5701

THE USE OF GEOTHERMAL ENERGY FOR BIOMASS-BASED ETHANOL PRODUCTION

Debra W. Struhsacker

Earth Science Laboratory
University of Utah Research Institute
Salt Lake City, Utah 84108

INTRODUCTION

Biomass-based ethanol fuel production converts a low-grade energy form such as surplus and waste farm products into a valuable, transportable liquid fuel. The ethanol generating process is energy intensive, requiring temperatures in excess of 100°C (212°F). The substitution of low-cost hydrothermal geothermal energy for more expensive conventional fuels is one way of reducing the energy costs of biomass-based ethanol production.

The suitability of a geothermal resource as the heat source for an ethanol facility depends upon the resource characteristics (temperature, flow and exploration status), availability of a local source of biomass feedstock, existence of a local market for the ethanol and by-products, and the institutional logistics associated with development of a given site. This paper suggests some geothermal systems with resource characteristics potentially suitable for an ethanol generating facility. In addition, a consideration of biomass availability and institutional parameters at selected geothermal resource sites is included.

ETHANOL PRODUCTION

The biomass-based ethanol generating process converts the sugar present in the feedstock into alcohol through fermentation. Depending upon the type of feedstock utilized, certain chemical and mechanical steps are necessary prior to fermentation. There are three common types of feedstocks: sugar crops, starch crops, and lignocellulosic residues.

Ethanol production from starch crops such as corn, sorghum, wheat, barley, potatoes, and sweet potatoes requires the breakdown of carbohydrate molecules to a simple sugar before fermentation can occur. Starch crop feedstocks must first undergo mechanical milling or grinding which breaks the walls of the starch molecules. The next step is the liquifaction process which introduces water into the starch molecules through an hydrolysis reaction. Following the liquifaction process is the saccharification process during which the starches in the feedstock are converted into simple sugars (dominantly glucose) by the addition of enzymes and heat. Once the starch in the feedstock has been reduced to a sugar, yeast is added and the fermentation procedure begins. In the final step, distillation, water and ethanol are separated from each other. The treatment of lignocellulosic feedstocks such as crop residues and forage crops is similar to that for starch crop feedstocks, and involves the breakdown of starch molecules into sugar prior to fermentation. Ethanol production from sugar crops such as sugarcane, sugar beets, sweet sorghum and Jerusalem artichokes is much simpler. The liquifaction and saccharification processes are unnecessary since the carbohydrate in sugar crops already exists as a sugar (SERI, 1980).

RESOURCE CHARACTERISTICS

Temperature Requirements. Certain phases of biomass-based ethanol production require a relatively high-temperature heat source. During liquifaction, a temperature of about 93°C (200°F) must be maintained for 2-1/2 hours (SERI, 1980). Shorter liquifaction process times can be achieved at higher temperatures (K. W. Jones, written communication). The distillation process requires temperatures in excess of 100°C (212°F) to allow distillative separation of the ethanol and water. The temperature requirements for the different ethanol production phases are summarized in Table 1.

Table I. Temperature Requirements During Ethanol Production (SERI, 1980).

Process	Temperature Requirement
Liquifaction	93°C (200°F)
Saccharification*	50°C (122°F) to 60°C (140°F)
Fermentation	27°C (80°F) to 32°C (90°F)
Distillation	100°C (212°F)

*The temperature requirements for the saccharification process depend upon the type of enzyme used.

With these temperature requirements in mind, it is obvious that a fairly high-temperature geothermal resource is necessary to serve as the sole heat source for an ethanol production facility. A geothermal resource with a well-head temperature of 110°C (230°F) has the minimum thermal energy necessary to satisfy the complete needs of the ethanol production process (R. J. Schultz, verbal communication). The introduction of a heat pump or other amplification scheme may allow utilization of lower temperature geothermal resources. However, the use of a hybrid system introduces an additional measure of economic uncertainty into the process (R. J. Schultz, verbal communication). Lower temperature geothermal fluids can also be used as the heat source for the lower temperature processes such as saccharification, fermentation, and drying of by-products. An additional energy source would, in this case, be necessary to meet the higher temperature demands of the liquifaction and distillation phases.

