2O is 'water'. In common parlance, however there are separate and distinct words to describe the forms of H_2O: Gaseous H_2O--steam vapor; liquid H_2O--water; solid H_2O--ice.

In respondent's argument, he takes the term 'water' in Section 613 ... to mean H_2O or 'water' in the chemical sense ... We think, however, that the term 'water' in Section 613 ... does not refer to H_2O, or 'water' in the chemical sense. We think it refers to 'water' in the ordinary sense, or liquid H_2O.

The second issue of the <u>Reich</u> case was whether or not the intangible costs of drilling and developing geothermal steam wells are deductible under Section 263(c):

> SEC 263. CAPITAL EXPENDITURES.
>
> (c) INTANGIBLE DRILLING AND DEVELOPMENT COSTS IN THE CASE OF OIL AND GAS WELLS. Notwithstanding subsection (a), regulations shall be prescribed by the Secretary or his delegate under this subtitle corresponding to the regulations which granted the option to deduct as expenses ["expense"] intangible drilling and development costs in the case of oil and gas wells...

Since the product of geothermal steam wells was ruled to be a gas, the Section 263(c) issue was resolved in favor of the Petitioners.

In his dissent, Judge Raum argued that

> "This is depletion run riot ... Regardless of whether steam may be technically regarded as a 'gas', it is at best doubtful that it is so generally considered in common usage ... When one considers that Congress has provided for percentage depletion measured by <u>less</u> than 27 1/2 percent in respect of natural resources other than 'oil and gas wells' and that it has specifically indicated that there is to be no percentage depletion whatever in respect of 'water' [Sec. 613(b)], it seems almost beyond belief that it intended to grant a 27 1/2 percent bonanza for water vapor."

Gofman, John W., "Some Important Unexamined Questions Concerning the Barnwell Nuclear Fuel Reprocessing Plant," Geothermal World Directory (Glendora, California: P. O. Box 997, 1972), 183-190.

1. Areas/places discussed ___
2. Byproducts ___
3. Costs ___
4. Depletion ___
5. Economies of scale ___
6. Energy demand/supply x
7. Environmental aspects x
8. Historical aspects ___
9. Legal aspects x
10. Well data ___

Dr. Gofman is coauthor (with Dr. Arthur R. Tamplin) of Poisoned Power-- The Case Against Nuclear Power Plants (Rodale Press, 1971), is professor of medical physics at the University of California, Berkeley, codiscoverer of U232, Pa232, U233, and is author of 150 articles over a 20-year period.

He examines the question of the possibility of, and the financial liability for, nuclear accidents at the Barnwell facility in South Carolina. According to the Price-Anderson Act, liability for the consequences of a nuclear accident is limited to $560 million. This Act, in the opinion of Dr. Gofman, is unconstitutional because it could mean that 95% of the damages that might occur would carry no financial liability.

Dr. Gofman asks what might be the consequences of a 1% and a .01% (one-ten thousandth) release to the environment of the radioactive inventory at Barnwell. The present summary will consider the implications suggested by Gofman for the .01% release. His attention in this case is focused upon the impact of the deposited radioactivity upon forage upon which cattle feed and whose milk is drunk by children (the "grass-cow-milk-child" pathway). His assumptions are the following:

1. One-ten thousandth of the radioactive inventory is released to the atmosphere at Barnwell, South Carolina.

2. In 24 hours the center of the radioactive "cloud" will be over some agricultural area. The radius of the cloud will be approximately 103 miles and its area 33,400 square miles at the time rainfall is assumed to occur (24 hours after release of

radioactive materials Cs137,Cs134, and Sr90). The results of such a release are, according to Dr. Gofman, as follows:

> "Children drinking such milk [from cows who grazed within the 33,400 sq. miles] would receive 58.4 rads, which is more than 100 times the yearly 'allowable' dose. Such a dose would cause a many-fold increase in cancers and leukemias in such children. It is obvious that milk from these 33,400 square miles is unthinkable for drinking purposes. The loss to agriculture from this and crop contamination would be phenomenal. In time, the Cs134, Cs137, and Sr90 would find their way into the soil, having been weathered off the forage. But the agricultural problem is not over, for we must now consider the crops grown in the area, the so-called 'soil-root pathway'... I would doubt that such agricultural products would be salable, and the effect would last for many years...
>
> "There is little doubt about one primary effect of either type [1% or .01%] of accident, which would be an immediate demand by the public for a shutdown, not only of Barnwell but also of the entire nuclear power industry."

