THE USE OF GEOTHERMAL ENERGY FOR
BIOMASS-BASED ETHANOL PRODUCTION

by

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Introduction

This report reviews the feasibility of using geothermal energy for biomass-based alcohol fuel production, and suggests several high priority sites where development of geothermal alcohol facilities might be feasible in the near future. The first portion of this report describes the alcohol generation process, the energy requirements for alcohol production, the applicability of geothermal energy to this process, and the envisioned future demand and costs for alcohol fuels. The second part of this report suggests potentially attractive geothermal sites for alcohol production.

Part I. Biomass-Based Alcohol Production and Economics

Biomass Based Ethanol Fuel Production Process

Making alcohol fuel from a biomass feedstock converts a low-grade energy form such as surplus farm products into a valuable transportable liquid fuel. This procedure involves four step-wise processes: liquefaction, saccharification, fermentation and distillation. The liquefaction process is a hydrolysis operation in which water is introduced into the starch molecules of the feedstock. Following the liquefaction process is the saccharification step during which the starches in the feedstock are converted into simple sugars (dominantly glucose) by the addition of enzymes. For cereal grain feedstocks, the saccharification process involves heating the grain in an aqueous solution to temperatures of 320°F for 30 seconds. Lower temperature (220°F) water can be used if the cooking time is increased to several hours. This energy intensive saccharification process is not necessary for sugar beet production since the carbohydrate in the sugar beet plant already exists as a sugar (Garing and Coury, 1979). Once the feedstock has been reduced into a sugar, yeast is added and the fermentation procedure begins. The fermentation process requires temperatures of no greater than 90°F; higher temperatures will kill the yeast. A 2-12% alcohol solution called beer and carbon dioxide are produced during fermentation. In the final step, distillation, water is removed from the beer, and alcohol is concentrated to 95% to 96% by volume. The distillation process is the most energy intensive step during ethanol production, requiring temperatures greater than 212°F, and consuming about two-thirds of all the thermal energy devoted to ethanol generation (Garing, 1979).

Ethanol Production Energy Economics

The production of ethanol from biomass feedstock is an energy intensive process, requiring from 40,000 to 70,000 BTUs per gallon of ethanol, depending upon the heat recovery design of the distillery. The net energy input, including the fossil fuel or waste material heat source, as well as the electricity needed in plant operation, generally amounts to about half of the net energy output in the alcohol. The cost of the this input energy contributes about 25% to the final cost of the alcohol (Lund, 1979). By reducing the cost of this input energy, the resulting cost of alcohol fuel could be significantly reduced.

Substituting low-cost geothermal energy for more expensive conventional fuels is an attractive method for reducing the energy input costs during alcohol production. Table 1 compares the costs of conventional energy and geothermal energy for alcohol fuel production.

TABLE 1

COMPARISON OF CONVENTIONAL ENERGY AND GEOTHERMAL ENERGY COSTS IN ALCOHOL FUEL PRODUCTION (Lund, 1979)

Fuel	$/mill BTU	¢/Kwhr
Natural Gas	3.60	1.2
Fuel Oil	3.90	1.3
Coal	5.00	1.7
Electricity	8.70	3.0
Geothermal*	2.20	0.8
Geothermal**	2.60	0.9
Geothermal***	0.50	0.2

*Based on a Colorado study for sugar beets

**Based on a Colorado study for corn (13,000 foot deep well and $350^{\circ}F$ temperature)

***Oregon estimate, 1000 foot well at $200^{\circ}F$. This does not include costs for heat pumps or compressors

In a planned geothermal alcohol facility in Klamath Falls, Oregon, the envisioned input energy costs will amount to only 5% of the net alcohol energy output (Lund, 1979). Thus it appears that the use of geothermal energy in alcohol generating facitlities is an attractive alterative to conventional fuels, and could significantly reduce the cost of biomass-based alcohol and the resulting consumer price of alcohol fuels.

