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SURVEY REPORT: STUDY OF INFORMATION/EDUCATION DISCUSSIONS WITH PRIVATE INDUSTRIES AND PUBLIC INSTITUTIONS ON THE DIRECT-HEAT UTILIZATION OF GEOTHERMAL ENERGY

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Publication Date
1977-03-01

520
5-18-77

DR-1019

LBL-5988
UC-66G
TID 4500-R65

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Energy and Environment Division

SURVEY REPORT: Study Of Information/Education Discussions With Private Industries And Public Institutions On The Direct-Heat Utilization Of Geothermal Energy

James V. Davey

March 1977

Lawrence Berkeley Laboratory University of California/Berkeley

Prepared for the U.S. Energy Research and Development Administration under Contract No. W-7405-ENG-48

LBL-5988

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Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy $4.00; Microfiche $2.25

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SURVEY REPORT

STUDY OF INFORMATION/EDUCATIONAL DISCUSSIONS WITH PRIVATE INDUSTRIES AND PUBLIC INSTITUTIONS ON THE DIRECT-HEAT UTILIZATION OF GEOTHERMAL ENERGY

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March 1977

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Abstract

This summary is the result of a four-month study of private and public institutions' response to the proposed use of geothermal energy in the form of direct heat. This heat energy is to be used as an alternate or supportive source for their process or other heat requirements.

The summary includes information from over 75 personal contacts with firms in several categories (see Reference Group I). No attempt is made to reference specific data to any particular company. Although not necessarily confidential, some financial information concerning energy costs to profits was considered sensitive and is respected as such. The companies contacted have been incorporated into the East Mesa Test Facility mailing list. The companies contacted are in several categories, as follows:

- Food processing — canning, drying, dehydration
- Chemicals
- Paper/wood-pulp processing
- Food machinery
- Horticulture
- Dairy

The area covered in the study was from Seattle, Washington to San Diego, California, during mid-1976. Industry's response varied from mild interest, as with corporations that had little or no knowledge of geothermal energy (and regard it as a new unproven science), to enthusiastic from corporations that employ their own energy departments. These enthusiastic corporations recognize the future energy crisis in fossil fuels and are seeking alternatives. However, geothermal science is still fairly vague.

The study clearly indicated the important areas of need for aiding the development of this valuable resource. Those needs are:

- An intense basic educational/promotional program.
- An operating demonstration project (industrial park) to prove economic feasibility and instill confidence in the potential of geothermal energy.

Goals

The goals of the study were threefold.

- Introduce to the private and public industrial sector the Energy Research and Development Administration's East Mesa Component Test Facility, make its availability known, its potential usefulness and capabilities, its location, its costs to the user, and arrange for its use. This facility was established by ERDA specifically to assist the rapid commercialization of the geothermal energy potential.

- Present a basic introductory program on geothermal energy and the role this energy can play in non-electric applications. Present a review of the economics of a single production well (Reference Group IV) and discusss specific areas of interest. Since the electric industry has considerable activity in the geothermal field, the emphasis was placed on the potential non-electric field that might benefit from an introduction to geothermal.

- Outline Lawrence Berkeley Laboratory's assistance programs in the geothermal sciences. These include not only operation of the geothermal component test facility but also the current "in house" geothermal research programs, the National Geothermal Information Resource (GRID) program, and the Technology Utilization Program.

Approach

An introductory program and a 35-mm slide presentation were assembled. A review of several current geothermal reports and contacts with several related agencies aided the investigation in obtaining the broadest coverage, and targeted the heat-intensive industries (Reference Group II).

Cooperation of several business publications in related fields was helpful in reaching each sector. Published articles proved to be ice breakers for some initial contacts (Reference Group III).

Discussion

The industries contacted, as a whole, know their present energy requirements and costs very well. The potential use of geothermal energy is almost unknown. At best it is known in relation to steam-powered electrical generating plants (The Geysers).

Many industries are aware of solar energy. Solar-energy sales and promotional effort are well advanced, compared to geothermal energy.

The major areas covered during discussions were:

- Defining the hydrothermal systems. Particular emphasis was placed on the scarcity of vapor-dominated (steam) systems, as compared with the relative abundance of liquid-dominated systems in the low-to-moderate temperature range (up to 200°C).

- The vast amount of energy available in the < 200°C range.

- A brief explanation of geo-pressured and hot-dry rock systems and their present state of the art. Geo-pressured development was of interest to large land owners with holdings in the Gulf states.

