DOE/ET/28434-12

DIRECT USES OF HOT WATER
(GEOTHERMAL)
IN DAIRYING

MASTER

-CLR CONSORTIUM-

WORK PERFORMED UNDER CONTRACT
NO. SY-76-c-03-1324

AC03-76ET 28434

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PREPARED FOR ENERGY RESEARCH
AND DEVELOPMENT ADMINISTRATION
(UNITED STATES DEPARTMENT OF ENERGY)
DIVISION OF GEOTHERMAL ENERGY

AUTHORS OF REPORT:

Edmund R. Barmettler ✓
W. Russell Rose, Jr. ✓

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CLR CONSORTIUM

PROJECT TEAM MEMBERS

(C) CALIFORNIA STATE UNIVERSITY, CHICO, CALIFORNIA

- 1) Dr. Robert Colwell
Director of Steady State Energy Investigation
Professor of Mechanical Engineering
- 2) Dr. Ralph Huntsinger
Director of Transient Energy Investigation
Professor of Computer Science
- 3) Alan George
Research Assistant
Mechanical Engineering
- 4) Greg Woods
Research Assistant
Computer Science
- 5) John Lambeth
Senior, Mechanical Engineering
- 6) Dale Murdock
Senior, Mechanical Engineering
- 7) Dale Richter
Senior, Computer Science
- 8) Don Wolski
Senior, Computer Science

(L) LASSEN COLLEGE, SUSANVILLE, CALIFORNIA

- 1) W. Russell Rose, Jr.
Director, Learning Resource Center
- 2) Robert Hershberger
Animal Scientist

(R) UNIVERSITY OF NEVADA, RENO, NEVADA

- 1) Darrell W. Foote
Animal Scientist, Physiology
- 2) Charles Speth
Animal Scientist, Nutrition
- 3) Timothy Powell
Agriculture Economist
- 4) Dr. Edmund R. Barmettler
Consortium Director
& Principal Investigator

CONTROLLED ENVIRONMENT
LIVESTOCK PRODUCTION SYSTEM COMPUTER
SIMULATION AND ANALYSIS (DAIRY)

Edmund R. Barmettler
Director

CHICO, LASSEN, RENO CONSORTIUM

ABSTRACT

Digital computer simulation was used to investigate the peak, steady energy utilization of a geothermal energy-supported dairy. A digital computer program was also written to assess the lifetime economics of the dairy operation. A dynamic simulation program was written to design water storage tanks under diurnal transient loading.

The geothermal site specified is the artesian spring named Hobo Wells near Susanville, California. The dairy configuration studies are unique, but consists of conventional processing equipment. In the dairy, cattle waste would be used to generate methane and carbon dioxide by anaerobic digestion. Some carbon dioxide would be removed from the gas stream with a pressurized water scrubber to raise the heating value. The product gas would be combusted in a spark ignition engine connected to an electric generator. The electrical power produced would be used for operation of fans, pumps, lights and other equipment in the dairy. An absorption chiller using a geothermal water driven generator would provide milk chilling. Space heating would be done with forced air hot water unit heaters.

The steady state computer simulation designs (sizes) much of the equipment in the dairy based on herd size. A building thermal analysis of all barns is performed based on user-controlled climate and building heat transfer parameters. The fluid transmission piping is sized and insulation thickness is selected for hot water pipes, using an optimization approach based on thermodynamic availability. The user has control of pipe length, flow rate, temperatures, and the model network of pipes to be used.

Computer runs were made for a 200 milking cow dairy (412 animals) for a particular dairy layout (building orientation and piping network) and building design. A winter run was used to size pipes and some other equipment. A summer run shows the energy utilization of the designed dairy under summer climate conditions.

The program is written in BASIC and is very well documented. The report includes an extensive user manual to aid in the application and/or alteration of the simulation.

The 412 animal dairy has been laid out and drawn to scale, showing all functional components. A list of equipment specifications for this dairy has been included.

Energy utilization studies under load conditions revealed no energy limitations of the system. Only a small fraction of the available energy flow from the geothermal reservoir would be required. The generated electrical power allows the dairy to operate with near energy independence.

The economic analysis of the 200 milking cow model dairy has been determined to break even in about the second year of

operation; however, it becomes cost and return equal to the conventional type operation in about the seventh year. Given the cost of investment normally involved in dairy operations, seven years is not unreasonable, since the net gain over the conventional system continues to widen over time for the non-conventional model.