Another problem associated with the Barnwell plant is its production of plutonium. Dr. Gofman feels that "There are several reasons to consider that the plutonium product may be a total nightmare." Besides being a fuel for electric power production, plutonium is the basic ingredient for the home-made fabrication of atom bombs. The 20 kiloton atom bomb that destroyed Nagasaki contained 14 pounds (7 kilograms) of plutonium. In the course of a year, according to Gofman's analysis of the Barnwell Environmental Report, there would be about 125 separate shipments of plutonium out of Barnwell. Each shipment would contain enough plutonium for about 9 Nagasaki-size atom bombs. Dr. Gofman asks

> "Can such shipments be hijacked? Before answering this question, it is worthwhile asking another question. If, two years ago, one had been asked about the likelihood that three huge airliners would be successfully hijacked to the Middle East within one week by terrorists, I am sure the probability estimate would have been vanishingly small. Until it happened. Anyone who <u>underestimates</u> the ingenuity of determined terrorists and underworld operators does so at grave peril. The probability that a plutonium shipment will be hijacked successfully will be estimated as very low until the first shipment is hijacked."

If a 25-kilogram container of plutonium were exploded open near a metropolitan center, there would be a potential 44,000 lung cancers caused thereby:

"That's alot of diplomatic leverage for terrorists. Please note that all the inhalation needn't occur right away. The plutonium oxide particles can settle to the ground,be resuspended and carried by the winds over and over, even to very great distances from the point of original dispersal. With a half-life of 24,000 years, such plutonium will be around to produce cases of lung cancer for periods of more than fifty times as long as world history from the birth of Christ to the present time."

Zeller, Edward J., "The Disposal of Nuclear Waste," *California Geology*, *26* (April 1973), 79-87.

1. Areas/places discussed ___
2. Byproducts ___
3. Costs ___
4. Depletion ___
5. Economies of scale ___
6. Energy demand/supply ___
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Nuclear-reactor generating plants produce radioactive waste materials which must be stored somewhere. At the end of 1972 there were 160 operating or planned reactors in 33 states capable of generating 142,500 MW. These plants produce as a byproduct high level (radioactive) wastes of two types--fission products and transuranium elements.

Most of the fission products have half lives of less than 100 years and emit beta or gamma radiation. Transuranium elements have half lives which are thousands of years in duration and they emit alpha particles as well as beta and gamma radiation.

Some of the fission products are soluble in water and can be absorbed by various organisms such as the shells of marine animals. The author indicates that there is general agreement that nuclear wastes must be completely isolated from all biologic life for at least 250,000 years by preventing them from reaching the atmostphere, surface, and ground waters throughout such a period: "In order to accomplish adequate storage of radioactive wastes the amount of long range planning needed is greater than any previously required in human history."

Seven methods have been proposed for the storage of high level wastes:

1. Rocket transport to the sun or deep space.

2. Utilization of present tank storage indefinitely (but the storage tank lifetime is itself limited and several leakages have already occurred).

3. "Disposal" by placement in deep chambers in granite or basalt.

4. Deep well injection methods.

5. Deposition in subduction zones at edges at continental plates.

6. Deposition under ice caps in polar regions.

7. Salt mine waste storage plan.

According to the author,

> "The following criteria must be met before any method can be given serious consideration:
>
> (1) The wastes must be isolated from all contact with the biosphere for at least 250,000 years.
>
> (2) Sites must be chosen which are proof [fail safe] against sabotage or accidental entry for 250,000 years.
>
> (3) Sites must be safe from the effects of natural disasters, such as earthquakes, floods, tornadoes, and hurricanes.
>
> (4) Sites which are chosen must not prevent the use of large land areas or destroy or contaminate valuable resources.
>
> (5) The sites must be geologically stable to the extent that their integrity is not breached by erosion, faulting, or volcanic eruptions.
>
> (6) Methods must be economically as well as technologically feasible."

None of the proposed methods of storage meets all of these criteria. The author concludes that the problems of nuclear waste disposal have received inadequate attention both in the United States and abroad.

Baxter, R. E. and R. Rees, "Analysis of the Industrial Demand for Electricity," Economic Journal, 78 (June 1968), 277-298.

1. Areas/places discussed ___
2. Byproducts ___
3. Costs ___
4. Depletion ___
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In the case of transportation one could look at the total demand or at the demand for each separate mode of transportation. In the case of energy there are likewise two possible approaches. One could reduce the different fuels to a common measure of "energy" which is an input in the firm's production function. Then the share of each fuel in the aggregate would be estimated in this, the so-called "energy approach."