- The geographic locations of surface manifestations of geothermal energy as shown on existing maps. These surface expressions are only indicators, but are significant enough to warrant further surface and possible subsurface investigation. The maps were used mainly to demonstrate the abundance and general locations of geothermal energy sources.

- The existing exploration techniques, such as resistivity, magneto-tellurics, seismic, geo-chemistry, or the combination of some or all to lend confidence to site selection or pre-drilling effort.

- The efficiency of direct-heat utilization methodologies.

- Presenting the economics of a single geothermal production well (Reference Group IV).

- Pointing out that direct-heat applications have fewer technical problems and can be made to work today, with existing hardware and engineering. They offer lower risks, which means lower development costs.

- The approach to initiate an investigation into possible locations. Public agencies, existing reports, commercial investigators, and laboratory assistance.
- The additional bonus of the opportunity to develop new industries in areas of economic need, as well as an opportunity to decentralize congested urban areas.
- Problems: geothermal energy is site-dependent, and obviously isn't the answer to all heat requirements. However, for future expansion, plant replacement, or new development, it has great potential.
- Emphasize the need for private industry to initiate its own geothermal development and outline Lawrence Berkeley Laboratory's assistance role.

Study Findings

The heat-intensive industries are, or have been, using natural gas or fuel oil. Of those on natural gas, many are on interrupted service and are presently converting to fuel oil, or are planning to do so. Private industry has invested many dollars and many hours of effort to improve its energy consumption and are well aware of energy costs as a factor of production costs. Reducing energy consumption within their current operations has taken the forefront of the efforts of many. Money is not readily available for research and development and new ventures are considered risky and expensive. Industry almost without exception considers geothermal energy as a relatively new science that needs government support to exploit.

To again emphasize the importance of a basic educational/promotional program, and present the general attitude of private industry, the following is a review of some typical queries that were received many times during the discussions:

- What is geothermal energy?
- Is it always in the form of steam?
- Do you use it in those panels on the roof?
- How hot is the water?
- Isn't it full of minerals and junk?

- Is it located everywhere?
- How do we find it?
- Do you find it for us?
- How do we use it in our process?
- What does it cost?
- How do we start?

These questions, and many more, are not intended to introduce humor to this report, but rather to point to the areas of need if the development of direct-heat utilization of geothermal energy is to proceed.

Study Data by Industry

Agriculture

As an energy consumer, the agriculture business is high on the list and is a good candidate for alternative energy. The operation, transportation, and processing of agricultural products used over 5.1% of the total energy consumed in the state of California during 1972, and has been increasing yearly (equivalent to nearly 40 million barrels of oil annually). Of that total, 53.1% is natural gas use. Table I shows the energy use (in declining order) for the most heat-intensive crops.

TABLE I. Energy Use for the Most Heat-Intensive Crops

	Category			
Energy source	Field crops	Vegetables	Fruits & nuts	Livestock
Natural gas	Sugarbeets	Tomatoes	Grapes	Dairy
Electricity	Cotton	Tomatoes	Grapes	Dairy
Diesel fuel	Cotton	Tomatoes	Grapes	Dairy
Gasoline	Alfalfa/Hay	Tomatoes	Grapes	Dairy
LP gas (propane)	Cotton	Tomatoes	Almonds	Dairy

Figures 1-3 and Tables II and III show the proportion of energy consumed, its distribution, and requirements in units and equivalent barrels of oil for the state of California (Reference Group II, "Energy Requirements for Agriculture in California — Joint Study").

TABLE II. Energy Requirements for Agriculture in California, 1972

Category	Natural gas (therms)	Electricity (kWh)	Diesel fuel (gal)	Gasoline (gal)	LP Gas propane butane (gal)	Aviation fuel (gal)
	Energy Source (millions of units)					
Field crops	364.784	464.681	96.400	19.477	2.381	--
Vegetables	165.999	358.193	38.792	25.031	4.441	--
Fruits and nuts	127.168	410.773	26.158	12.602	3.296	--
Livestock	107.111	1,460.966	46.443	7.813	12.261	--
Irrigation	40.618	7,177.441	6.531	0.487	4.521	--
Fertilizers	305.748	579.362	6.738	3.529	1.114	--
Frost protection	--	40.501	60.003	6.854	0.904	--
Greenhouses	102.700	83.427	--	--	--	--
Agricultural aircraft	--	--	1.072	1.607	--	8.994
Vehicles (farm use)	--	--	10.447	117.798	--	--
Others	--	--	--	--	23.711	--
TOTAL	1,214.128	10,575.344	292.584	195.198	52.629	8.994

TABLE III. Energy Requirements for Agriculture in California, 1972 (in equivalent 1,000,000 barrels of crude oil).