The model dairy operation simulation, the subject of this study, is not conceived to be at maximum efficiency. Further analysis and experimentation with manure recycling as a fraction of the feed input over a transplant system, complementary activity such as greenhouse or fish culture operations, have not been included to determine the possible benefit for either the conventional or non-conventional dairy operation. It is thought that any of these activities would favor the non-conventional system economically. The latter is likely, since a good deal of the necessary capital is in place for non-conventional dairy operations that would also be adequate for various selected complementary operations.

CHAPTER I

THE OBJECTIVES AND PURPOSES OF THIS STUDY

It was the initial intention of the study group (CLR Consortium) to find out how the hot water available at Hobo Wells in Lassen County, California could be used in operating a dairy business. The question raised in the mind of the researchers was: "Is it possible to make a dairy operation independent from purchased outside fuel?" That is, could a dairy business be made energy self-contained.

The more specific objectives of the study group were the following:

1. To simulate various configurations of a controlled environment livestock production system.
2. To determine what extent specific geothermal reservoirs in the area of Northern California and Nevada can be used for applications of this type.
3. To compare the use of conventional energy sources with low temperature geothermal energy in this model.
4. To determine the technical and economic feasibility of harnessing the energy of a normal geothermal reservoir in an integrated multiple use system for livestock operations.
5. To investigate an integrated system configuration engineered to utilize livestock and crop waste, sewage system outfall (sludge), and other organic materials as nutrients for livestock feeding and fertilizer--either direct or indirect.

Although the preceding objectives could be used in the study of any number of different geothermal sites, the research group chose to use the Hobo Wells site as its working model. The Hobo Wells site is described further on in this report, but it suffices to say at this point that the amount and quality of the hot water output seemed to be adequate to justify the study.

The research (study group) identified the modern dairy operation as the direct application activity. The reason for choosing the dairy to test the practical direct use of the Hobo Wells hot water output was that the dairy seemed to have both economic (dollar and cents) and technical (engineering and operations) potential.

THE PROCEDURE USED IN THIS STUDY

The objectives of this study are as stated previously in the section dealing with objectives and purposes; however, they are discussed in the report in a different order than listed in the aforementioned section. In writing this report, it was determined that the objective or objectives most applicable to a particular discussion and analysis is shown in the box at the beginning of the particular discussion or analysis.

To determine the technical and economic feasibility of harnessing the energy of a normal (known) geothermal reservoir in an integrated multiple use (Cascade) system for livestock operations.

OBJECTIVE 4

Following the selection of the Hobo Wells reservoir and the determination that the dairy activity would be employed to find out how hot water could be used to substitute for purchased gas, oil and electricity, a procedure needed to be developed for testing the ideas presented in the objective cited previously.

The research group determined that some way was needed to test the practical applications and usefulness of the Hobo Wells hot water without building a full-blown dairy operation. To do this the large and fairly complex computer systems available to the study group was used. Computer programs were written that could simulate all of the normal as well as the unusual activities of the dairy. It was possible not only to simulate the substitute energy effect of Hobo Wells hot water, but to draw comparisons between the conventional type of dairy and the one assisted with hot water.

System Description: At the beginning of the study, the research group suggested a probable group of systems or sub-activities that would be involved in the operations of the dairy model. A flow system was designed (See Figure I-1) which included all of the probable activities of a modern dairy. Sub-systems included in the initial flow diagram were as follows:

1. Refrigeration and storage
2. Anaerobic digestion and waste treatment
3. Refeeding technology - manure and other waste
4. Greenhouses - hydroponic grass growing
5. Evaporators and driers

FIGURE I-1*

GEOTHERMAL DAIRY FLOW DIAGRAM

*See Appendix B for specific designs of selected elements of the flow diagram

FIGURE I-1

3-aa

SYMBOLS FOR FIGURE I-1 & III-2

- A Chilled water storage tank
- B Chilled water circulation pump #2
- C Absorption cooler #1
- D Chilled water circulation pump #1
- E Milk tank
- F Absorption cooler #2
- G Cooling water circulation pump
- H Cooling tower
- I Fresh hot water tank
- J Fresh hot water heat exchanger
- K Geo-water pump #1
- L Geo-water storage tank
- M Geo-water pump #2
- N Sludge bulk tank
- O Sludge influent pump
- P Anaerobic digester
- Q Sludge recirculation and effluent pump
- R Sludge heat exchanger
- S Generator
- T Methane engine
- U Biogas compressor
- V Fresh water/geo-water mixing value
- W Flash tank
- X Scrub water make-up tank
- Y Scrub water pump
- Z Packed tower CO₂ scrubber
- a Fresh water pump