The geothermal resource sites selected in this paper as potentially attractive for ethanol generating facilities include those geothermal systems with known or estimated temperatures greater than or near 110°C (230°F). Known temperatures are based upon drill-hole data; estimated temperatures are obtained from geothermometry. The use of very high-temperature systems for ethanol production may be attractive where the high-temperature geothermal fluids are used in a series of cascaded applications from high temperature to lower temperatures.

Flow Requirements. The amount of geothermal fluid required in an ethanol production facility depends upon the geothermal resource temperature, the volume of ethanol produced, and the energy required to convert the feedstock into ethanol. This conversion energy generally ranges from 40,000 to 70,000 BTU per gallon of ethanol and depends upon the efficiency of the plant design (Lund, 1979). Table 2 lists the geothermal fluid flow requirements of various sizes of ethanol facilities using a range of resource temperatures and assuming a conversion factor of 50,000 BTU/gallon of ethanol. In a similar fashion, Table 3 tabulates the geothermal fluid flow requirements assuming an energy use of 40,000 BTU/gallon. The temperatures listed in Tables 2 and 3 are those temperatures available to the plant, and not necessarily the well-head temperature. Calculation of these flow requirements also assumes that the heat capacity of the geothermal fluid is the same as that of water, and that the geothermal fluid leaves the plant at temperatures less than or equal to 43°C (110°F). Only the process heat requirements have been considered; plant utilities are not included (W. F. Domenico, written communication).

Predicting the flow rate from a geothermal well is difficult since permeability and reservoir production characteristics are poorly understood for most geothermal systems. Fluid production rates depend upon the careful selection of a successful drill site, and can be influenced by well drilling and completion techniques. Thus for many systems, particularly those for which there is little or no drill-hole data, geothermal fluid flow estimates represent the largest unknown and risk-laden factor. Also, the relatively large flow rates required by large-scale ethanol facilities may necessitate drilling several production wells.

Table 2. Geothermal Fluid Flow Requirements Assuming 50,000 BTU/gallon Ethanol Conversion Factor (W. F. Dimenico, written communication)

Geothermal Fluid Temperature	Annual Ethanol Production			
	2 Thousand gal/year[1]	2 Million gal/year[2]	20 Million gal/year[2]	50 Million gal/year[2]
110°C (230°F)	1.2 gpm	199 gpm	1987 gpm	4968 gpm
132°C (270°F)	0.9 gpm	150 gpm	1501 gpm	3753 gpm
154°C (310°F)	0.7 gpm	121 gpm	1208 gpm	3020 gpm
177°C (350°F)	0.6 gpm	102 gpm	1015 gpm	2539 gpm

1. 8 hr/day, 6 months/year
2. 24 hr/day, 12 months/year

Table 3. Geothermal Fluid Flow Requirements Assuming 40,000 BTU/gallon Ethanol Conversion Factor (W. F. Dimenico, written communication)

Geothermal Fluid Temperature	Annual Ethanol Production			
	2 Thousand gal/year[1]	2 Million gal/year[2]	20 Million gal/year[2]	50 Million gal/year[2]
110°C (230°F)	0.9 gpm	159 gpm	1590 gpm	3975 gpm
132°C (270°F)	0.7 gpm	120 gpm	1201 gpm	3002 gpm
154°C (310°F)	0.6 gpm	97 gpm	966 gpm	2416 gpm
177°C (350°F)	0.5 gpm	91 gpm	812 gpm	2031 gpm

1. 8 hr/day, 6 months/year
2. 24 hr/day, 12 months/year

Exploration Status. Another important factor that should be considered in site selection is the level of knowledge for a particular geothermal system, or the exploration status. There are some geothermal systems that have been the site of relatively intensive exploration efforts, including drilling. Development of these sites will involve less risk since the chances of drilling a successful well are better than in a system for which no drill-hole data exist. Confirmation of resource production characteristics (temperature and flow) should take less time and money at a well-understood system.

