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CONCEPTUAL STUDY FOR TOTAL UTILIZATION OF AN INTERMEDIATE TEMPERATURE GEOTHERMAL RESOURCE

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CONCEPTUAL STUDY FOR TOTAL UTILIZATION OF AN INTERMEDIATE TEMPERATURE GEOTHERMAL RESOURCE

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ABSTRACT

A multi-use, integrated project plan has been developed for the combined electrical and direct utilization of an intermediate temperature geothermal resource. This concept addresses an integrated project plan with industrial participation, which could make a significant contribution to the national plan for energy independence, by creating new and realistic energy choices for the immediate future.

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1.0 INTRODUCTION

Although potential uses for geothermal energy have existed for many decades in the U.S., actual utilization of this energy has been limited. To date, both electrical energy generation from geothermal energy sources and non-electrical geothermal utilization has been on a minor scale. Also to date, the limited non-electrical uses of geothermal energy have centered around space heating whereas a potentially large application could be in industrial processes. This potentially large application may actually be the most profitable application of the geothermal resource although a combination of power production plus process heat application may prove more desirable. Geothermal water in the temperature range found at Raft River (∿300°F); i.e., the intermediate temperature range which is typically the more common temperature range of geothermal resource found in the U.S.,[1] appears usable in process applications and power productions, or usable as a demonstration of a combined electrical, non-electrical utilization.

A successful demonstration of the process application of geothermal energy for a combined system utilizing this typical resource could stimulate widespread development of similar resources in other areas of the U.S. and contribute significantly to creating new energy choices for the future which is a substantial part of the national plan for energy independence in the years ahead[2].

The Raft River Geothermal Demonstration Project will provide experience in practical application of low temperature (<300°F) geothermal water for both electric power production and direct heat utilization in industry. The thrust of this report is directed to the project plan for the combined or integrated electrical and non-electrical utilization of geothermal energy with maximum utilization of available heat. Therefore, the benefit that may be derived from an integrated use of low temperature geothermal water on the cost of electrical power production is included for discussion. This report addresses the project plan in its' entirety, i.e., the total integrated system, whereas initial steps may involve a lesser number of participants. However, progress and participant interest to date in the concept herein proposed, have been encouraging.

2.0 GEOTHERMAL ENERGY UTILIZATION

Despite the tremendous potential of geothermal energy, use has historically been for one application at a time, usually space heating or electrical power production. The heat which could be supplied by a resource such as that available in the Raft River Valley, (∿300^{0}F water), should be applicable to a number of different uses by various industries concurrently.

2.1 Electrical Power Production

The production of electrical power from intermediate temperature geothermal water could potentially have a larger impact on geothermal power production than geothermal steam. This is due primarily to the wider distribution of water at this temperature relative to steam. A demonstration plant for the intermediate temperature resource will provide information to the public utility companies as to the cost and reliability of power generation from this type of geothermal resource.

2.2 Non-Electrical Applications, Potential and Benefits

The industrial processes for the direct applications of geothermal heat at Raft River Demonstration Project will by necessity be low temperature in nature and energy intensive. The food production, storage, and processing industries, which are indiginous to southern Idaho, exhibit the greatest potential for low temperature energy utilization in the Raft River area.

The potential heat available from one geothermal well assuming 300°F water is reduced to 130^{0}F with a flow of 1200 gpm is 10.2×10^7 Btu/hr. Approximately 600,000 Btu/hr/well can be derived for each usable degree thereafter. These figures should be reduced to account for distribution losses when determining usable quantities of heat. The exiting water from a geothermal power plant at 130°F can also supply a usable source of low temperature heat.

Industrial demonstrations should provide stimulus to industry to adapt geothermal energy as a source of process heat. The net effect of massive geothermal heat utilization would be to reduce the demand on fossil fuel energy supplies, particularly natural gas, which currently supply most industrial heat. This would also have a favorable effect on reducing the energy dependence this country has on the OPEC Nations while improving our balance of trade situation. The usable heat from geothermal wells with 300°F water could compete favorably with current fossil fuel prices. Geothermal heat could be sold at 3-8¢/Therm while current coal and natural gas costs are 14¢/Therm and 17¢/Therm respectively in the intermountain area.

2.3 Relation of Direct Geothermal Applications to Electrical Power Costs

The projected power costs (Table I) are much higher, for all cases shown, than the current costs of power in the Raft River area. A significant portion of the plant costs are the costs of the wells which can be amortized over a broader base if direct heat applications are incorporated into the overall use scheme. The sale of the heat for these applications could reduce the required selling price of the electricity to a level which is competitive with power systems currently going on line.

One argument is that the use of waste heat is an unfair way to offset geothermal power plant costs since this procedure could be used with a coal fired or nuclear plant. This is not a valid analogy, however, as most industries require a continuous heat source and a geothermal source provides uninterrupted heat even if the power plant is not in service while this is not true of coal, oil or nuclear plants.

2.4 Cascading Temperature Uses

The cascading concept is the use of geothermal heat at various temperature levels such that exiting geothermal water from one industrial process is the feed water to the next lower temperature process. One process may use heat which would decrease the water temperature from 300°F to 210°F. The next process, may utilize heat resulting in an exit water temperature of 180°F with still another process discharging exit water at a temperature of 130°F. The purpose of the cascading process is to obtain the maximum use of the available energy source by extracting the maximum quantity of usable heat energy.

TABLE I

POWER PLANT COST ESTIMATES AND RESULTING POWER COSTS
(All based on wells producing 1250 gallons/minute of 300^{0} water)

Plant Type	10 MWe $/kW Installed	10 MWe Mills/kW-hr	50 MWe $/kW Installed	50 MWe Mills/kW-hr
Double Boiler Binary Flexible Power Plant (130 + 210^{0}F)	2080	45.9	1542	34.6
Double Boiler Binary Bare Power Plant (130 + 210^{0}F)	1605	35.4	1190	26.7
Single Boiler Binary Flexible Power Plant (205^{0}F)	2635	58.1	2116	47.5
Single Boiler Binary Bare Power Plant (205^{0}F)	2170	47.9	1746	39.2
Single Flash Steam Flexible Power Plant (240^{0}F Flash)	3145	69.4	2885	64.7
Single Flash Steam Bare Power Plant (240^{0}F Flash)	2590	57.1	2375	53.3
Double Flash Steam Bare Power Plant (250 + 206^{0}F Flashes)	2095	46.2	1688	37.9

2.5 Integrated Park Concept

The cascading system in concert with a small electrical generating plant would by necessity of proximity and cooperation be ideally suited for an Integrated Geothermal Industrial Park. The Park will be connected both geographically and systematically by the geothermal fluid flow.

2.6 Participant Program

In order to implement the demonstrated use of direct geothermal heat, involvement of private industry is mandatory. The demonstrated visible advantage of low cost energy to a few users, will provide the incentive to commit other potential users to the new technology. In this regard all demonstrations at Raft River will, with the exception of the power plant, be wholly owned and operated by private industry with technical assistance provided by INEL.

3.0 POTENTIAL ELECTRICAL USE SCHEMES

The use of 300°F water for electrical power production can be approached in a number of different ways. The efficiency of heat use, the amount of geothermal fluid required, the environmental effects, the cost of power, and the potential operating difficulties are all affected by the use scheme. Three potential systems are examined, and though not exhaustive, they do represent the main alternative system types.

3.1 Single Flash Steam Power Plant

In this system the 300°F water is flashed at 25 psia or about 240°F. The steam generated is then passed through a turbine which drives the electrical generator. This system requires about 5.1×10^6 pounds of water per hour most of which stays with the liquid phase from the flasher and is reinjected into the geothermal reservoir. The exiting steam from the turbine is condensed and reinjected with the liquid phase from the flasher. The costs of the power plants were shown in Table I along with the resulting power costs. The single flash steam system has the highest power costs of all systems investigated.