Scale of Operations

A recent DOE study indicates that significant economies of scale are achieved by large (greater than 40 million gallons per year) alcohol plants. This is primarily due to lower fixed capital costs for larger facilities (Yu, 1979). However, the costs of collecting, transporting and storing raw materials may make smaller-scale operations more economical in some cases. According to the 1979 DOE Alcohol Fuels Policy Review Report (p.14) very small-scale operations, (less than 1,000 gallon per day) may be profitable on a local scale. This may be an especially attractive niche for geothermal-powered alcohol facilities. Local cooperatives or individual farmers could make use of geothermal systems using locally derived biomass feedstock.

Market Penetration of Ethanol (as Gasahol)

The Department of Energy estimates that in 1990 the U. S. gasoline demand will be 115 billion gallons or 14.3 quads (Park and others, p. 17). Nation-wide consumption of a 5% ethanol/95% gasoline blend rather than pure gasoline could reduce this demand to 111 billion gallons of gasoline, thereby reducing annual petroleum imports of gasoline by 4 billion gallons (Park and others, p. 31-33)

The amount of ethanol required for this volume of gasahol fuel would be 5.8 billion gallons. This is nearly 29 times the current national production of biomass-based ethanol. Based on an average plant capacity of 207,600 gallons of ethanol per day (67.3 million gallons per year) 86 such ethanol plants would be required to produce enough ethanol for a 5% gasahol blend. The cost of a single plant of this size is about 126.8 million dollars. Eighty-six plants would thus cost 10.9 billion dollars. This probably represents the maximum attainable ethanol market penetration (Park and others, p. 25-26).

Gasahol Consumer Costs

Based on May 3, 1979 gasoline prices of 77.9 to 84.9 cents for unleaded regular, gasahol prices range from 82.9 cents per gallon to 86.9 cents per gallon (DOE Alcohol Fuels Policy Review Report, p. 10). Although this cost difference between gasahol and gasoline is small on a per gallon basis, the difference is significant on a nation-wide scale. By the year 1990, a federal subsidy of $6.9 billion would be required to make nation-wide consumption of a 5% ethanol blend cost-competitive with gasoline. A large-scale geothermal alcohol production program could help reduce this required subsidy by lowering the net energy input costs of alcohol production. As mentioned above, the net energy input costs account for about 25% of the final alcohol costs (Lund, 1979).

Net Energy Balance for Biomass-Based Ethanol Production

There is some disagreement concerning the net energy efficiency (net energy output minus net energy input) of biomass-based ethanol production. Some critics maintain that ethanol production actually consumes more energy than is available in the ethanol end-product. A major factor influencing the net energy input consumed in ethanol production is the type of biomass feedstock used. Different feedstocks require varying amounts of energy in the ethanol process. It should be noted that the energy requirements of a given feedstock variety are not necessarily reflected in the selling price of ethanol produced from that feedstock. For example, processing of corn feedstock results in only a 5% net energy gain, but corn-based ethanol sells for less than other biomass-based ethanol products. Table 2 compares the net energy gain and estimated ethanol selling price for several biomass feedstock varieties.

Table 2

Comparison of Energy Gain and Ethanol Selling Price

(DOE Alcohol Fuels Policy Review Report, p. 15)

Feedstock	Net Energy Gain (%)	Estimated Ethanol Selling Price ($/gallon)
Corn	5	1.05
Sugar Cane	143	2.07
Sweet Sorghum	89-100	1.40

Comparison of different net energy balance figures can be difficult since variable assumptions are commonly made in their computation. Of critical importance is a comparison of those factors used in defining net energy input and net energy output. Some calculations also include an energy credit for useable by-products generated in the ethanol production process.

Proponents of biomass-based ethanol production contend that the salient argument supporting biomass-based alcohol production despite a negative or marginal net energy balance is that this process converts biomass waste products into a valuable liquid fuel. In doing so, the ethanol production process uses a relatively abundant low-grade or renewable form of energy such as coal, wood, or geothermal energy to generate a substitute for scarce liquid petroleum fuels. Although the net energy balance for the process may be negative, the process yields a net <u>petroleum</u> gain. In times of dwindling petroleum supplies, this may be an attractive option.