Category	Energy Source (1,000,000 barrels of crude oil)						
	Natural gas	Electricity	Diesel fuel	Gasoline	LP Gas propane butane	Aviation fuel	Total
Field crops	6.289	0.273	2.327	0.416	0.039	--	9.344
Vegetables	2.862	0.211	0.936	0.535	0.072	--	4.616
Fruits and nuts	2.192	0.242	0.631	0.269	0.054	--	3.388
Livestock	1.847	0.859	1.121	0.167	0.199	--	4.193
Irrigation	0.700	4.220	0.158	0.010	0.072	--	5.160
Fertilizers	5.271	0.341	0.163	0.075	0.018	--	5.868
Frost protection	--	0.024	1.448	0.147	0.015	--	1.634
Greenhouses	1.771	0.049	--	--	--	--	1.820
Agricultural aircraft	--	--	0.026	0.034	--	0.192	0.252
Vehicles (farm use)	--	--	0.252	2.518	--	--	2.770
Other use	--	--	--	--	0.387	--	0.387
TOTAL	20.932	6.219	7.062	4.171	0.856	0.192	39.432

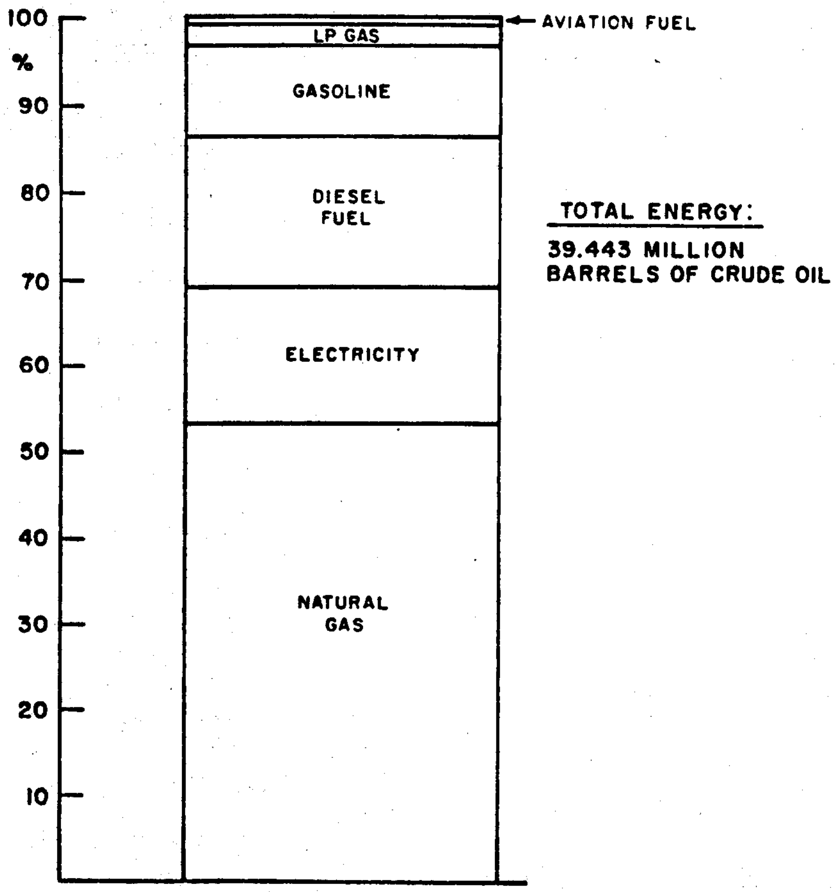

Figure 1. Proportion of required energy sources in California agriculture (1972).