The main potential problems of the single flash system are the possibility of solids coming out of solution during the flashing operation and the large volume of fluid that has to be disposed of. When the pressure is dropped to flash the water, dissolved CO_2 is allowed to come out of solution thus shifting the $CaCO_3$ equilibrium and resulting in crystalization and possible fouling of the system. If any crystalization that occurs can be confined to the flashing vessel itself with some provision made for removal of solids that build up, the problem can be controlled. Though all three systems would have considerable water volumes to dispose of, the single flash system would have the largest. This system would require more wells for both production and reinjection and thus a more extensive distribution system requiring either ownership or easements on more land.

3.2 Single Boiler Binary Power Plant

In this system the geothermal water is used to vaporize a secondary fluid such as isobutane or one of the freons. The secondary fluid vapor would then be used to drive the generator turbine. Assuming that the outlet water temperature is 205°F the required flow rate would be 3.8×10^6 pounds of water per hour. After the brine is heat exchanged with the secondary fluid, it would be reinjected as with the previous system. The power costs are lower for this system than for the single flash system.

As with the single flash system, a large volume of water (~75% of that for single flash) will have to be disposed of. The design of efficient non-fouling heat exchangers is the other potential problem; though by maintaining adequate pressure on the fluid to prevent gassing, deposition should be controlled as the most troublesome species, $CaCO_3$, has an inverse solubility vs temperature curve when pressure is maintained.

3.3 Double Boiler Binary Power Plant

As in the single boiler binary system, the geothermal fluid is used to vaporize a second working fluid which in turn drives the turbines. In the dual boiler case, the secondary fluid is vaporized at two different temperatures and drives both a high and low pressure turbine. Assuming an outlet brine temperature of 130°F a geothermal fluid flow of 2.5×10^6 pounds per hour would be required. This is markedly less flow than either of the other options discussed. The power costs for this system are lower than either of the other two options.

The problems in the double boiler and single boiler systems are similar. The double boiler system requires only 66% of the flow required of the single boiler system and 50% of the flow required of the single flash system, thus resulting in significantly smaller water volumes to handle and dispose of. Again, the water will be reinjected to minimize environmental impact. The smaller water flow for this type of plant would require fewer wells and thus a less extensive distribution system, affecting a smaller portion of the Raft River ecosystem.

4.0 POTENTIAL NON-ELECTRICAL DEMONSTRATION UNITS

Industries for potential demonstration of the utilization of geothermal energy at Raft River were selected using the following criteria:

1. The industry should have sizeable requirements for low to moderate temperature heat.
2. One installation should be representative of the particular industrial process at large.
3. The process is either indigenous to the Raft River area or is readily adapted to the area. Both raw materials and markets should be readily available.
4. The processes should cascade to use energies at all levels.
5. The industry should have acceptable social and environmental impacts on the Raft River Valley.

The following industries have been tentatively selected:

	Process	Desirable Size
1.	Potato Processing	200,000 #/day
2.	Manure Processing	300,000 #/day (raw manure basis)
3.	Cattle Feeding	10,000 head feedlot
4.	Greenhousing	10 acres
5.	Fish Farming	200,000 #/yr of fish
6.	Slaughterhouse and Meat Storage	1000 Tons refrigeration
7.	Tree Breeding	10 acres (experimental)

These industries are well suited to meet the criteria outlined above, and a combination of these processes with a geothermal electric plant would form a symbiotic arrangement as shown in Figure 1. Not only is energy used efficiently, but the product of many of these industries can be used as input to other industries in the demonstration unit.

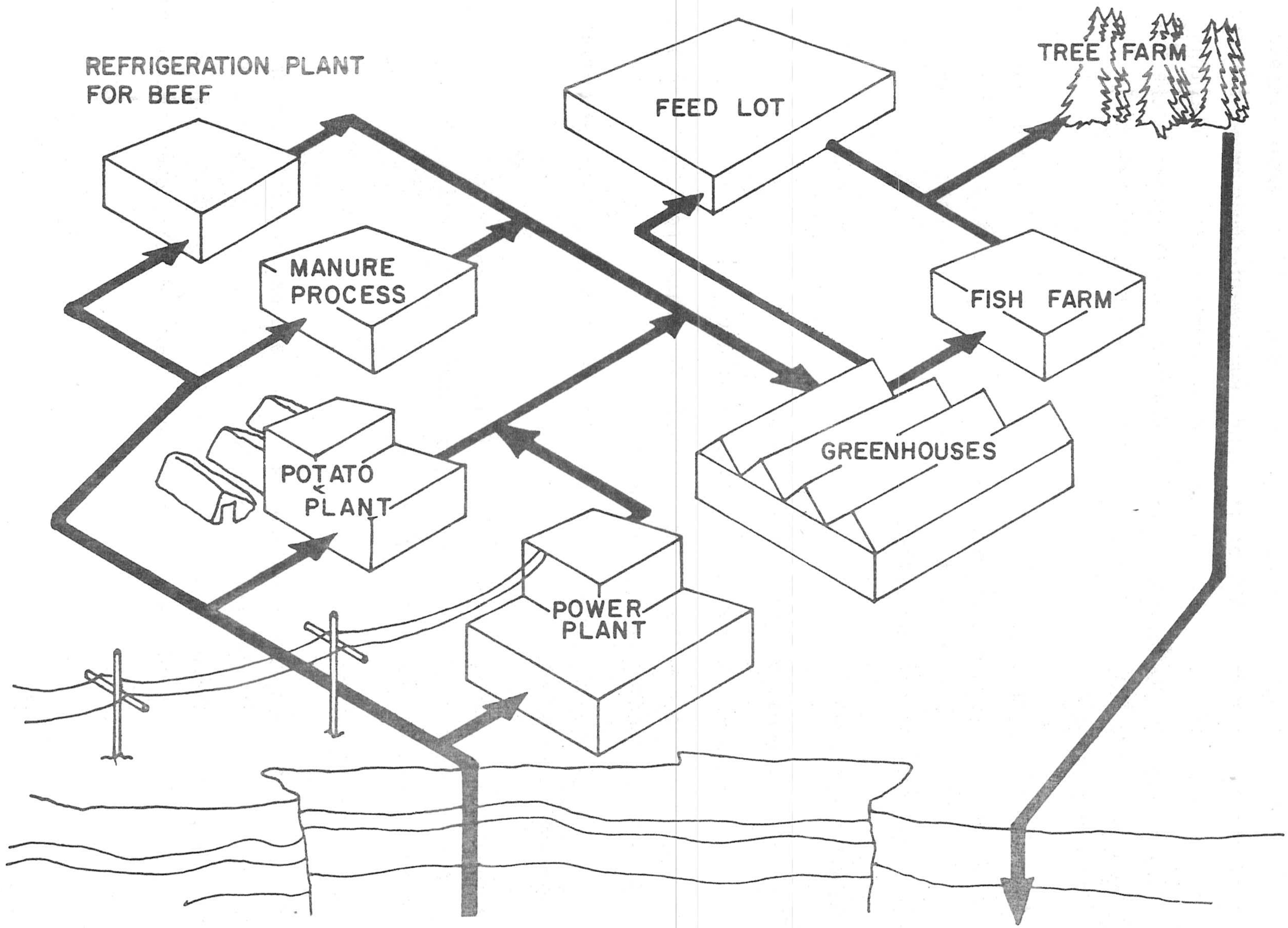

Figure 1 Integrated Geothermal Energy Park

4.1 Potato Processing

A potato dehydration plant with an output of 100 tons/day uses approximately 25,000 Therms of heat per day, requires about 1200 gpm of fresh water and about 100 acres of land. If an acceptable method of process water disposal can be developed, as much as 80% of the land requirement could be eliminated. Water cleanup and recycle could cut water requirements materially but this will require industry incentives. The low availability of water in the Raft River area may force this kind of development in order to utilize the inexpensive energy source.