Part II. Geothermal Sites Suitable for Alcohol Production

Part II of this report suggests those geothermal resources that may be suitable for the near-term development of geothermal ethanol production facilities. In choosing these sites, several criteria must be considered. Of primary importance is the temperature of the geothermal water. Conventional cooking processes require temperatures of up to 350^{0}F for processing corn; somewhat lower maximum temperatures are required for processing sugar beets (230^{o}F) (Garing and Coury, 1979), and potatoes (about 200^{o}F) (Yu, 1979). Introduction of a heat pump or other amplification schemes may allow utilization of lower temperature geothermal fluids. However, use of a hybrid system introduces an additional measure of economic uncertainty into the process (B. Schultz, verbal communication). Therefore, only those geothermal systems with known or estimated temperatures greater than 212^{o}F (100^{o}C) will be considered in this list of first choice potential sites for geothermal alcohol facilities.

A second important criteria in site selection is the level of knowledge for each particular geothermal system. Those systems which have already received intensive exploration efforts should be considered the highest priority sites since it will take less time and money to develop these comparatively well-understood sites than those systems about which we know relatively little.

A third important factor is biomass feedstock availability. Clearly those geothermal sites located near a biomass feedstock resource should be considered higher priority sites than areas with no local biomass supply.

Finally, institutional barriers to development of a given site must be considered. These would include, but are not restricted to, land status (federal, private, state) possession of water rights or water use permits, environmental considerations, etc.

The following list is divided into two sections: A) highest priority potential geothermal alcohol sites, and B) high priority potential geothermal alcohol sites. The highest priority sites are these 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 temperature 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 described for those sites at which it has been identified. Finally, legal and institutional impediments to development are described. 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 sites due to currently unrecognized resource deficiencies or development barriers (Unless otherwise noted, all resource information is from Muffler, 1979).

A. Highest Priority Potential Geothermal Alcohol Production Sites

The Geysers, California

Resource Parameters. The vapor-dominated geothermal system at The Geysers is currently producing about 660 megawatts of electricity from 237°C steam. Following use in the electricity generating process, it may be feasible to utilize the geothermal fluids prior to re-injection in a cascaded direct-use scheme which could include alcohol production. In addition, recent studies (   ) suggest that The Geysers geothermal system is larger than originally envisioned. The area should be considered a high quality high-temperature and low- to moderate-temperature geothermal exploration target.

Biomass Availability. Various sources of biomass feedstock are probably available from the fertile Nampa and Sonoma valleys. This area is well-known for its production of crops suitable for fermentation!

Development Barriers. Obtaining an agreement with Pacific Gas and Electric to use The Geysers geothermal fluids for direct use applications may be very 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 finished product ethanol.

Clear Lake Volcanic Field Area

Resource Parameters. The geothermal setting is similar to The Gyesers although the system is probably water-dominated rather than vapor-dominated.

Biomass Availability. Same as for The Geysers. Transportation logistics are much simpler than at The Geysers.

Development Barriers. Procurement of land and water-use rights. Some exploration necessary prior to development.

The Imperial Valley, California

Resource Parameters. Temperatures in the Imperial Valley geothermal system range from 160° to 360°C. 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. Many of the Imperial Valley geothermal fluids are hypersaline brines which may limit their use for direct applications.

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. The co-location of the geothermal resource and abundant agricultural products makes the Imperial Valley an ideal site for alcohol production.

Development Barriers. 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. 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-Sulphurale, Utah

Resource Parameters. This area has been the site of active exploration for several years. To date, the maximum recorded down-hole temperature is 179°C. Availability of water may be a problem at Cove Fort; geothermal fluids must be pumped to the surface from depths of up to 1,000 feet.

Biomass Availability. A local developer is trying to purchase a Formico well (42-7) at Cove Fort. This developer plans to use sugar beets grown in the Enterprise and St. George areas as biomass feedstock. Locally produced potatoes may also be used.

Development Barriers. Negotiations with Forminco are in process; some difficulties have been encountered. The water table is at 1200-1400 feet. Pumping requirements will complicate utilization of the geothermal resource at Cove Fort.

Roosevelt Hot Springs, Utah

Resource Parameters. The Roosevelt area is one of the most intensively explored geothermal systems in the world. Measured well temperatures range from 269° to 243°C. The area is being developed as an electricity generating site. However, development of direct use projects might be feasible.