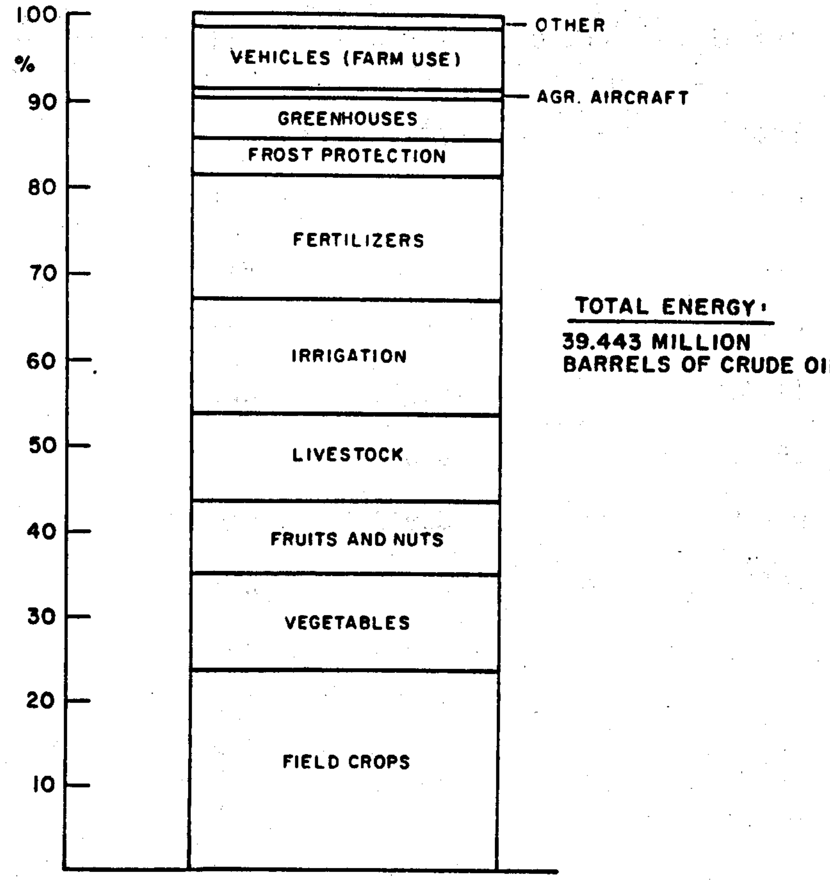

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Figure 2. Proportion of energy as consumed by various sectors in California's agriculture (1972).