Flashing should provide enthalpy of vaporization for the processes requiring steam. Sensible heat required to bring the steam up to 350°F could be provided by heat pump, solar topping, fossil fuel, or electricity whichever provides the greatest cost advantage.

4.2 Manure Processing

The manure process has three main products:

1. A feed material equivalent to corn silage.
2. A high protein (∿30%) feed suitable for swine, poultry, fish and other concentrated protein users.
3. A soil conditioner which could also be used as a fuel. (Heating value ∿7000 Btu/lb).

A manure processing plant capable of handling the waste from 10,000 head of cattle would require ∿5 acres. The water requirements are ∿10 gpm. The plant heat use is ∿2000 Therms/day.

4.3 Cattle Feeding

The cattle feeding should be done on a concrete pad feedlot with an area of about 7 acres. The water consumption for 10,000 head should be about 125 gpm. To insure optimum living conditions for the cattle, the lot should have a roof and closable sides for heating in winter. Maximum heat loads during the coldest winter weather would run about 1.8 x 10^6 Btu/hr and would drop to zero during the summer. The manure from the feedlot would be processed in the manure plant and the silage equivalent product could be fed back to the cattle.

4.4 Greenhousing

Greenhouse operations including both cut flower and vegetable culture could total about 10 acres under cultivation or about 12 acres total installation area. The fresh water irrigation requirements should be about 185 gpm. Maximum heat loads during the winter could reach 7.2 x 10^7 Btu/hr with an average of about 5 x 10^7 Btu/hr year round and a minimum of zero on warm sunny days. Water of 130-135°F would be hot enough for greenhouse heating. Soil conditioner from the manure process could be used in the greenhouse bed.

4.5 Fish Farming

The fish farm would raise warm water fish such as channel catfish, tilapia, and a species of fresh water shrimp. About .3 acre of pond surface would be required with a total area for the installation of about 2 acres. Water is recirculated at about 7,200 gpm with a 33% make-up. The resulting water demand is about 2400 gpm. The water requirement is not consumptive as the water discharged could go back to the ground water system with an allowable buildup of fish wastes or be used for irrigation.

The maximum heat demands will be 1.9 x 10^7 Btu/hr with a minimum of 4.8 x 10^7 Btu/hr and an average use of $\sim$1.8 x 10^7 Btu/hr. Geothermal water as cool as 120°F could be used and still provide sufficient heat energy.

4.6 Refrigeration

The refrigeration system will be used for storage of products from the feedlot and the fish farm. No fresh water is required for this process. About 1 acre is required and would include adequate space for slaughtering, cutting, chilling, and deep freeze. The heat required for a 1000 ton ammonia absorption refrigeration unit (part for the chiller for fresh slaughtered beef and part for the freezer) could be supplied by the water from one well (1200 gpm 300°F) while dropping the outlet geothermal temperature to ∿220°F.

4.7 Tree Breeding

Tree Breeding would be the lowest grade use of the geothermal heat. An underground piping network is used for soil heating to extend the growing season. Trees could be grown from 5 to 9 years, uprooted, and chopped up for particle board manufacture. Geothermal water could be used in irrigation of the tree-breeding plot. Water temperatures (geothermal) would start below 120°F at the inlet of the tree breeding plot and could be useful down to ∿90°F. Tree breeding would be operated on an experimental basis until such time as it proves economically favorable enough to interest private industry in such a commercial venture.

5.0 PROCESS DESCRIPTIONS

The processes chosen for the demonstration site vary from simple space heating of a plant or animal environment to complex industrial processes.

5.1 Potato Process

Figure 2 shows a potato dehydration process schematic flow sheet. The operational energy demands for potato dehydration are:

1. Peeling 7.3×10^6 Btu/hr into a caustic solution of 180°F.
2. Precook 10.4×10^6 Btu/hr into water @ 170°F.
3. Cook 7000 #/hr atmospheric steam.
4. Dry
   a) Flakes 45,000 #/hr steam @ 350°F 135 psia.
   b) Slices $\sim 25 \times 10^6$ Btu/hr into dry air @ 180 to 230°F.

The potato dehydration process relies on a hot caustic solution to loosen the peels which are then removed by a system of rollers and water jets. The potatoes are then sliced and pre-cooked in ∿ 170°F water to expand the starch cells before cooking. The slices are then cooked in atmospheric steam. The cooked slices are either dehydrated by passing hot dry air up through a belt carrying the slices or are mashed and dried on a rotating drum which is heated internally with 350°F steam. Some supplemental energy will have to be added to bring the flashed steam to temperature. Other processes are available, but they appear less amenable to use with intermediate temperature geothermal water systems. Heat for the peeling and pre-cooking will be provided by heat exchange of the geothermal fluid with the process fluids.

5.2 Manure Process

The manure process is shown schematically in Figure 3. The two major points of heat use are the evaporator and dryer (both of which require steam). This steam can be supplied by flashing the geothermal water, to provide the enthalpy of vaporization, then fossil fuel can be used to provide the additional sensible heat needed. Heat pumping and solar topping are also possible as methods for adding additional heat to the flashed steam.