AVAILABILITY OF BIOMASS FEEDSTOCK AND MARKET POTENTIAL

In order for alcohol fuels to make a positive impact upon the nation's total energy budget, the consumption of petroleum in the ethanol generating process must be kept to a minimum. The energy consumed in transporting the biomass feedstock to the ethanol generating facility, and the energy used to transport the ethanol and any by-products to the market must be included in the overall energy budget. To reduce this energy consumption as much as possible, geothermal ethanol facilities should be co-located with nearby sources of biomass feedstock and with a nearby market for the ethanol and any by-products. Large-scale ethanol facilities cannot rely upon surplus or waste farm products whose cost and availability may vary. Crops grown specifically as feedstock will be needed by large operations. Supplies of surplus farm products may be sufficiently reliable for small-scale operations. This paper briefly considers biomass availability for the geothermal systems sited. A much more detailed analysis of biomass availability and ethanol market potential must be undertaken prior to selection of a geothermal resource as a potentially attractive site for an ethanol generating facility.

INSTITUTIONAL PARAMETERS

Prior to site selection, the institutional factors associated with the exploration and development of a given site must be carefully considered. These could include, but are not restricted to, land ownership, (federal, state or private), resource ownership, environmental considerations, and permitting. The availability of water may present a serious barrier to geothermal ethanol development in areas where water is in short supply. Large-scale ethanol facilities will need irrigation water for the feedstock crops in addition to geothermal fluids and processing water. It may be feasible in some cases to use the geothermal fluids as irrigation and process water. This paper briefly comments upon possible institutional barriers to development at those sites for which they have been identified. A more detailed analysis should be undertaken prior to site selection.

POTENTIAL GEOTHERMAL ETHANOL PRODUCTION SITES

The following list of geothermal systems potentially suitable for biomass-based ethanol production is divided into two sections: A. Highest Priority Potential Geothermal Ethanol Sites, and B. High Priority Potential Geothermal Ethanol Sites. The highest priority sites are those geothermal systems where the resource potential has been quantified to some degree by drilling and other resource evaluation methods. Development of these known resources should require comparatively little additional resource assessment, and could therefore proceed rapidly. The high-priority sites include systems with unquantified resource parameters but with excellent potential for sufficient water temperatures and volume for alcohol production. Development of these lesser known systems will probably require extensive exploration efforts prior to design and installation of an alcohol-generating facility.

For each suggested site a brief discussion of the known and inferred resource characteristics is given. The biomass availability is briefly described for those sites at which it has been identified. Finally, potential institutional impediments to development are briefly discussed. This list is not intended to be inclusive; there are undoubtedly other high-priority sites. In addition, some of the listed sites may not actually be feasible due to currently unrecognized resource deficiencies or development barriers. Unless otherwise noted, all resource information is from Muffler (1979).

A. HIGHEST PRIORITY SITES

The Geysers Area, California

Resource Characteristics. The vapor-dominated geothermal system at The Geysers is currently producing about 660 megawatts of electricity from 237°C (459°F) steam. Following use in the electricity generating process, it may be feasible to utilize the geothermal fluids prior to injection in a cascaded direct use scheme that could include alcohol production. The area around The Geysers, including the Clear Lake volcanic field has tremendous geothermal potential and is currently the site of active exploration.

Biomass Availability. Various sources of biomass feedstock are probably available from the fertile Napa and Sonoma Valleys.

Institutional Parameters. Obtaining an agreement with Pacific Gas and Electric to use The Geysers geothermal fluids for direct-use applications may be difficult. California's strict environmental regulations may complicate direct use of these fluids. The road to The Geysers is long, narrow and treacherous. A new road or perhaps a rail system may be required to transport large quantities of biomass feedstock and ethanol. Transportation logistics for the Clear Lake volcanic field area may be much simpler.