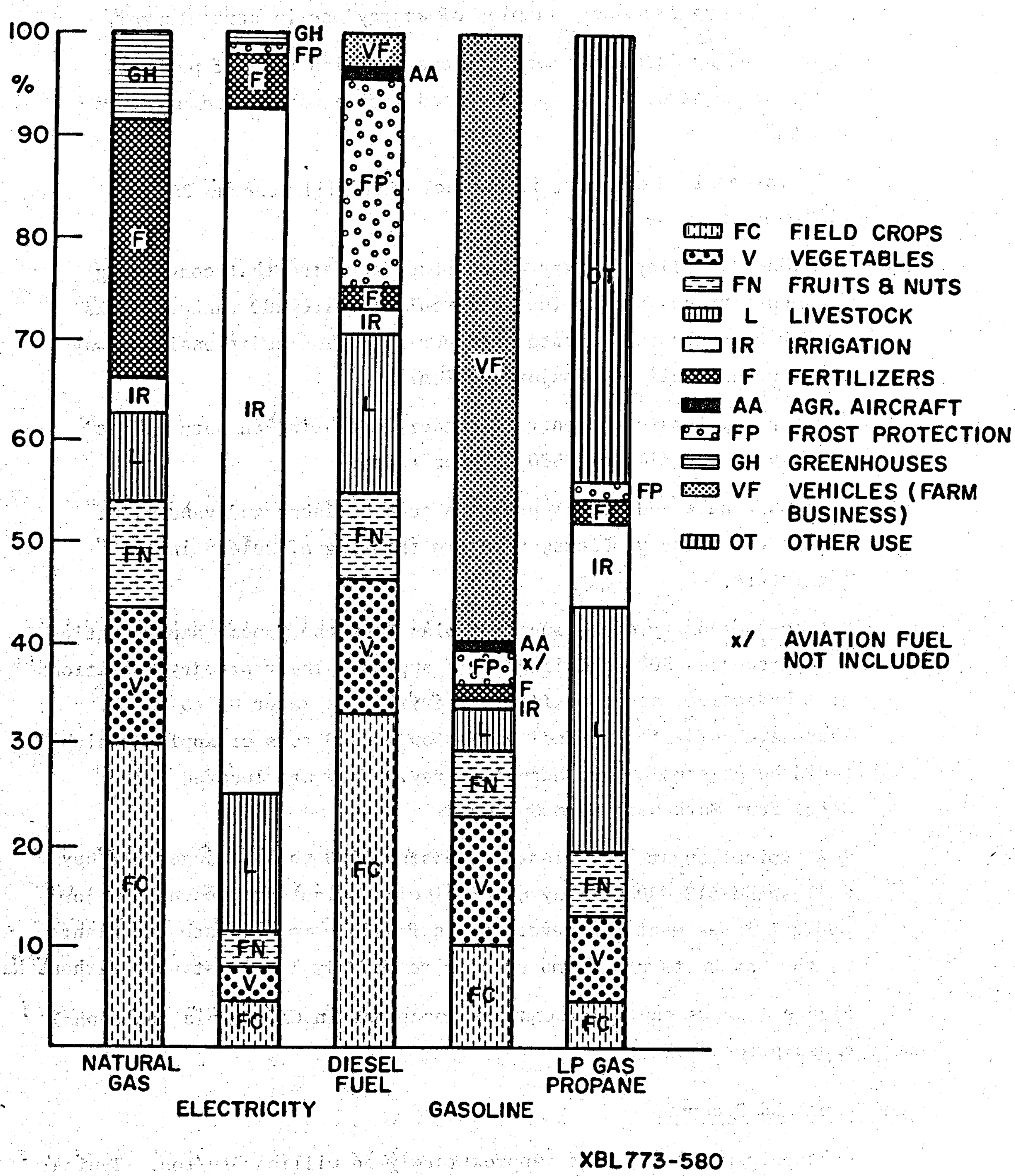

Figure 3. Distribution of energy requirements in California's agriculture (1972).

The following are some examples of energy use in agriculture:

- The canning industry processes one trillion cans of products per year, most of which is processed with a maximum temperature of 250°F.

- A medium-sized cannery, if on fuel oil, will consume 2500 gallons of oil per day.

- A central valley cannery co-op study revealed that converting from current gas use to fuel oil would require 200 tanker trucks moving oil into the Modesto area per day. The additional highway load would itself be a major problem.

- A typical tomato-concentrate cannery operating on natural gas can have a gas bill of $500,000 per month.

- Canners have additional problems such as labor and vandalism. In view of these problems, some are thinking of relocating in the future.

- A co-op cannery operating four plants in the Sonoma-Napa counties area processes 50% of California's apples. Their primary operations of dehydration, sauce making, and drying use water up to 150°F. They have cold-storage facilities for 10,000 tons of apples, which could be powered by geothermal energy. They are located 7-10 miles from Mark West Warm Springs.

- A typical sugar beet plant processing 5000 tons of sugar per day will spend $12,000 per day for fuel oil. Plants represent a major capital investment. However, it is feasible to relocate the plants, as the raw beets can be moved over relatively long distances without harm.

Figure 4 shows the major cannery locations in California and annual energy consumption (1974).

Paper Pulp/Wood Products

Wood-pulp processing uses approximately 36 million Btu/ton. Typical operations use direct heat in the range of 350°F down to drying at 150°F. One major corporation spent $243 million on energy for 1975. Of this total, $103 million was out-of-pocket cost with $140 million replaced by burning waste products (bark-chips-dust).

Area	Natural Gas (Therms)	Boiler Fuel Oil (Gallons)	Electricity KWh
1	11,960,868	7,016	24,145,011
2	13,414,239	661,863	20,349,123
3	36,268,267	196,518	63,345,470
4	41,398,229	199,788	60,144,729
5	22,946,676	30,661	35,484,170
6	21,640,392	49,498	31,175,360
7	59,129,315	230,545	64,984,685
TOTALS	206,757,986	1,375,889	299,628,548