FLOW LINES*

Geo-water	_____ + _____ + _____ + _____ + _____
Fresh water	_____ - _____ - _____ - _____ - _____
Fresh cooling water	_____ - - - _____ - - - _____ - - - _____ - - -
Fresh chilled water	_____ - - - - _____ - - - - _____ - - - - _____ - - - -
Waste water	_____ ◇ _____ ◇ _____ ◇ _____ ◇ _____
Fresh hot water	_____ ° _____ ° _____ ° _____ ° _____
Sludge	_____ // _____ // _____ // _____ //
Biogas CH ₄ + CO ₂	— ° — ° — ° — ° — ° — ° — ° — ° — ° —
CH ₄	_____ - _____ - _____ - _____ - _____ - _____ - _____
CO ₂	.....
Fresh water + CO ₂	_____ . _____ . _____ . _____ . _____ . _____ . _____

*Used with Figure I-1 & III-2

6. Gasification system and scrubbers
7. Hot water transmission and storage
8. electrical generation

Not all of the above listed activities survived. The greenhouse, although having complimentary economic potential (See Figure I-2) was eliminated from consideration at a later stage because greenhouse grown grass was found to drive up the cost of producing milk by more than \$2.00 per cwt. when compared to the conventional dairy operation.

Data Collection: The three educational institutions involved in the research team (CLR Consortium) also needed to work out methods where the special abilities of each person at any of the cooperating schools could be used most effectively. It was determined that for the best research results, a system of open communication needed to be established. This was achieved by having periodic meetings, by liberal use of the telephone, and by regular operations of a computer information network. In this way, it was possible to identify specific data elements needed to put together the simulations. Specific information, including statistical and technical data was developed through interviews with knowledgeable people in the dairy industry, in the construction industry, engineers and other scientists. It is notable that no new or untried hardware or technology was required in the design of the geothermally assisted dairy.

In the development of the computer simulations model, standard mathematical and engineering techniques were employed.

FIGURE I-2

Summary Table No. 1 - 7.6×10^6 Lbs. Hot Water Per Hr. System
Cost and Estimated Energy Per System - Model #A

*Candidate Activities

ACTIVITY	Δ Temp. Degree F	Ext. Cost Per Hour	Bbls. Heat- ing Oil Equi./Hour	Unit Size
At Well: Total In.	300°F	Dollars - \$	Bbls - 42 Gal.	Various
Elec Gen.	47.5°	\$1,112.40	61.40	10 M.W.
Heat Exchange	10.0°	234.20	13.95	345,000 gph
Regrigeration	7.5°	175.65	10.45	10,000 tons +
High Energy Proc.	* 5.6°	131.15	7.80	7,500 tons yr.
Dehydration	5.6°	131.15	7.80	10,000 tons +
Crop Processing	4.4°	103.05	6.15	25,000 tons +
Kiln: Lumber	* 6.3°	147.55	8.80	46,800 M.b.f.
By-products	2.0°	46.85	2.80	25,000 tons +
Greenhouses	* 21.0°	491.80	29.30	100 acres
Feeding	0.7°	16.40	1.00	15,000 h.d.
Slaughter	0.1°	2.35	0.15	13,000 h.d.
S.C.P.	* 7.0°	163.95	9.75	10 acres
Fish Ponds	18.8°	440.30	26.20	50 acres
District Heating	46.1°	1,079.60	64.25	5,000,000 sq. ft.
Soil Heating	26.4°	618.25	36.80	200 acres
Leakage	10.0°	234.20	13.95	System
Totals: Out	219.0°	\$5,128.80	305.30	(\$42,683,371 yr.)

Energy Values: (1) Total 300° F Brine 7.6×10^6 lbs. per hr.
 (2) Estimated Price for No. 1 heating oil=40¢ per gal
 (3) Price per Therm= 27.571¢
 (4) Price Energy Cost per Degree F of Energy
 per hr. \$23.42 (This System Only)

Calculation: Revenue Equivalent for Energy
 $\$23.42 \times 219 = \$5,129 \times 24 = \$123,095.50$ per day
 $\$123,095.50 \times 365 = \$44,929,864$ per year
 Less 5% for Leakage = \$42,683,371 Net

The mathematical computer model can be found at both the Argonne National Laboratory and in the Master Report available at the CLR Geothermal Library at Lassen College in Susanville, California.