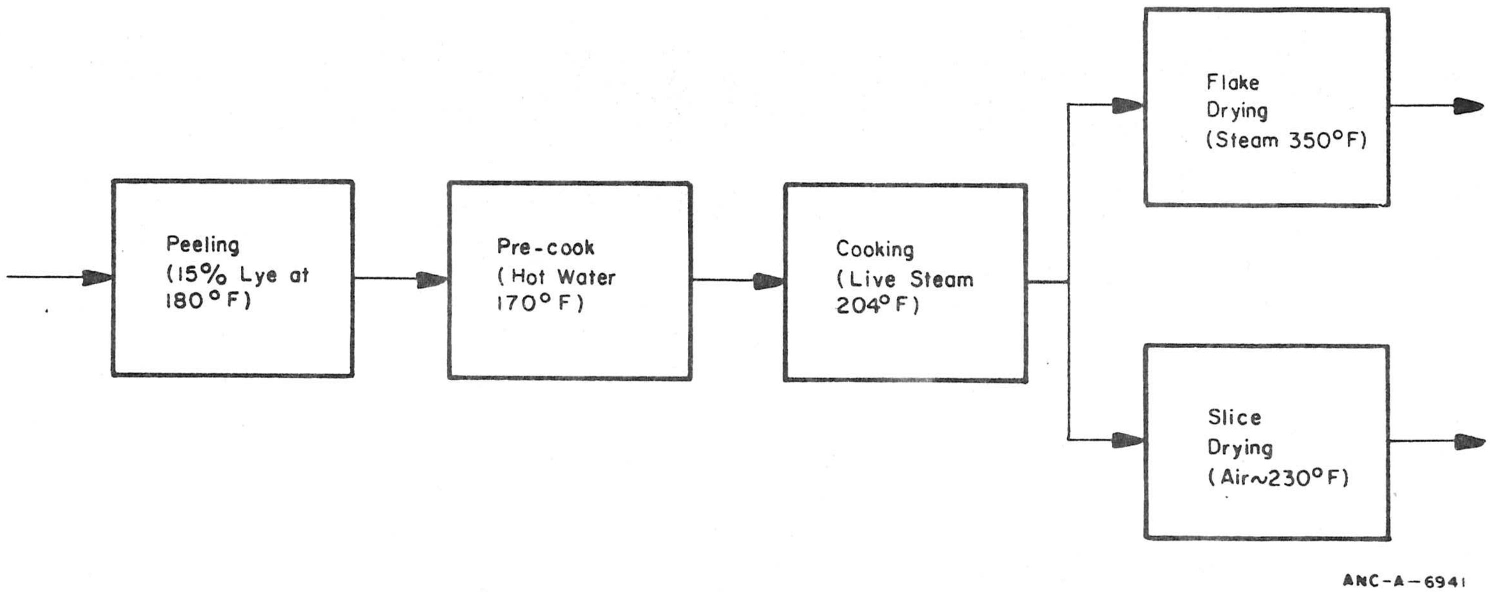

Figure 2 Potato Process

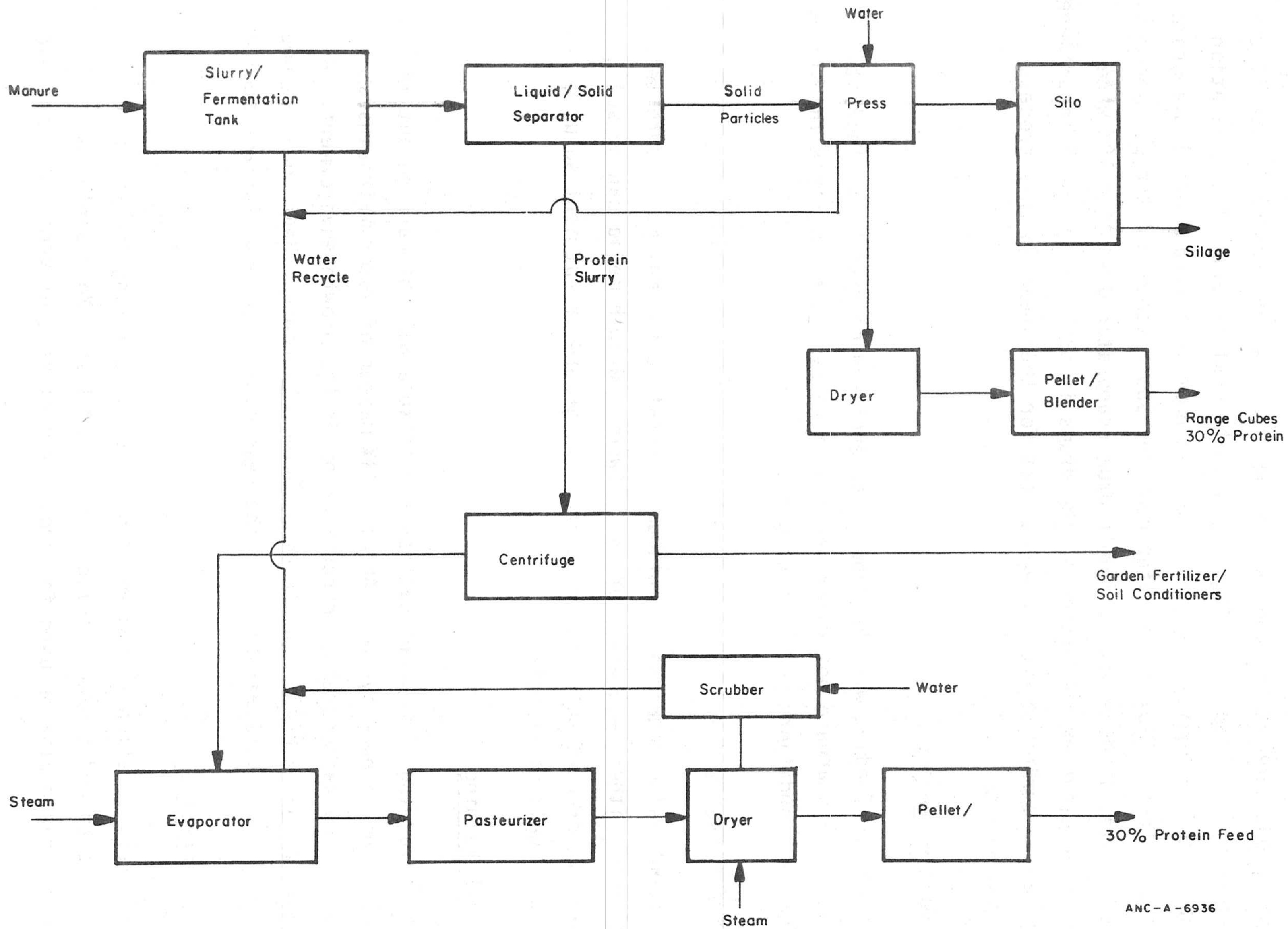

Figure 3 MANURE PROCESS

The manure process starts with a slurry/fermentation step where the anaerobic production of NH_4 causes a change in pH which eventually sterilizes the mixture. This step is followed by a mechanical liquid-solid separation. The high protein (liquid) fraction is boiled down in a scraped-wall evaporator to an H_2O content of 70%. This step requires 350°F steam. After pastuerization, the final drying is done with a double drum evaporator down to a 10% water content. The steam on the inside of the drums is ~300°F. The soil conditioner product can be buried to provide extra heat for the steam in this process and for the potato process.

5.3 Cattle Feeding

The cattle feeding will be done on an enclosed concrete slab feedlot which can use a standard hot water space heating system to maintain the optimum environmental conditions for fattening the cattle.

5.4 Greenhousing

Greenhousing requires an optimum temperature for maximum growth and production of either vegetables or cut flowers. Growth media can be soil, sand, gravel, or pure nutrient solution. The ground or nutrient solution can be heated as well as the air.

5.5 Fish Farming

Fish farming of channel catfish and tilapia will be carried out in a recirculating raceway system. About a 33% makeup of water maintains a sufficiently low waste product concentration in the growth environment. A temperature range of 80-85°F would be optimum for growth. Heat loads assume warm water (~70°F) is available from the reasonably warm near surface aquifer.

5.6 Refrigeration

The refrigeration system would provide for chilling (~45°F) of slaughtered beef and frozen storage of beef and fish. Moderately low temperatures could also be used for short term storage of vegetables and cut flowers.

TABLE II

PROCESS CONDITIONS WITH VARIOUS POWER PLANT OPTIONS

System & Input lb/hr	Steam For Potato & Cereco Processes	Refrig-eration	Potato Peeling	Pre-cooking	Green-housing	Fish Farming	Cattle Feeding	Tree Breeding
Single Flash 5.1×10^6 from P.P. 240°F $.3 \times 10^6$ other 300°F 5.4×10^6 Total 9 wells	9.0×10^4 lb/hr @ 210°F	2.6×10^6 lb/hr 240-210°F	2.8×10^6 lb/hr 210-205°F	2.8×10^6 lb/hr 205-198°F	5.4×10^6 lb/hr 204-160°F Max.Drop (60 acres)	4.7×10^6 lb/hr 160-136°F (1.5×10^6 #/yr)	$.7 \times 10^6$ lb/hr 160-136°F	5.4×10^6 lb/hr 136-101°F (650 acres)
Single Boiler Binary 3.8×10^6 from P.P. 205°F 1.0×10^6 for other 300°F 4.8×10^6 Total 8 wells	9.0×10^4 lb/hr @ 210°F	4.8×10^6 lb/hr 206-194°F	2.4×10^6 lb/hr 194-188°F	2.4×10^6 lb/hr 194-186°F	4.8×10^6 lb/hr 187-145°F Max.Drop (50 acres)	4.0×10^6 lb/hr 145-125°F (10^6 #/yr)	$.8 \times 10^6$ lb/hr 145-125°F	4.8×10^6 lb/hr 125-101°F (400 acres)
Double Boiler Binary 2.5×10^6 from P.P. 130°F 1.7×10^6 for other 300°F 4.2×10^6 Total 7 wells	9×19^4 lb/hr @ 220°F	$.6 \times 10^6$ lb/hr 300-210°F	1.1×10^6 lb/hr 220-207°F	1.1×10^6 lb/hr 207-189°F	4.2×10^6 lb/hr 156-128°F 30 acres	3.0×10^6 lb/hr 128-115°F (5×10^5 #/yr	1.2×10^6 lb/hr 128-115°F	4.2×10^6 lb/hr 115-101°F (200 acres)

5.7 Tree Breeding

The growing season for trees could be extended in cold climates by soil heating. Pipes carrying the geothermal water are placed two feet underground on six foot centers for heating.