An alternate approach, and the one used by the authors, is "simply to treat each separate fuel as an input entering into the production function, implying that firms have specific demand functions for each separate fuel."

The outstanding feature of the electricity demand over the period 1954-1964 (quarterly data was used) is that it has grown faster than output in every industry. To account for this Phenomenon, the authors propose two hypotheses:

(1) There has been a substitution of electricity for other fuel inputs and for, possibly, labor because of relative price movements; and

(2) Electricity - intensive technological change has induced the substitution in favor of electricity over other fuel inputs and labor. However, it was not possible to clearly distinguish these two hypotheses on the basis of the empirical results obtained.

On the basis of the best performing regression equations, estimates were made, for each of the 16 industries covered, of the elasticities of electricity demand with respect to production and with respect to relative price of electricity (price of electricity deflated by price index of all other fuels).

The production elasticities for the 16 industries are provided in Table 1 and the price elasticities are in Table 2. Of these 16 industries, the authors have classified the following as being capital-intensive: bricks; chemicals; food, drink, and tobacco; iron and steel; metals, n.e.s.; non-ferrous metals; other manufacturing and paper. The other 8 industries were classified as labor-intensive.

The authors noted that, when industry expenditure on electricity was expressed as a ratio to value of industry output, there did not appear to be any relationship between the importance of electricity as a cost factor and the price elasticities of demand. A possible explanation is a strong complementarity between fuels and capital equipment.

The authors conclude that

> "...relative price changes are not unambiguously an important determinant of growth in industrial electricity consumption. The chief determinants are growth in output and changes in technology. Taken at face value, the results for the relative price variables suggest that in at least nine out of sixteen industry groups price elasticity of demand is zero; in a further two it is relatively inelastic; and in only five does there appear to be a marked responsiveness of demand to relative price changes. This, if valid, would seem to have relevance for current developments in the energy economy. It suggests, for example, that quite considerable changes in relative fuel prices would be necessary to offset even partially the effects of growth in industrial output, so that natural-gas discoveries need not, in a time of economic growth, have a significant effect on electricity's share of the industrial energy market...
>
> "The main conclusion, then, is that electricity demand is highly responsive to changes in output and fuel technology but relatively unresponsive to price."

TABLE 1

ELASTICITIES OF ELECTRICITY DEMAND WITH RESPECT TO PRODUCTION

Industry Group		Elasticity
A.	Statistically Significant	
1.	Food, Drink, Tobacco	2.57
2.	Iron and Steel	1.51
3.	Non-ferrous Metals	1.31
4.	Textiles	1.31
5.	Vehicles	1.22
6.	Other Manufacturing	1.21
7.	Engineering	.94
8.	Chemicals	.82
9.	Paper	.75
10.	Bricks	.72
11.	Metals, n.e.s.	.65
12.	Mining and Quarrying	-1.95
B.	Not Statistically Significant	
1.	Leather and Fur	.30
2.	Timber	.18
3.	Clothing	.16
4.	Shipbuilding	-.62

TABLE 2

ELASTICITIES OF ELECTRICITY DEMAND WITH RESPECT TO RELATIVE PRICE

Industry Group	Elasticity
A. Statistically Significant	
1. Metals, n.e.s.	-2.28
2. Mining and Quarrying	-2.02
3. Textiles	-1.65
4. Paper	-1.08
5. Chemicals	-1.07
6. Bricks	-.74
7. Engineering	-.59
B. Not Statistically Significant	
1. Timber	-3.18
2. Leather and Fur	-2.53
3. Clothing	-2.44
4. Iron and Steel	-2.26
5. Vehicles	-1.43
6. Other Manufacturing	-1.21
7. Shipbuilding	-.90
8. Non-ferrous Metals	-.84
9. Food, Drink, Tobacco	-.42

Houthakker, Hendrik S. and Michael Kennedy, "Demand for Energy as a Function of Price," (Harvard University, Department of Economics, Cambridge, Massachusetts 02138), Paper presented to the American Association for the Advancement of Science, February 1974, 26 pp.

1. Areas/places discussed ___
2. Byproducts ___
3. Costs ___
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The authors criticize the current "deluge of bad economics" by pointing out that "Rarely do we see any recognition that energy, in common with virtually all other commodities, is used in larger volume when it is cheap than when it is expensive." Previous projections of energy demand rising geometrically at 6-7 percent a year through the year 2000 have failed to take into account that, although the energy-GNP ratio has been rising, real energy prices (energy prices relative to other prices) have been falling for the past 15 years, until just recently.