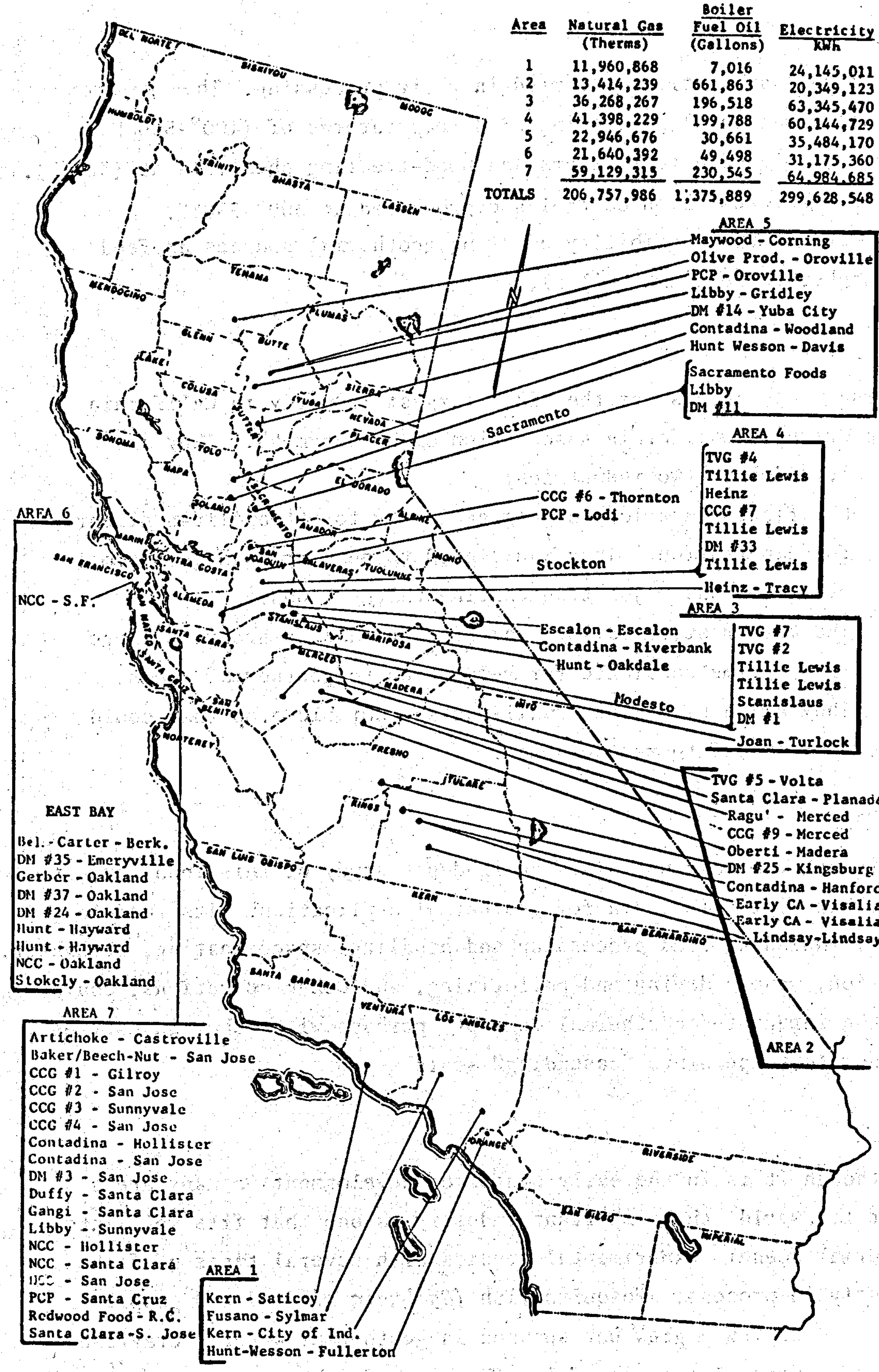

Figure 4. Major cannery locations in California and annual energy consumption (1974). (Reference: Canners League of California, 1007 L Street, Sacramento, California).

Chemicals

Chemicals are extremely varied in their processing. They go from fatty-acid (animal fats) processing with temperatures of (400°-500°F at 300-400 psi), to garden fertilizers and wood-treating chemicals at (320°F). Catalysts for auto-emission control are processed at 300°-350°F. However, there is the possibility of using geothermal sources as feed water to higher-temperature boilers.

Horticulture

Nursery operations are the ninth largest industry in California (Reference Group I, California Association of Nurserymen). They are primarily divided into two industries:

a. Cut flowers are locked geographically to metropolitan airports for exportation. They would need to be near both geothermal resources and major transcontinental airlines.

b. The bare-root, seedling, and seed operations are very large and a prime candidate for relocation to geothermal areas. They are a high-cost, small-package durable crop that could lend itself to remote areas.

Dairy Industry

Although time did not allow an in-depth study of this industry, it is a major heat-intensive area for geothermal application. Its feed-lot operations, including feed processing and handling, space heating, slaughter, refrigeration, manure drying and pelletizing, and other operations, could fit into the integrated geothermal concept, perhaps with other industries on the moderate-temperature "cascading" scale.