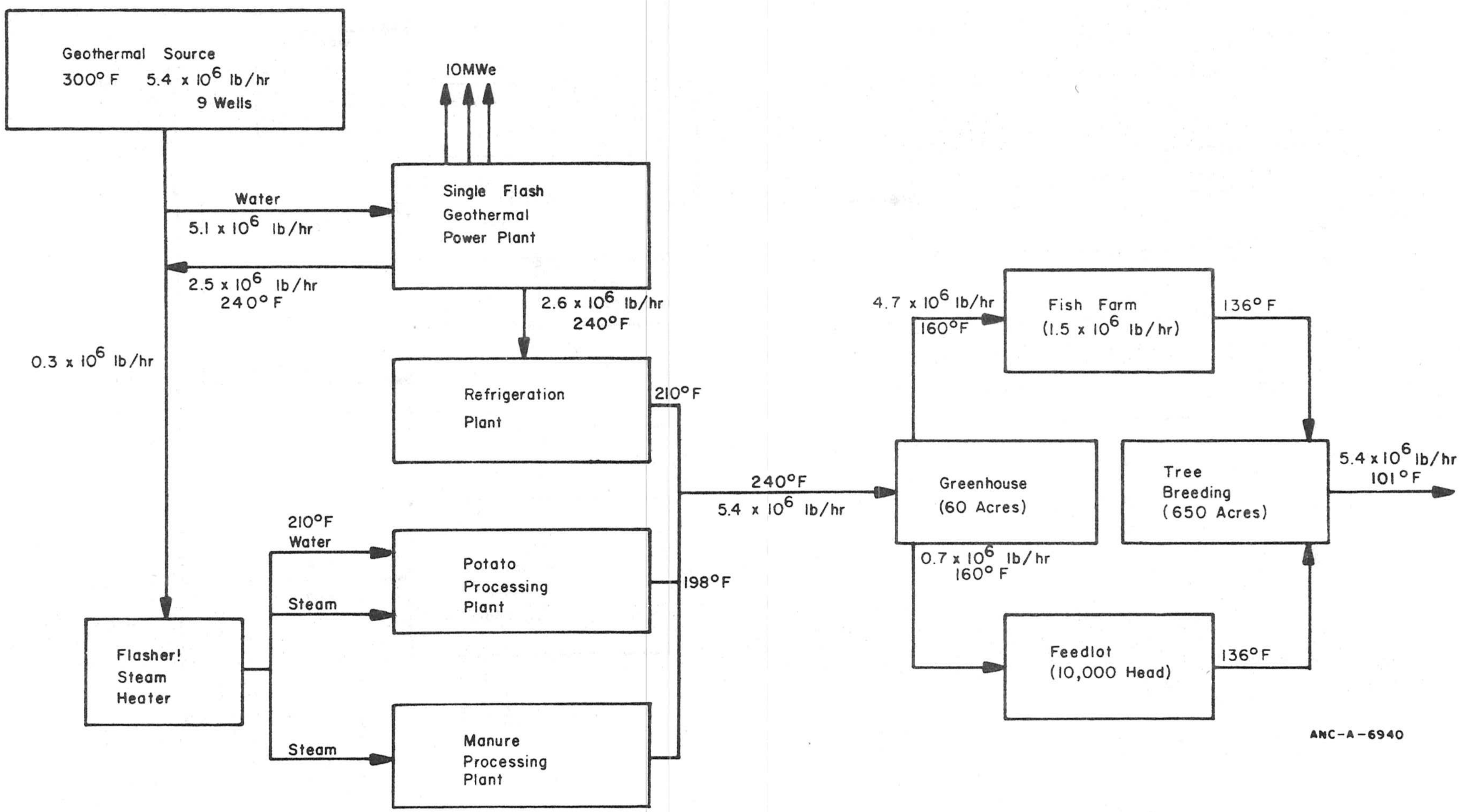

Figure 4 ENERGY PARK FLOW SHEET WITH SINGLE FLASH POWER PLANT

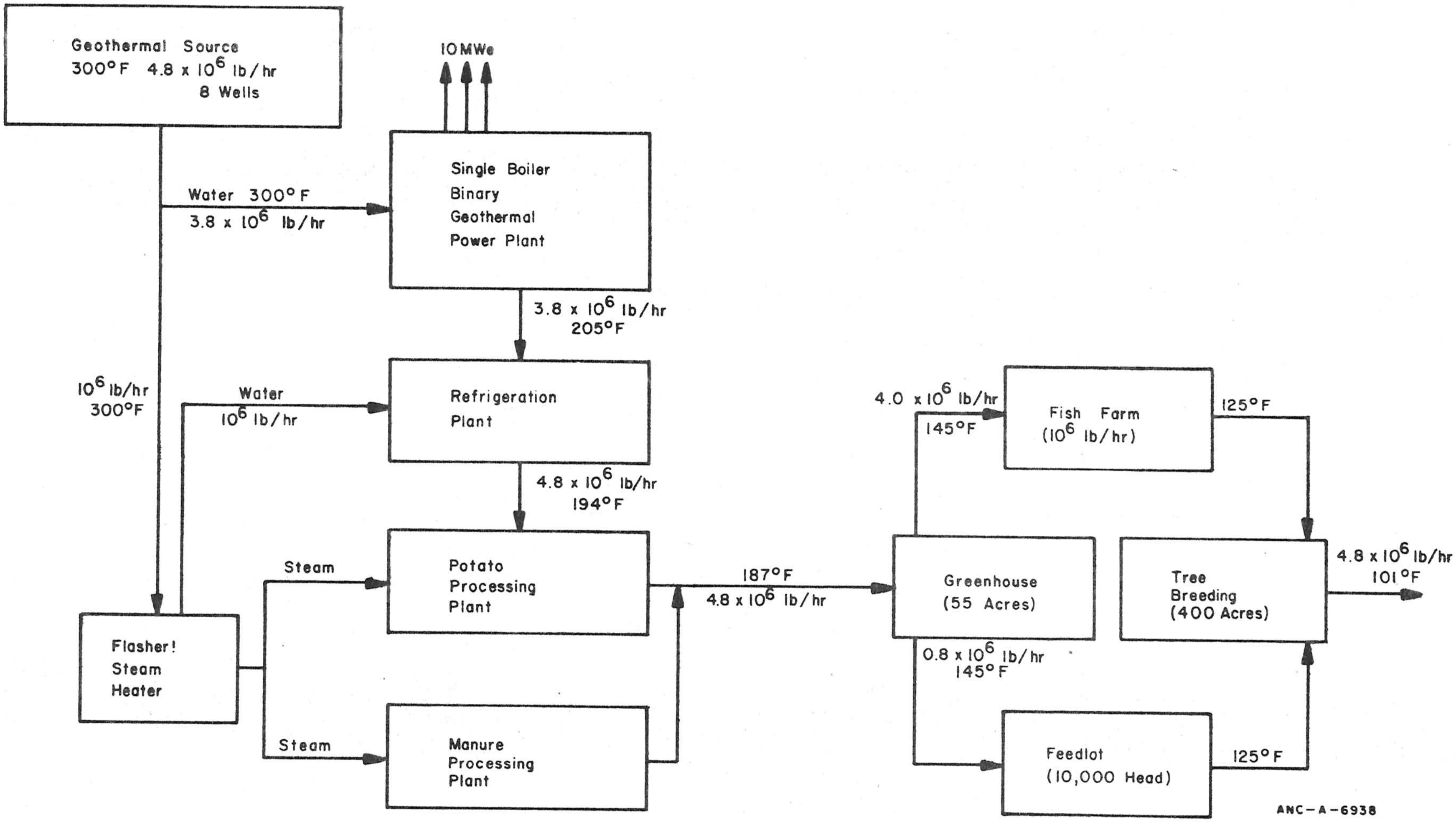

Figure 5 ENERGY PARK FLOW SHEET WITH SINGLE BOILER BINARY POWER PLANT

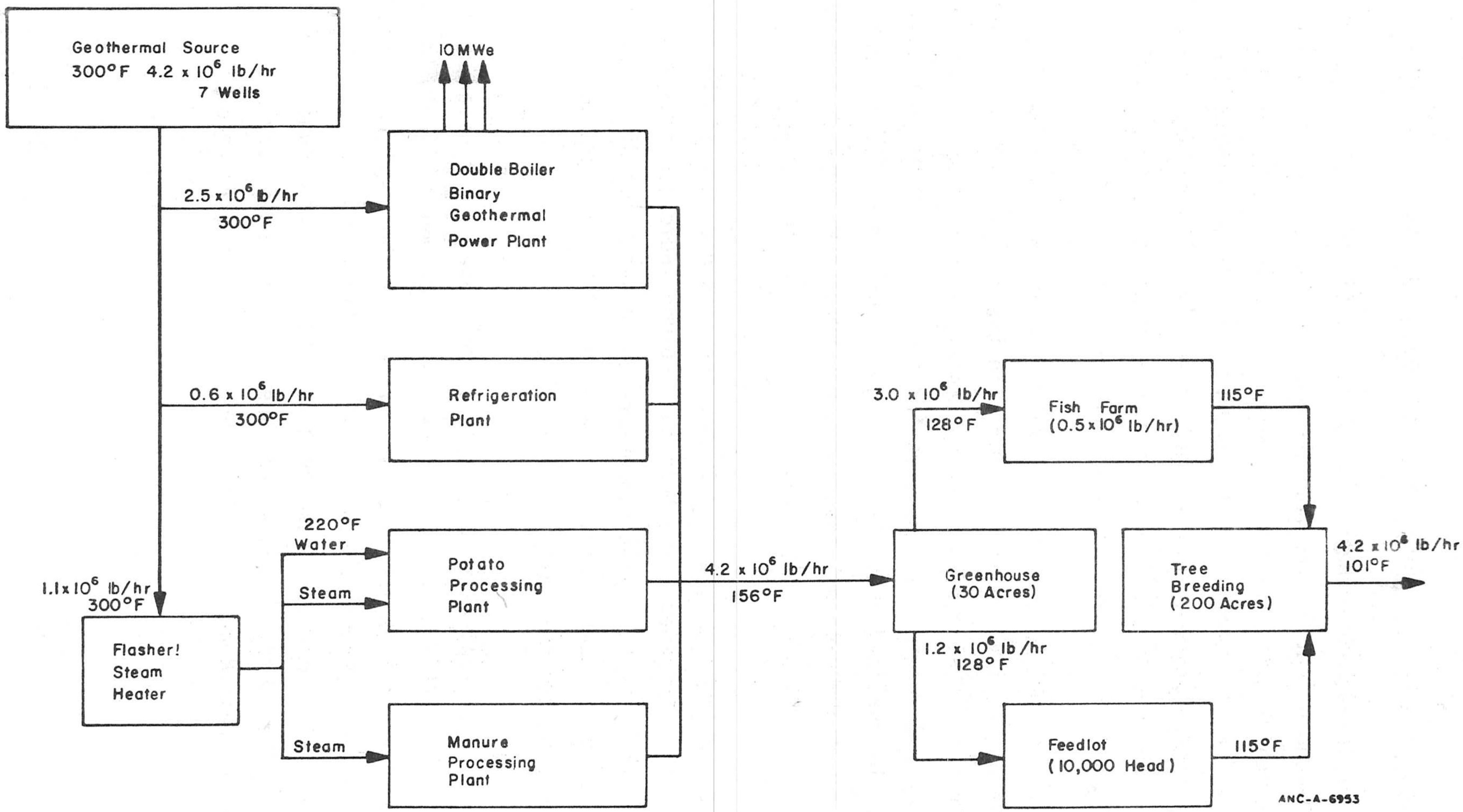

Figure 6 ENERGY PARK FLOWSHEET WITH DOUBLE BOILER BINARY POWER PLANT

6.0 INTEGRATION OF THE POWER PLANT OPTIONS WITH DIRECT HEAT USES

The efficient and economic use of the available heat in a geothermal system is dependent on: (1) matching the availability of heat in a given temperature regime with an appropriate end use or (2) adjusting the requirements of the end use to fit the available temperature. In discussing the concept of cascading temperatures, the desirability of bringing the geothermal fluid usefully to the lowest possible end temperature was discussed. This results in efficient use of the heat available in the system.

The three power plant options, discussed in Section 3, will be compared in this section relative to integration with the direct heat uses proposed. It should be noted that for both binary systems a significant volume of water directly from the wellhead is required for the higher temperature uses. It must also be realized that all of the users would not likely start operations simultaneously but that the use scheme shown here is considered a realistic endpoint for a vigorous development program.

Table 2 and Figures 4, 5, and 6 show the cascading use of the water in the three systems examined. The left hand column indicates the water used for power production, its' exit temperature, the water for direct use at $300^{0}F$, and the total number of wells required. It is assumed that 6×10^{5} lb/hr is the production from an average well.