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

Development Barriers. A water-use agreement with the Roosevelt Unit will be required.

Raft River, Idaho

Resource Parameters. 143°C water is presently being used to generate 5 megawatts of electricity in a DOE-sponsored pilot geothermal power plant. Bechtel is currently involved in a feasibility study of the Raft River area as a geothermal alcohol site. However, as discussed below, Raft River may not be an attractive site.

Biomass Availability. According to the Idaho Office of Energy (D. 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.

Development Barriers. There would be many institutional impediments to development of an alcohol facility at Raft River. An additional well would have to be drilled on the INEL site. Water, already in short supply, would have to be obtained from the INEL facility. However, the ethanol producing facility would have to be built outside of the INEL site (D. McClain, verbal communication).

Klamath Falls Area, Oregon

Resource Parameters. Geothermal energy has supplied warm water for space heating in Klamath Falls for many years. Over 500 shallow geothermal wells exist in the area ranging in depth from 40 to 550 m, with measured down-hole temperatures as high as $113^{\circ}C$. In a planned 1.2 million gallons per year alcohol fuel plant, $190^{\circ}F$ water will be heated to temperatures as high as $370^{\circ}F$ 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.

Development Barriers. There should be relatively little difficulty in developing geothermal alcohol facilties in the Klamath Falls area. The community is already aware and supportive of geothermal, 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 Parameters. 154°C water is used in a commercial vegetable dehydration plant. It may be feasible to develop a cascaded direct use scheme suitable for alcohol production.

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.

Development Barriers. Use of the geothermal fluids at Brady Hot Springs would require an agreement with Geothermal Food Processors, Inc.

Lightening Dock Area, New Mexico

Resource Parameters. The Lightening Dock area has been the site of significant geothermal exploration. Measured temperatures as high as 107°C have been recorded at shallow depths (90m?). The area apparently lacks sufficient water for electrical generation.

Biomas Availability. Grain and corn are grown in the Lightening Dock area. Sufficient biomass resources are probably available.

Development Barriers. Procurement of water rights and lease holdings would be necessary. A farmer's co-operative group in the Animas Valley has expressed interest in a geothermal alcohol facility (D. Fedor, verbal communication).

B. High Priority Potential Geothermal Alcohol Production Sites

The Weiser, Idaho-Vale, Oregon Area

Resource Parameters. Measured spring temperatures in the Weiser area are as high as 77°C; the mean estimated reservoir temperature based on chemical geothermometers is 130°C. The mean estimated reservoir temperature at Vale is 157°C, with measured surface spring temperatures up to 97°C. This area is a high quality geothermal exploration target.

Biomass Availability. A wide variety of potential biomass feedstock resources are available in the Weiser area and from adjacent Payette County, Idaho. Locally grown crops include corn, wheat, barley mixed grains and potatoes (D. McClain, verbal communication). The adjacent Treasure Valley in Oregon is a fertile agricultural area.

Development Barriers. Development of this potential field will require significant exploration efforts. The Idaho Office of Energy has identified the Weiser area as the most attractive potential geothermal alcohol production site in Idaho (D. McClain, verbal communication).

Crane Creek, Idaho

Resource Parameters. There are two groups of springs in the Crane Creek area with measured temperatures up to 92°C. The mean estimated reservoir temperature is 171°C. Rumor has it that Phillips has drilled a 300°F well in the Crane Creek area.

Biomass Availability. Local Sources of biomass feedstock are readily available (D. McClain, verbal communication).

Development Barriers. Additional resource definition is needed. The Idaho Office of Energy has identified the private land in the Crane Creek KGRA as an attractive site for a geothermal alcohol facility. Access to biomass supply and rail transportation is good (D. McClain, verbal communication).

Development Barriers. Significant exploration work would be required prior to development.

Roystone Hot Springs, Idaho

Resource Parameters. Five springs at the Roystone system discharge 75 l/min. of up to 55°C water. Based on chemical geothermometers, the mean estimated reservoir tempreatures is 135°C.

Biomass Availability . Local supplies of biomass feedstock are readily available (D. McClain, verbal communication).