Aquaculture

Although it is in the early stages of development in many areas throughout the world, this important industry is one that fits well into the geothermal scene. Experimental studies with several types of fish are currently in process. Mosquito fish *(Gambusia allins)* and guppies *(lebister SA.)* not only grew but spawned in geothermal water. Crayfish *(cambaras sp.)* were also successful. The giant freshwater prawn *(macro-brachium rosenbergii)* was chosen as the best to use to develop a technology for aquaculture using geothermal water. It has been successfully cultured in the Orient since 1969. Today it is being raised in ponds in Florida, Hawaii, California, and Puerto Rico, and the warm effluent water from electrical power plants in New Jersey and Nevada. These prawns are in great demand and bring $5.00 per pound wholesale in Honolulu. The United States imports over one million pounds a year. Early studies at Oregon Institute of Technology indicate by visual observations that the prawns doubled in size in less than one month's time. Optimum water temperature is 27.6°C (79.9°F) (see Geo-Heat Quarterly Bulletin, July 1976).

Other

As geothermal development occurs, other industries that require direct heat for their product or process, or fill-in "seasonal operational" gaps, will fit into the developing scheme. Freeze-drying, hospital equipment sterilization, cosmetics, and many more not encountered in this study will surface.

Summary

As evidenced at the many conferences, meetings, and technology exchanges *within* the geothermal community, it is certain that this energy resource can be developed. The geothermal community is hard at work solving the scientific and technical problems for sophisticated systems that go beyond the temperature-range development covered by this report.

As emphasized in the findings of this report (page 4), an equally important task is that of reaching *outside* the geothermal community into the private sector to educate, stimulate, and disseminate this knowledge.

There are other factors that would enhance the economics in favor of geothermal development:

- Possible depletion allowance
- Possible intangible drilling cost expense
- Investment tax credit

Recognizing the need for stimulation to aid geothermal development, some suggested areas of effort to help meet the development goals would be:

- Effort through the media to reach the public (grass-roots level).

- More local- and state-level support for all stages of development.
- Public (and private) funding for actual "showcase" demonstration operations.

Reference Group I

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Reference Group II

"Assessment of Geothermal Resources of the United States," D. E. White and D. L. Williams, Eds., Geological Survey Circular No. 726 (1975).

California Agriculture, California Principle Crop and Livestock Commodities, Department of Food and Agriculture (1975).

Dairy Institute of California, Sacramento.

Director of Nurserymen, State of California, Department of Food and Agriculture.

"Energy Requirements for Agriculture in California — Joint Study," California Department of Food and Agriculture, University of California, Davis (January 1974).

"Energy Resources of Washington," Information Circular No. 50, Vaughn E. Livingston, Jr., State Geologist.

"Guide to Energy Conservation for Food Service," Federal Energy Office.

B. Kaysing, Great Hot Springs of the West, Capra Press, Santa Barbara, California (1974).

J. F. Kunze and A. S. Richardson, "Idaho National Engineering Laboratory National Program Definition Study for the Non-Electrical Utilization of Geothermal Energy," (June 1975).

"Multipurpose Use of Geothermal Energy," Oregon Institute of Technology, Paul J. Lineau and John W. Lund, Eds. (October 1974).

National Canners Association Bulletin 26L.

"Present Status and Future Prospects for Nonelectrical Uses of Geothermal Resources," J. H. Howard, Ed., UCRL-51926 (October 1975).

Proceedings of Conference on Research for the Development of Geothermal Energy Resources, September 23-25, 1974, Jet Propulsion Laboratory/ California Institute of Technology, Grant AG-545.

Gordon M. Reistad, "Analysis of Potential Nonelectrical Applications of Geothermal Energy and Their Place in the National Economy," UCRL-51747 (February 1975).

"Susanville Geothermal Energy Project Workshop Proceedings — Final Technical report," James Jeskey, Program Manager, Alfred B. Longyear, Principal Investigator, City of Susanville (July 1976).

"A Technology Assessment of Geothermal Energy Resource Development," Futures Group for National Science Foundation (April 1975).

Gerald A. Waring, "Thermal Springs of the United States and Other Countries of the World — A Summary," Geological Survey Professional Paper 492.

Reference Group III

"Ag-Alert," published by California Farm Bureau Federation, Don Fitzhugh, Managing Editor, article in 4th Quarter, 1976.

"The Farmers Corner," Leland H. Ruth, Executive Vice President, Agricultural Council of California, Calvin E. Adams, Director of Programs, News Service, P.O. Box 1712, Sacramento, California (May 27, 1976).

Canners League of California, James W. Bell, President, Sacramento, Mailing List of California Canners.

"Geothermal Heat Potential," in California Farmer, Jack T. Pickett, Editor, San Francisco (June 19, 1976).

"National Geothermal Test Center Opened," in UC Clip Sheet, Wallace Bryant, 52, No. 20 (January 11, 1977).