Figure 7 shows realistic potentials for the use of hot water in the Raft River Area. The required additional use which would have to be stimulated for complete heat utilization is shown for each of the power plant options. The difference between what could be realistically stimulated at this time and the potential from the plants indicates the relative amount of heat which would actually be wasted at projected feasible development levels. The amounts of heat wasted are shown in Figure 7 as these differences.

The double boiler binary system requires fewer total wells even with the direct heat uses and at the same time more effectively uses the available heat. It must be realized that these heat loads for all systems, are based on minimum winter temperatures.

The performance of each of the systems with the different temperature inputs is essentially equivalent with the exception of the refrigeration system. Some of the other systems, greenhousing for example, might require additional heat transfer surface due to the lower driving force when lower temperature water is used. The refrigeration systems depend on higher temperature heat to produce lower temperature refrigeration.

Figure 8 shows how heat sales might be used to lower electricity prices by broadening the base for amortizing the wells and distribution system. Heat sales are assumed to be at the same level for all three systems and equal to that which would be sold to the entire Energy Park assuming total, simultaneous operation at the level of total heat use with the double boiler binary plant.

Integration of the direct heat uses with the double boiler binary system provides the most efficient use of the available heat, the smallest system of wells, and the lowest cost of power production. This combination would also provide the most flexibility for the refrigeration system.