The Imperial Valley, California

Resource Characteristics. Temperatures in the Imperial Valley geothermal system range from 160°C (320°F) to 360°C (680°F). The area is a site of intensive geothermal exploration and reservoir evaluation. Like The Geysers area, the Imperial Valley may be an attractive site for cascaded direct use applications of geothermal energy. Using the Imperial Valley geothermal fluids for direct applications may be difficult since they are hypersaline brines.

Biomass Availability. The Imperial Valley is one of the most important agricultural areas in the country. Wheat and sugar beets, both excellent biomass feedstock sources, are among the dominant crops produced in the area. Co-location of the geothermal resource with abundant agricultural products makes the Imperial Valley an ideal site for alcohol production. Occidental Petroleum is studying the feasibility of an ethanol-generating facility in the Imperial Valley (Carmen Smith, 1980).

Institutional Parameters. Development of DOE-funded geothermal alcohol facilities should be relatively easy at the East Mesa DOE test facility and at the DOE-SDG&E Geothermal Experimental Loop Facility, Salton Sea Geothermal Field near Niland. The Imperial Valley would be an excellent site for a DOE geothermal ethanol demonstration project. Other sites would involve negotiations with the various users and producers in the Imperial Valley field. The necessary environmental reviews have been completed for the Imperial Valley field.

Cove Fort-Sulphurdale, Utah

Resource Characteristics. The Cove Fort area has been the site of intensive exploration for several years. The maximum bottom-hole temperature is 179°C (354°F) at 2226 m (7304 ft.). The static water level at Cove Fort ranges from 366 m (1200 ft.) to 427 m (1400 ft.). Pumping requirements may thus be a significant consideration in the economics of ethanol generation at Cove Fort.

R & R Energies is planning to use 165°C (330°F) geothermal fluids from well 42-7 for a 12 millon gallon per year ethanol facility (R. Helber, verbal communication). Forminco, Inc. will be the resource producer. Plant construction is scheduled to begin in June, 1980 (Anderson, 1980).

Biomass Availability. The proposed feedstock for the Cove Fort ethanol plant is sugar beets grown in nearby Enterprise and St. George, Utah. Locally produced potatoes may also be used (R. Helber, verbal communication).

Institutional Parameters. Environmental study requirements must be satisfied at Cove Fort prior to development. Additional institutional barriers are not yet identified.

Roosevelt Hot Springs, Utah

Resource Characteristics. The Roosevelt area is one of the most intensively explored geothermal systems in the world. Measured well temperatures range from 269°C (480°F) to 243°C (469°F). The area is being developed as an electricity generating site. However, development of direct-use projects might be feasible as a series of cascaded applications prior to fluid injection.

Biomass Availability. The Escalante Valley is an agricultural area. A suitable biomass feedstock source for an ethanol facility is probably locally available.

Institutional Parameters. A water-use agreement with the Roosevelt Unit will be required. Land acquisition for a plant site will be necessary. Other institutional barriers are not yet identified.

Raft River, Idaho

Resource Characteristics. Geothermal fluids with an average temperature of 147°C (297°F) are produced from several deep wells ranging in depth from 866 m (2840 ft.) to 1996 m (6550 ft.) at Raft River. A DOE-sponsored pilot binary system 5-megawatt power plant is under construction.

Raft River is currently the site of experiments testing the use of geothermal energy for ethanol production. Geothermal fluids with a temperature of about 116°C (240°F) have been used as the heat source for both the fermentation and distillation phases of the ethanol-generating process. Sugar beets are used as the feedstock (Anderson, 1979).

Biomass Availability. According to the Idaho Office of Energy (D. W. McClain, verbal communication) there is insufficient locally-derived biomass to support a large-scale geothermal alcohol facility. There is probably an adequate supply of sugar beets (about 163,000 tons/year) to support a small-scale operation.

Institutional Parameters. There may be many institutional impediments to development of an ethanol facility at Raft River. An additional well would probably have to be drilled on the Raft River site. However, the Raft River valley is a closed ground water basin; obtaining the water necessary for an ethanol plant might be difficult. The ethanol producing facility would probably have to be built outside of the Raft River development (D. W. McClain, verbal communication).