The authors' empirical results are based on a dynamic flow-adjustment model of demand. Desired demand for a particular product (q^*) depends upon income (y) and price (p):

(1) $q^* = f(y, p)$.

The functional form chosen is the log-linear:

(2) $q^* = \alpha y^{\beta} p^{\gamma}$,

which may be regarded as a first order Taylor series approximation of

(3) $\ln q^* = \ln f$.

With this specification, β and γ are, respectively, the income and price elasticities.

Actual demand adjusts toward desired demand gradually:

(4) $q/q_{-1} = (q^*/q_{-1})^{(1-\lambda)}$,

where q_{-1} is last period's consumption.

The estimating equation is obtained by substituting (4) into (2):

$$\ln q = \ln a + (1-\lambda)\beta \ln y + (1-\lambda)\gamma \ln p + \lambda \ln q_{-1}. \tag{5}$$

The long-run elasticities of demand are β and γ and the short-run price and income elasticities are $(1-\lambda)\gamma$ and $(1-\lambda)\beta$, respectively.

The flow-adjustment model has been applied to 2 sets of U.S. data (demand by consumers for gasoline and residential electricity) and to 4 sets of O.E.C.D. data (demand for gasoline, kerosene, distillate fuel oil, and residual fuel oil). The U.S. data results will be discussed below.

The gasoline demand function was based on quarterly data for 48 states over the period 1963-1972 and the following equation resulted (standard errors in parentheses):

$$\ln q = .593 + \underset{(.017)}{.303} \ln y - \underset{(.013)}{.075} \ln p + \underset{(.019)}{.696} \ln q_{-1}$$

$$R^2 = .92$$

Elasticities:

	Short-run	Long-run
Price	-.075	-.24
Income	.303	.98

The speed of adjustment coefficient value of $\lambda = .696$ indicates a "rather sluggish response of demand to changes in price and income, which is consistent with the long life of automobiles, the main gasoline using equipment... the price elasticity of -.24 indicates that an increase in the pump price of gasoline from 40¢ to 80¢ should decrease demand about 15% in about two years. This is precisely the magnitude of the gasoline shortage now quoted in Washington."

The residential electricity demand equation was based on annual data for the states over the period 1961 to 1971:

$$\ln q = .072 + \underset{(.026)}{.143} \ln y - \underset{(.020)}{.089} \ln p + \underset{(.015)}{.913} \ln q_{-1}$$

$$R^2 = .99$$

Elasticities:

	Short-run	Long-run
Price	-.089	-1.0
Income	.143	1.6

Based on this equation, the authors conclude that "we can confidently predict that the growth of electricity consumption will slow down markedly in the coming years."

All of the four OECD energy equations reveal that price is an important factor in the demand for energy.

The authors suggest that they have found "strong evidence for the influence of price on gasoline consumption, other things being equal... [evidence which] lays to rest the idea that Americans drive big cars because of advertising pressure or other psychological factors. Americans drove big cars because gas was cheap, and now that gasoline is becoming more expensive they are rapidly changing the pattern."

Wilson, John W., "Electricity Consumption: Supply Requirements, Demand Elasticity and Rate Design" (6425 Belleview Drive., Columbia, Maryland 21046), Paper presented at Annual Meeting of the American Economic Association, New York, December 1973, 28 pp.

1. Areas/places discussed ___
2. Byproducts ___
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The author discusses both residential and nonresidential power consumption. In 1970 the residential use of electricity in the United States (large cities) was 6,367 kWh per household, an increase of 45 percent over the 1965 value; the 1950 value was 2,000 kWh per residential unit. This increase has been partly due to new products (air conditioners, television sets, clothes dryers, and dishwashers) and partly due to shifts to electricity from other fuels in space heating, water heating, and cooking. Over the 20-year period personal incomes rose considerably and the price of electricity fell.

The author's Table 1, reproduced below, indicates annual electric energy requirements for major household appliances and equipment. Table 2 reveals that saturation levels have not yet been reached for most of these appliances and equipment.

Nonresidential electricity consumption accounts for approximately two-thirds of total electricity demand. Manufacturing industries, in turn, account for close to two-thirds of the nonresidential electric power consumption. There is considerable variation across industries and the author provides estimates of the electricity and total energy intensiveness of 201 industries.