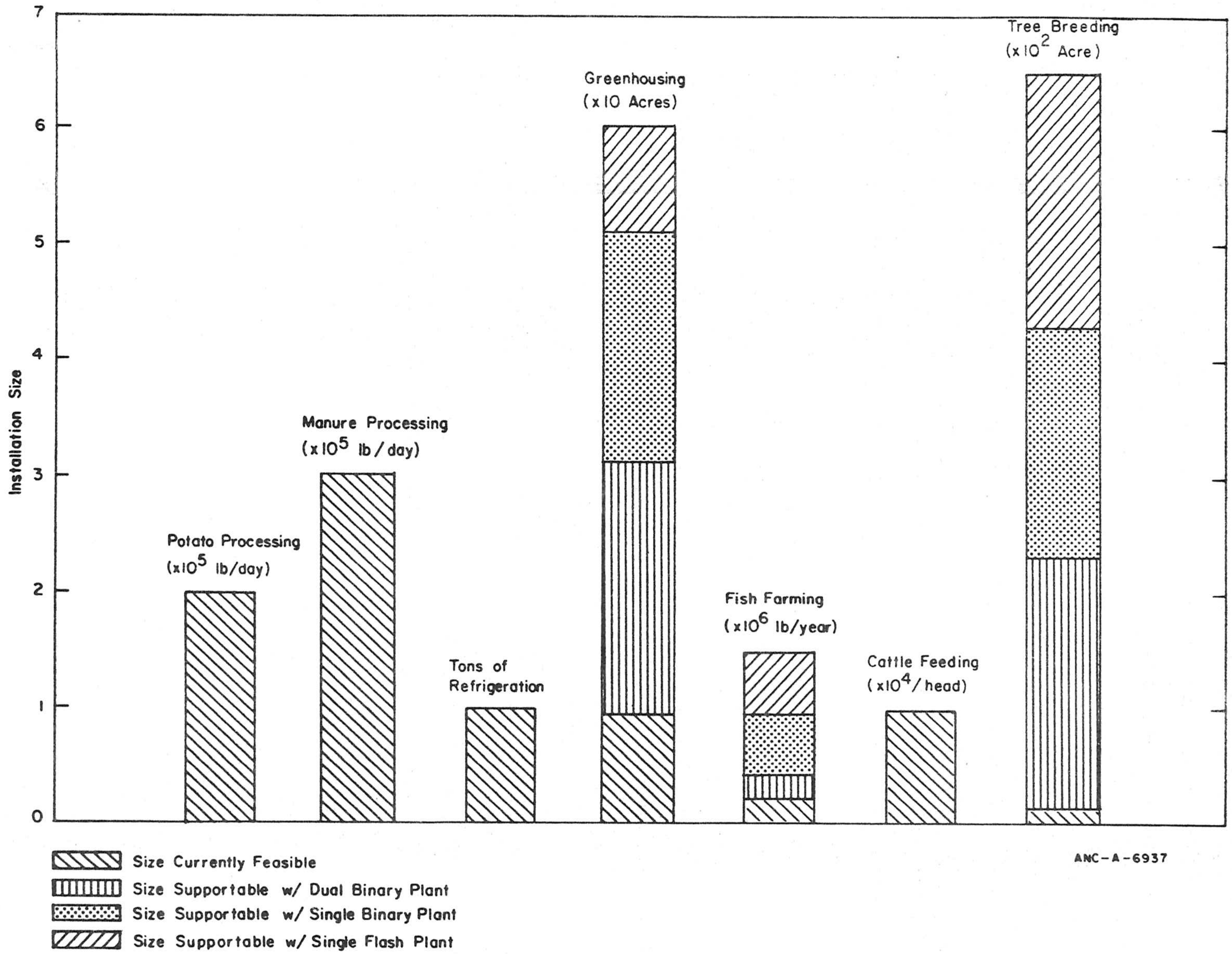

Figure 7 POTENTIAL INDUSTRIAL PROCESS SIZES

7.0 UTILIZATION SUMMARY AND RECOMMENDATIONS

The individual and total heat use rates for seven potential direct heat users are shown in Table 3. It should be noted that it is not expected that all of these uses will begin simultaneously, but that a gradual, but still well planned, industrial buildup should take place. It must be realized that not all of these processes are heavily base loaded and that large seasonal variations occur.

Table 4 presents a summary of energy consumption, water use, land requirements, capital investments and potential process interactions for the prospective direct heat users.

All of the potential direct uses represent significant capital investments for the participants involved. Aid should be made available by ERDA and its' contractors in the following areas to enhance and encourage industrial participation:

1. Provision for distribution of energy at a low initial cost.
2. Technical aid in adapting the process to the energy resource.
3. Assistance in acquiring process water.
4. Assistance in finding purchasable or leasable land.
5. Assistance with environmental impact analysis.
6. Some provision for compensation, or substitution of another energy source should the geothermal resource fail.

Due to economical considerations, efficiency of heat utilization, amount of geothermal fluid required, and the greater overall system flexibility, the Double Boiler Binary Power Plant is the recommended system for development at the Raft River Site.

TABLE III

RAFT RIVER DIRECT HEAT USE SUMMARY

PROCESS	UTILIZATION POTENTIAL TH/yr.	USE REQD. FOR DUAL BINARY TH/yr	USE REQD. FOR SINGLE BINARY TH/yr	USE REQD. FOR SINGLE FLASH TH/yr
Potato Dehydration	5.8×10^6	5.8×10^6	5.8×10^6	5.8×10^6
Manure Processing	7.0×10^5	7.0×10^5	7.0×10^5	7.0×10^5
Fish Farming	1.6×10^6	4.0×10^6	8.0×10^6	1.2×10^7
Greenhousing	1.5×10^6	4.4×10^6	7.3×10^6	8.8×10^6
Refrigeration	2.8×10^6	2.8×10^6	2.8×10^6	2.8×10^6
Tree Breeding	5.5×10^4	1.1×10^6	2.2×10^6	3.6×10^6
Feedlot Heating	8.8×10^5	8.8×10^5	8.8×10^5	8.8×10^5
	13.3×10^6	19.7×10^6	27.7×10^6	34.6×10^6