Klamath Falls Area, Oregon

Resource Characteristics. Geothermal energy has supplied warm water for space heating in Klamath Falls for many years. Over 500 shallow geothermal wells ranging in depth from 40 m (130 ft.) to 550 m (1800 ft.), with measured down-hole temperatures as high as 113°C (235°F) exist in the area. In a planned 1.2 million gallons per year alcohol fuel plant, 88°C (190°F) water will be heated to temperatures as high as 188°C (370°F) using a compressor (Lund, 1979).

Biomass Availability. An estimated 3 million hundred weight of potato waste products are produced annually in the Klamath Basin (Lund, 1979). Wood biomass is also readily available.

Institutional Parameters. There should be relatively little difficulty in developing geothermal alcohol facilities in the Klamath

Falls area. The community is already aware and supportive of geothermal energy; the geothermal reservoir is relatively well defined; and a local supply of biomass feedstock is readily available. Moreover, initial feasibility studies of geothermal alcohol production in Klamath Falls (Lund, 1979) indicate that the use of geothermal energy would significantly lower the cost of alcohol fuel production.

Brady Hot Springs, Nevada

Resource Characteristics. The maximum reported down-hole temperature at Brady Hot Springs is 214°C (417°F). Numerous exploration wells ranging in depth from 73 m (240 ft.) to 2219 m (7280 ft.) have been drilled. Geothermal fluids with a temperature of 154°C (309°F) are currently being used in a commercial vegetable dehydration plant. Development of a cascaded direct-use scheme including ethanol production may be feasible at Brady Hot Springs.

Biomass Availability. The vegetables used in the dehydration facility must be transported to the site from varying distances. Significant transportation requirements might also apply to any biomass feedstock source. This expenditure of petroleum might make alcohol production unattractive. Any waste products produced from the dehydration process could be considered as a potential biomass source.

Institutional Parameters. The use of the geothermal fluids at Brady Hot Springs would require an agreement with Geothermal Food Processors, Inc. Specific barriers to development of an ethanol facility are not yet known.

Beowawe, Nevada

Resource Characteristics. Two deep wells and numerous shallow exploration wells have been drilled at Beowawe. The maximum recorded bottom-hole temperature is 211°C (412°F) at 2917 m (9571 ft.).

Biomass Availability. Crescent Valley immediately south of Beowawe is an agricultural area with possible feedstock.

Institutional Parameters. Despite favorable resource characteristics and a potential local source of biomass, the Beowawe area may be too remote to support a large ethanol facility. Additional institutional parameters have not yet been identified.

Steamboat Springs, Nevada

Resource Characteristics. Several hot springs at Steamboat discharge 250 l/min from an extensive sinter apron. The area is currently undergoing geothermal exploration. The maximum recorded temperature is 186°C (367°F) at 221 m (725 ft.). Phillips Petroleum Co. recently completed a 937 m (3075 ft.) hole described as a potential geothermal producer. Geothermometers estimate a mean reservoir temperature of 200°C (392°F) for the Steamboat system.

Biomass Availability. Biomass, specifically in the form of waste products, should be available from the Reno area. Feedstocks suitable for ethanol generation may also be locally available.

Institutional Parameters. The Reno area would be an excellent market for any ethanol or methanol produced at Steamboat Springs. Specific barriers to development at Steamboat have not yet been identified.

B. HIGH PRIORITY SITES

Vale Hot Springs, Oregon

Resource Characteristics. Vale Hot Springs is one of the most attractive potential moderate-temperature geothermal resources in the country. The hot springs at Vale discharge 97°C water. The mean estimated reservoir temperature of the Vale system is 157°C. There are no deep exploration wells at Vale Hot Springs; several shallow wells were drilled near the hot spring vents. One old shallow well has a temperature of 120°C (247°F) at 22m (73 ft.) (G. Culver, written communication). The Vale area has been the site of recent gradient drilling. However, this information is proprietary.