Development Barriers. Significant exploration work would be required prior to development. The Idaho Office of Energy has identified the privately-owned portion of the Roystone system as a very attractive potential geothermal alcohol site. There is good biomass availability, rail transportation, and the owners are eager to develop an alcohol facility (D. McClain, verbal communication).

Lakeview, Oregon

Resource Parameters. There are several springs in the Lakeview area with temperatures up to 96°C, discharging 2500 l/min. Mean estimated reservoir temperature is 150°C.

Biomass Availability. Coury and Associates, Lakewood, Colorado, are studying the feasibility of using the wood resources in the Lakeview area in a geothermal alcohol facility. This study is part of a PRDA for the Lakeview area.

Development Barriers. Institutional barriers not yet identified. Significant exploration would be required prior to development.

Radium Hot Springs, Dona Ana County, New Mexico

Resource Parameters. A broad area of elevated heat flow (generally greater than 100m W/m^2) is known in this area. Measured temperatures at Radium Hot Springs may be as high as 85°C. The mean estimated reservoir temperature is 98°C. Kilbourne Hole KGRA is also in this area.

Biomass Availability. This area is considered the bread basket of New Mexico (D. Fedor, verbal communication). Biomass feedstock should be readily available.

Development Barriers. None identified to date. Some community interest has been expressed in utilizing geothermal energy. Significant exploration required prior to development.

Abraham Hot Springs, Utah

Resource Parameters. Spring temperatures are as hot as 84°C; mean estimated reservoir temperature is 97°C. Springs discharge 1000 l/min.

Biomass Availability. Sufficient biomass feedstock could probably be obtained from the Delta, Utah area (W. Wagstaff, verbal communication).

Development Barriers. The property is currently tied up in litigation. Some of the water rights currently being used for irrigation may be turned over to the Intermountain Power Project (IPP). This could effect crop production and biomass availability (W. Wagstaff, verbal communication).

Lovelock, Nevada Area

Resource Parameters. Several geothermal systems with sufficient potential temperatures occur in the Lovelock area: the Colado Area (97°C mean estimated reservoir temperature) and Humboldt House (217°C mean estimated reservoir temperature).

Biomass Availability. The Lovelock area has some agricultural development. A local supply of biomass feedstock is probably available.

Development Barriers. Institutional barriers not yet identified. Significant exploration necessary prior to development.

Winnemucca - Grass Valley, Nevada Area

Resource Parameters. Numerous geothermal systems with mean estimated temperatures greater than 100°C are near Winnemucca, including: Humboldt House (217°C mean estimated reservoir temperature), Kyle Hot Springs (159°C), Leach Hot Springs (162°C), Hot Springs Ranch (147°C), and Hot Pot Hot Springs (112°C).

Biomass Availability. There is some agricultural development in the Winnemucca area which could probably supply the necessary biomass feedstock.

Development Barriers. Institutional barriers not yet identified. Exploraion work required prior to development.

Fernley Area, Nevada

Resource Parameters. In addition to the geothermal development at Brady Hot Springs, several other geothermal systems in the Fernley area may be attractive geotheral alcohol sites. These areas are: the Stillwater area (mean estimated reservoir temperature of 159°C), the Fernley area (182°C), Desert Peak (208°C), and Soda Lakes area (157°C).

Biomass Availability. This area of Nevada is fairly remote; biomass availability may be a problem. As mentioned above, vegetable dehydration products must be shipped to the Brady site.

Development Barriers. Institutional barriers not yet identified. Resource definition work required. Biomass availability may be a problem.

Elko - Carlin, Nevada Area

Resource Parameters. Springs at Carlin measure 79°C, mean estimated reservoir temperature is 96°C. At Elko, the hot springs measure 56°C; mean estimated reservoir is 93°C.

Biomass Availability. The area near Elko and Carlin has some agricultural development; biomass feedstock supplies should be available. Transportation of supplies should be no problem; both areas are served by rail and interstate highway.

Development Barriers. Institutional barriers not yet identified. Both areas will require extensive exploration work prior to development. Elko is the site of a PON (for space heating).

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