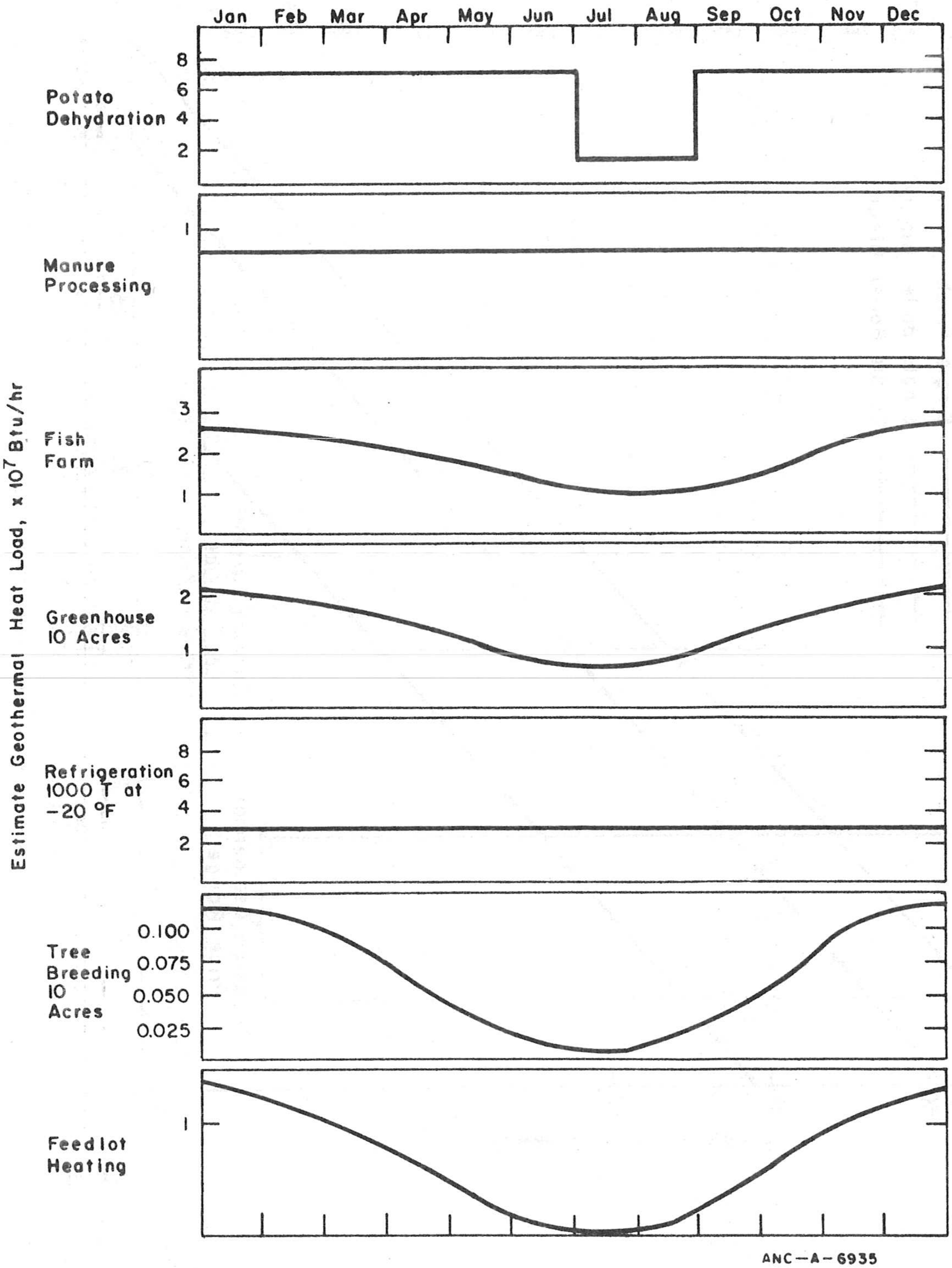

Figure 8 YEARLY ENERGY USE RATE

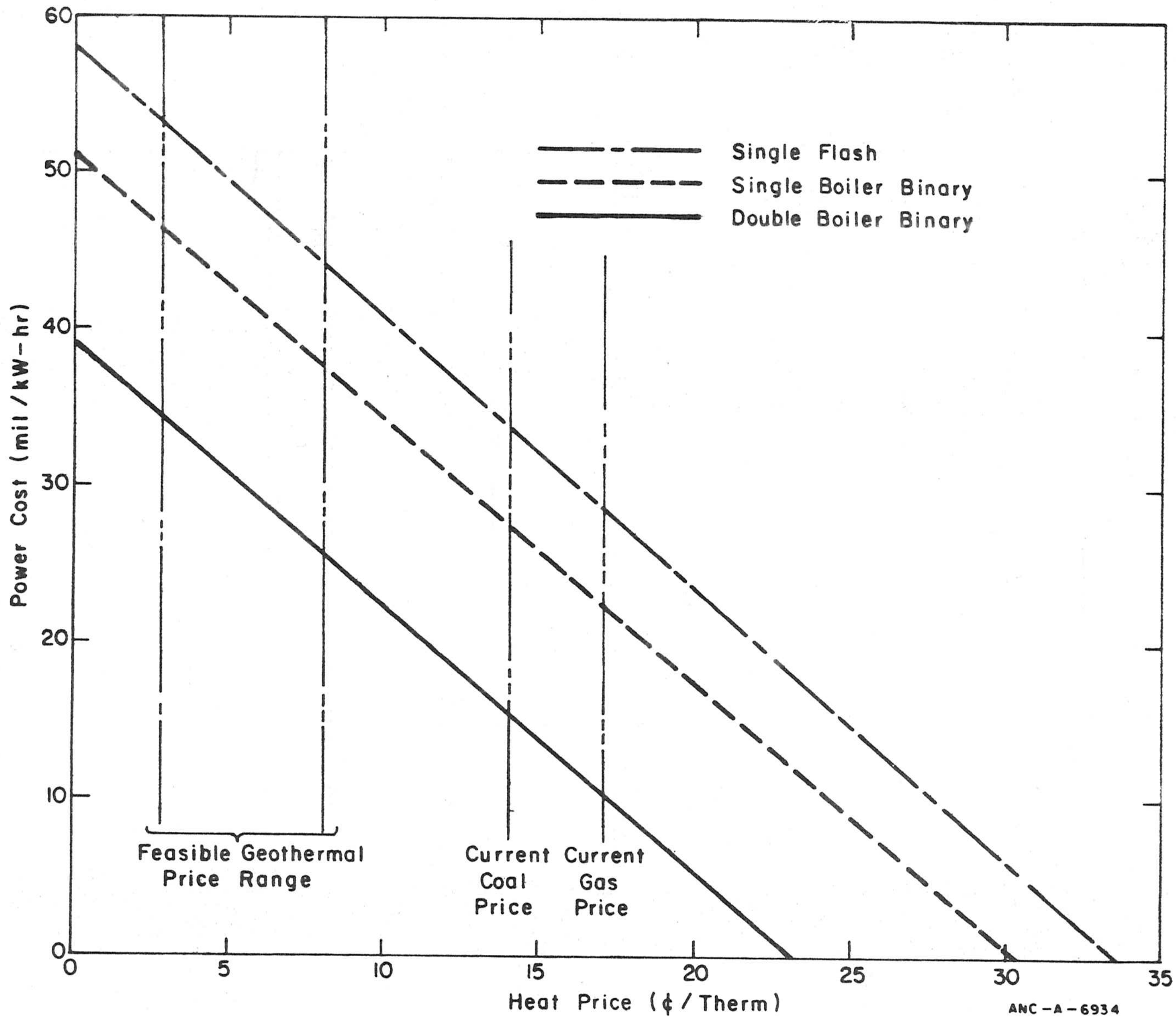

Figure 9 POWER PRICE REDUCTION WITH HEAT SALES

TABLE IV

SUMMARY OF NON-ELECTRICAL REQUIREMENTS AND INTERACTIONS

Process	Annual Energy Use	Max. Fresh Water Use Rate	Land Requirements	Approximate Electrical Requirements	Index	Potential Interactions	~Capital Investment
Potato Dehydration	5.8 x 10" Btu/yr	1200 gpm	100 acres	3000 kw	a	c	$ 7,000,000
Manure Processing	7.0×10^{10} Btu/yr	10 gpm	5 acres	400 kw	b	e,c,d,g	1,500,000
Cattle Feedlot	8.8×10^{10} Btu/yr	125 gpm	7 acres	<150 kw	c	a,b,f	2,000,000
Green-housing	1.5×10^{11} Btu/yr	60 gpm	12 acres	500 kw	d	b,f	1,500,000
Fish Farming	1.6×10^{11} Btu/yr	2400 gpm	2 acres	600 kw	e	b,f	600,000
Refrigeration-Slaughter house	2.8×10^{11} Btu/yr	0	1 acre	<10 kw	f	c,d,e	1,000,000
Tree Breeding	5.5×10^{9} Btu/yr	25	10 acres	<10 kw	g	b	100,000

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3. ANCR - 1214 - National Program Detection Study for the Non-Electrical Utilization at Geothermal Energy A. S. Richardson J. F. Kunze

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