The results for a sampling of these industries is reported in Table 3 below. As can be seen, there is considerable leeway for additional electricity consumption by most of the industries shown in Table 3. Over the period 1962-1972, the average annual growth rate of nonresidential and residential electric energy sales (measured in kWh) has been 6.8% and 8.5%, respectively. These rates of increase are expected to decline by 1990 (per <u>Electric World</u>, September 15, 1973) to 6.5% and 7.1%.

TABLE 1

ANNUAL ELECTRIC ENERGY REQUIREMENTS

Type of Equipment	kWh Per Year
Electric Space Heating	16,003
Electric Water Heating	4,219
Central Air Conditioning	3,600
Frostless Refrigerator (14 cu. ft.)	1,829
Frostless Food Freezer (15 cu. ft.)	1,761
Window Air Conditioner	1,389
Food Freezer (15 cu. ft.)	1,195
Electric Range	1,175
Refrigerator (14 cu. ft.)	1,137
Electric Clothes Dryer	993
Color Television	502
Dishwasher	363
Black and White Television	362
Clothes Washer	103

TABLE 2

INCIDENCE OF RESIDENTIAL ELECTRIC EQUIPMENT
(PERCENTAGE OF HOUSING UNITS WITH SPECIFIED EQUIPMENT)

	U.S.	
Type of Equipment	1960 (%)	1970 (%)
Clothes Washer	73.7%	71.1%
Electric Cooking	30.8	40.6
Air Conditioning	12.4	35.7
Electric Clothes Dryer	11.9	29.4
Two or more T.V. sets*	9.9	28.7
Food Freezer*	18.4	28.2
Electric Water Heating	20.4	25.4
Dishwasher	--	18.9
One room air conditioner	7.6	17.8
Central Air Conditioning	1.9	10.7
Electric Space Heating	1.8	7.7
Two or more room air conditioners	2.9	7.2

*Saturation levels are close to 100% for refrigerators and one T.V. set.

TABLE 3

INDUSTRIAL ENERGY REQUIREMENTS

SIC Code	Industry Description	Electricity*	Total Energy**
2061	Raw cane sugar	.78	23.54
2062	Cane sugar refining	.22	29.69
2063	Beet sugar	.52	101.18
2211	Weaving mills, cotton	4.23	10.52
2221	Weaving mills, synthetic	3.80	8.83
2421	Sawmills and planing mills	2.11	11.97
2491	Wood preserving	.70	23.23
2621	Papermills, except buildings	5.42	63.21
2871	Fertilizers	4.96	30.59
2911	Petroleum refining	3.68	83.14
3241	Cement hydraulic	9.23	169.30
3251	Brick and structural tile	10.75	119.68
3271	Concrete block and brick	3.04	21.41
3273	Ready mixed concrete	.48	17.38
3315	Electrometallurgical products	40.64	105.98
3323	Steel foundries	2.63	21.79
3444	Sheet metalwork	.51	3.94
3552	Textile machinery	.72	4.14
3573	Electronic computing equipment	.47	1.07
3711	Motor vehicles	.78	4.58
3731	Shipbuilding and repairing	.81	2.87

*Purchased kilowatt-hours per dollar of value added by manufacturing.

**Quantity of electric energy and the kilowatt-hour equivalent for all fuels used for heat and power per dollar of value added by manufacturing.

The author has used 1962 and 1963 SMSA industrial electricity power consumption data (reported in the 1963 Census of Manufactures) for each of 15 SIC two-digit industry groups in order to estimate price elasticities and to see if there is a relation between this elasticity and the electric-energy-intensiveness of the industry (there is). These results are summarized in Table 4.

Table 4 reveals that the price elasticity is significant in 12 of the 15 industries. It is insignificant only in printing, rubber and plastics, and petroleum and coal products.

TABLE 4

Two-digit Industry	Price Elasticity	kWh/V.A.*
Chemicals	-2.23	8.39
Primary Metal	-1.51	6.34
Petroleum & Coal Products	**	5.44
Paper & Related Products	-1.48	5.28
Textile Products	-1.22	2.65
Stone, Glass, & Clay	-1.08	2.61
Rubber & Plastics	**	1.69
Lumber Products	-1.64	1.48
Food Products	-1.09	1.01
Transportation Equipment	-1.01	.90
Electrical Machinery	-1.76	.78
Machinery	-1.16	.67
Furniture	-.97	.62
Leather Products	-.76	.49
Printing	**	.38

*number of kilowatt-hours consumed per dollar of value added.

**price elasticity not statistically significant.

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