Biomass Availability. Vale Hot Springs is located in Treasure Valley Oregon, a fertile agricultural area characterized by large-scale farming efforts, a long growing season and relatively abundant water supplies (Lienau, 1978). This local agriculture can probably supply the feedstock required by an ethanol plant.

Institutional Parameters. The institutional aspects of development have not yet been identified for the Vale area.

Weiser, Idaho

Resource Characteristics. Measured spring temperatures at Weiser Hot Springs are as high as 77°C (171°F). Geothermometers estimate a mean reservoir temperature of 130°C (266°F). The Phillips Petroleum Company has drilled three shallow exploration wells in the Weiser Hot Springs area. The current owners of the property are planning a drilling program for 1980 (McClain and Eastlake, 1979).

Biomass Availability. The Weiser geothermal system is located along the northern edge of West Weiser Flat, a fertile agricultural area. Local produce includes potatoes, corn, wheat, sugar beets, and onions. In a recent study McClain and Eastlake (1979) contend that the Weiser area produces adequate quantities of grain, sugar beets or potatoes to serve as the feedstock for a 1 million gallon per year ethanol facility.

Institutional Parameters. Institutional barriers to development have not yet been identified.

Crane Creek, Idaho

Resource Characteristics. The Crane Creek - Cove Creek Hot Springs area is one of the hottest geothermal systems in Idaho, with a surface temperature of 92°C (198°F). Geothermometers for the area predict a mean reservoir temperature of 171°C (340°F). Phillips Petroleum Co. drilled a deep (about 245 m/8000 ft.) well in the area. A temperature of about 177°C (350°F) was measured at approximately 1830 m (6000 ft.).

Biomass Availability. The biomass availability at Crane Creek should be comparable to that for nearby Weiser Hot Springs.

Institutional Parameters. The institutional parameters affecting development at Crane Creek have not yet been identified.

Roystone Hot Springs, Idaho

Resource Characteristics. Five springs at Roystone Hot Springs discharge 75 l/min of water with a maximum temperature of 55°C (131°F). The geothermometers predict a mean reservoir temperature of 135°C (275°F) for the Roystone system. An old, partially caved well measures 85°C (180°F) at 35 m (115 ft.). A drilling operation is currently underway at Roystone.

Biomass Availability. Studies by the Idaho Office of Energy suggest that the Roystone system is an attractive potential site for a geothermal ethanol facility due to sufficient biomass availability and proximity to rail transportation (D. W. McClain, verbal communication). The owners of the Roystone property are hoping to develop an ethanol facility.

Institutional Parameters. No institutional barriers to development have yet been identified.

Magic Reservoir Area, Idaho

Resource Characteristics. A 79 m (260 ft.) well at Magic Hot Springs Landing on the northern end of Magic Reservoir produces 20 l/min of 72°C (162°F) water. Geothermometers predict a mean reservoir temperature of 149°C (300°F). No deep wells exist in the area.

Biomass Availability. According to McClain and Eastlake (1980), a 1 million gallons per year ethanol plant at Magic Reservoir would require any one of the following feedstocks: 375,370 bushels of corn, 384,615 bushels of wheat or oats, 416,666 bushels of barley, 714,286 hundred weight of potatoes, or 49,261 tons of sugar beets. Crops produced locally in the Magic Valley portions of Blaine, Camas, Gooding, Jerome and Lincoln counties could support an ethanol facility of this size.

Institutional Parameters. The area around the Magic Hot Springs Landing well is currently zoned for rural recreation; a zoning change would be necessary prior to development of an ethanol facility. Geothermal lease applications on adjacent BLM land have been pending since November, 1978 (McClain and Eastlake, 1980).

Lakeview, Oregon

Resource Characteristics. There are several hot springs in the Lakeview area with temperatures as high as 96°C (205°F); their cumulative discharge is 2500 l/min. The mean estimated reservoir temperature for the Lakeview system is 150°C (302°F). Geothermal wells drilled in the area include two exploration wells 189 m (620 ft.) and 1658 m (5440 ft.) deep, and several shallow wells used for space heating.