PUBLIC NOTIFICATION AND POTENTIAL USER ACCESS

One of the important intents of the CLR member institutions is to make any of the findings or things learned available to the citizens of the communities served. To this end, the CLR Consortium has established an energy reference collection at the Lassen College Library in Susanville, California. Included in this growing collection are copies of the Master Report from which this report is taken. The Master Report is entitled:

CONTROLLED ENVIRONMENT

Livestock Production System Computer Simulation and Analysis (DAIRY)

In addition to this report, the CLR faculty has extracted the several computer simulation programs which were part of this contract. Copies of these simulation programs are available at both the Lassen College Library and the Argonne National Laboratory (the DOE Computer Software Center). Available from the Master Report are the design specifications for the various energy using elements composing the geothermal dairy configuration adopted for this study.

CHAPTER II

THE GEOTHERMAL RESOURCE

As noted in Chapter I of this report, the research team chose the Hobo Wells site because it lies within the Wendel-Amedee K.G.R.A. and that one of the CLR member institutions is located at or near the K.G.R.A. However, the major reason is that the Wendel-Amedee K.G.R.A. is exceptionally representative of geothermal resources throughout the CLR service area. The latter includes all of Northeastern California and the state of Nevada. In this respect the Hobo Wells site has the potential for serving as a model for parallel development of the CLR area.

Wendel-Amedee (Hobo Wells) was attractive to the research team for a number of reasons in addition to those cited above. First, the resource seemed to be abundant and persons knowledgeable about geothermal resources felt that the visible flow from Hobo Wells is but a minute fraction of the long-run sustained production potential. Secondly, the temperatures of the hot water produced are well within the usable range of temperatures that justify direct application investment. Thirdly, the research by CLR would contribute to the pool of knowledge required to make this particular K.G.R.A. more attractive to investors, and thereby ultimately contributing to fossil energy substitution and to the necessary conversion technology. Investment in the development of the resource and in the achievement of efficient cascading arrangements are believed to provide potentials in new industry, increase job opportunities, and substantially

broaden infrastructure in the subject area, particularly Lassen and Modoc Counties in California.

The Wendel-Amedee K.G.R.A. is situated in the Honey Lake Valley. The Valley is a northwest-southeast trending topographic feature bound on the north by the Amedee, Shaffer and Skedaddle Mountains, and to the south by the Diamond Spellings Mountains. The Fort Sage Mountains are located at the southeast end of the Valley.

The Honey Lake Valley is in a graben (depression or trench) bound by the Litchfield and Honey Lake faults to the northeast and southwest. The center of the valley is occupied by Honey Lake, which is intermittently dry. The approximate size of the lake is about 194 square kilometers or about 75 square miles.

Exploratory work by the Bureau of Reclamation's geological research to date, as well as other exploratory work in some parts of the Honey Lake-Susanville area, tends to indicate that the hot water temperatures may range between 160° - 300° F. Gulf Oil Company has drilled two deep wells (exploratory) in the Wendel-Amedee area, near Wendel. One of these wells was drilled to 5,056 feet and the maximum spot temperature logged was 248°F. The second well was drilled to 5,029 feet with a bottom hole temperature of 230°F.

Some investigations suggest a mixing model where the observed thermal waters contain substantial proportions of admixed shallow (cold) ground water and that the real temperature of the hot water at point of origin may be appreciably higher,

possibly at 300°F or more. This latter point is not well certified; however, it does not in any way affect the usefulness of the Hobo Wells as a model in this simulation.

A factor which does have long-run implications for this study and all potential investment in the area, is the question of the size of the resource. The Wendel-Amedee K.G.R.A. has not been adequately measured for temperature, but also, it has not been determined as to the amount of water at whatever temperature is available on a continuing or sustained basis. Almost all projections and technical applications are based on tentative assumptions. The one sure thing is that the Hobo Wells output (artesian) at this time is approximately 1200 liters/minute (317 gallons/minute), and a temperature where it bubbles out of the ground at 99°C (209°F). This is substantially more water than is needed to energize the model dairy.

The latter statement, that Hobo Wells produces substantially more hot water than is required, raises the very important question of technical efficiency in situations where a geothermal hot water resource is used for a single purpose. Later on in this report it is pointed out that the model dairy uses less than 7% of the hot water produced even at peak energy demand times. This means that if the only activity located at the well is a single activity, capable of extracting less than 7% of the heat energy, the economic and practical conservation justification is lost--perhaps not to the dairyman, but surely insofar as national and local energy conservation and economic develop-

ments are concerned. It is for this reason that the dairy model is conceived to be a part of a major geothermal or waste heat flow cascade (See Figure II-1).