"Will U.S. Geothermal Resources Win a Role in Process Plants," in Chemical Engineering, Nicholas R. Immartino, 83, No. 24, p.79 (1976).

Reference Group IV

Economics of a Single Production Well

At the onset of this study, each industry's total heat requirements were unknown. In an attempt to cover large and small industries, it was felt that a look at the economics of a single production well would offer ball park figures.

Recognizing that technological development (down-hole pumps and other hardware) could result in higher or lower costs, the numbers are considered subject to change. Other factors, such as depletion allowance for geothermal development, are not included. However, the changes would not significantly alter the economics.

It is considered that the economics presented here are conservative, and current rising fuel costs would enhance the favorable economics of the geothermal role.

ENERGY ECONOMICS FOR ONE GEOTHERMAL PRODUCTION WELL

1. Production Well Cost

   \$100/ft × 5000 ft = \$500,000

   (Amortized for 20 years @ 10% interest)

   $$\$500{,}000, \left[\begin{matrix} 0.1 & (1.1)^{20} \\ (1.1)^{20} & -1 \end{matrix}\right]$$

   \$500,000 (0.1175) ≅ \$58,730/yr

2. Additional Wells Drilled

   - Success ratio in a proven area (1 in 2)
   - One replacement well in 20 years
   - Use dry well for injection

   2(\$58,730) = \$117,460/yr

3. Pump-Down Hole

   - Pump cost \$50,000

   (Amortized for 5 years @ 12%)

   \$50,000 × 0.2774 ≅ \$13,870/yr

   - Pumping power cost

   (Use turbine drive from geo-heat) = \$ 0/yr

4. Pump Injection

   - Pump cost \$30,000

   \$30,000 × 0.2774 = \$ 8,320/yr

   - Pumping power costs = \$ 3,000/yr

5. Piping Costs

   Assume \$40/ft for pipe

   1-well/20 acres — 16 wells

   Mean distance to a well — 1375'

   \$40 × 1375' × 2* = \$110,000

   (Amortized for 20 years @ 10%)

   \$110,000 × 0.1175 = \$12,920/yr

*One production well, one injection well

6. Operation and Maintenance

Assume 5%/yr of well cost

0.05 × \$500,000 ≅ \$25,000/yr

7. Insurance

Assume 1%/yr of well cost

0.01 × \$500,000 ≅ \$ 5,000/yr

8. Lease Royalties

Assume 10% of yearly energy value

0.10 × \$250,000 = \$25,000/yr

9. TOTAL Yearly Costs = \$269,300/yr

10. Process Heat Exchanger

Assume transfer of 180°C (356°F) down to 100°C (212°F).

Yields 148 Btu/lb available (across heat exchanger)

11. 148 Btu/lb (200,000 lb/hr/well) × (8760 hr/yr) × (0.70 capacity) = 182,000 MBtu/well/yr (1 MBtu = 1×10^6 Btu)

12. 269,300/yr ÷ 182,000 MBtu/yr =

- Cost of geothermal energy = \$ 1.48/MBtu
- Imperial Valley existing KGRA (known geothermal resources area)

Fuel Oil Comparison

(\$12/bbl ÷ 5.8 MBtu/bbl) =	\$ 2.07/MBtu
(\$2.07/MBtu) ÷ (0.80 boiler efficiency) =	\$ 2.59/MBtu
(\$2.59/MBtu) × (182,000 MBtu/yr) =	\$470,690/yr

Natural Gas Comparison

(\$0.15/100,000 Btu(therm)) $\left(\frac{10\ \text{therms}}{\text{MBtu}}\right)$ =	\$ 1.50/MBtu
(\$1.50/MBtu) ÷ (0.80 boiler efficiency) =	\$ 1.88/MBtu
(\$1.88/MBtu) × (182,000 MBtu/yr) =	\$341,250/yr

Energy Expenditures per well for 20 years
(escalation per year @ 7%)

• Fuel oil	\$20.6 Million
• Geothermal	\$ 6.8 Million
• Savings	\$13.8 Million/well
• Natural gas	\$15.0 Million
• Geothermal	\$ 6.8 Million
• Savings	\$ 8.2 Million/well

Acknowledgments

The author would like to thank the many private business leaders and the private, state, and Federal agencies mentioned in this report. Without exception they all gave their complete cooperation as well as their candid opinions that gave direction to this survey. It is our hope that further thanks will be in the rewards shared by all in the development of geothermal power as an alternative or supportive energy source that can absorb a significant fraction of our future energy needs.

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