Biomass Availability. Coury and Associates of Lakewood, Colorado, are studying the feasibility of using the wood resources in the Lakeview area as the feedstock for a geothermal alcohol facility. This study forms part of the Program Research and Development Announcement (PRDA) entitled "Geothermal District Heating for Multiple Applications in Lakeview, Oregon" (G. E. Coury, verbal communication).

Institutional Parameters. The institutional factors influencing development at Lakeview have not yet been identified.

The Escalante Desert Area, Utah

Resource Characteristics. There are numerous warm water wells in the Escalante Desert of southwestern Utah. Water in ten shallow irrigation wells in the Newcastle, Utah vicinity ranges in temperature from 20°C (68°F) to 78°C (172°F). A 152 m (500 ft.) deep well near Newcastle encountered a maximum of 108°C (226°F) water at 82 m (269 ft.). The maximum estimated reservoir temperature for the Newcastle system is 130°C (266°F). A 3747 m (12,295 ft) deep geothermal test well drilled near Beryl, Utah produced 1000 gpm of 149°C (300°F) water from a depth of 2133 m (7000 ft.) (Goode, 1978).

Biomass Availability. Since agriculture is the mainstay of the communities in the Escalante Desert (Goode, 1978), the area may be capable of producing sufficient feedstock supplies.

Institutional Parameters. The institutional aspects of development in the Escalante Desert have not yet been identified.

The Hawaiian Islands

Resource Characteristics. The Island of

Hawaii has numerous geothermal systems with temperatures high enough for ethanol generation. Exploration wells have been drilled at both the Kamaili Homesteads area and the Kapoho Reservoir area.

Biomass Availability. Hawaii is well known for its production of sugarcane, an attractive feedstock.

Institutional Parameters. The high cost of land on the island of Hawaii may prohibit the development of ethanol generating facilities, (W. F. Dimenico, verbal communications).

ACKNOWLEDGEMENTS

I wish to thank R. J. Schultz, T. W. Lawford, K. W. Jones, and E. G. DiBello of EG&G Idaho, Inc. for reviewing a preliminary draft of this paper. I am especially grateful to W. F. Dimenico of EG&G Idaho, Inc. for his many useful comments and for furnishing Tables 2 and 3.

The submitted manuscript has been authorized by a contractor of the U. S. Government under contract NO. DE-AC07-80ID12079. Accordingly, the U. S. Government retains a non-exclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U. S. Government purposes.

REFERENCES CITED

Anderson, D.N. (ed.), 1979, Geothermal energy used in gasahol production: The Bulletin of the Geothermal Resources Council vol. 8, no. 10, 8 p.

_____, 1980, Utah geothermal-alcohol plant planned: The Bulletin of the Geothermal Resources Council vol. 9, no. 2, 8 p.

Carmen Smith, M. del (ed.), 1980, Gasahol, biomass energy production could wreck U.S. food system: Geothermal Report vol. IX, no. 6, 4 p.

Goode, H.D., 1978, Thermal waters of Utah - topical report: Utah Geological and Mineral Survey, 176 p.

Lienau, P.J., et al., 1978, Geothermal energy for agribusiness for Klamath and western Snake River Basins, Oregon: Oregon Institute of Technolgy, 181 p.

Lund, J.W., 1979, The use of geothermal energy for alcohol production: testimony before the National Alcohol Fuels Commission, September 8, 1979, Portland, Oregon.

McClain, D.W., and Eastlake, W.B., 1979, Weiser Hot Springs, Idaho - Site specific development analysis: Idaho Office of Energy, 27 p.

_____, 1980, Magic Hot Springs, Idaho - Site specific development analysis: Idaho Office of Energy.

Muffler, L.J.P., 1979, Assessment of geothermal resources of the United States--1978: U.S. Geological Survey Circular 790, 163 p.

Solar Energy Research Institute, 1980, Fuel from farms: Oak Ridge, Tenn., 87 p.