The cascade concept was initially presented for consideration in the Susanville study.¹ In the instance of the Susanville study, it was assumed that the geothermal resource in the Honey Lake Valley might be able to produce 7.6×10^6 lbs. of 150°C hot water per hour. Given this volume of hot water, the need for an effective access, distribution and utilization systems becomes obvious. The alternative is some random and usually excessively wasteful and sometimes damaging single use access system that is unlikely to achieve optimum development. In the Susanville study, Barmettler suggested 14 candidate activities (Table II-1).

TABLE II-1

Summary Table - 7.6×10^6 lbs. hot water
per hr. Systems cost and estimated energy system
(Figure II-1)

The Susanville project determined that the hot water temperature would need to be at least 120°C for food processing and kiln drying and could be as low as 30°C for S.C.P. production if the water flowed directly into algae ponds. From the very practical point of view, if stove oil had to be used to fuel these activities and heat the hot water, it would have used 55 bbls.

---

¹Edmund R. Barmettler, Geothermal Energy Utilization

TABLE II-1

Summary Table No. 1 - 7.6×10^6 Lbs. Hot Water Per Hr. System
Cost and Estimated Energy Per System - Model #A

*Candidate Activities

ACTIVITY	Δ Temp. Degree F	Ext. Cost Per Hour	Bbls. Heat- ing Oil Equi./Hour	Unit Size
At Well: Total In.	300°F	Dollars - \$	Bbls - 42 Gal.	Various
Elec Gen.	47.5°	\$1,112.40	61.40	10 M.W.
Heat Exchange	10.0°	234.20	13.95	345,000 gph
Regrigeration	7.5°	175.65	10.45	10,000 tons +
High Energy Proc.	* 5.6°	131.15	7.80	7,500 tons yr.
Dehydration	5.6°	131.15	7.80	10,000 tons +
Crop Processing	4.4°	103.05	6.15	25,000 tons +
Kiln: Lumber	* 6.3°	147.55	8.80	46,800 M.b.f.
By-products	2.0°	46.85	2.80	25,000 tons +
Greenhouses	* 21.0°	491.80	29.30	100 acres
Feeding	0.7°	16.40	1.00	15,000 h.d.
Slaughter	0.1°	2.35	0.15	13,000 h.d.
S.C.P.	* 7.0°	163.95	9.75	10 acres
Fish Ponds	18.8°	440.30	26.20	50 acres
District Heating	46.1°	1,079.60	64.25	5,000,000 sq. ft.
Soil Heating	26.4°	618.25	36.80	200 acres
Leakage	10.0°	234.20	13.95	System
Totals: Out	219.0°	\$5,128.80	305.30	(\$42,683,371 yr.)

Energy Values: (1) Total 300° F Brine 7.6×10^6 lbs. per hr.
 (2) Estimated Price for No. 1 heating oil=40¢ per gal.
 (3) Price per Therm= 27.571¢
 (4) Price Energy Cost per Degree F of Energy
 per hr. \$23.42 (This System Only)

Calculation: Revenue Equivalent for Energy
 $\$23.42 \times 219 = \$5,129 \times 24 = \$123,095.50$ per day
 $\$123,095.50 \times 365 = \$44,929,864$ per year
 Less 5% for Leakage = \$42,683,371 Net

FIGURE II-1

GEOHERMAL OR WASTE HEAT FLOW SYSTEM (ENERGY CASCADE) MODEL A

of No. 1 heating oil per hour. The total cascade was estimated to be capable of substituting for about 305 barrels of heating oil per hour. The value for the hot water if oil had to be used for heating is calculated at \$123,100 per day.

Activity No. 9 (Cattle and Poultry Feeding) is realistically one of the lesser items in the cascade. As a point of reference, based on an ambient condition of 27°C (80°F), there is an energy flow of 3.6×10^5 KJ/min. (3.5×10^5 BTU/min.) using current electricity costs in the Wendel, California area of about 0.05 \$/kw/hour. The per minute flow for Hobo Wells under the above conditions is roughly \$4.80 or almost \$7,000 per day if the water temperature had to be brought to 209°F for purposes of producing sufficient energy to heat, cool, refrigerate, burn lamps, pump fluids, run milking machines, etc. for the model dairy. Obviously, there is significant opportunity to develop more effective geothermal hot water cascade systems.

CHAPTER III

THE HOT WATER ASSISTED DAIRY

The modern commercial dairy business has come a long way since the Second World War. The changes have been various and in some instances rather subtle. The largest change has been in the increased size of the average commercial dairy plant, the number of cows in the herd and the increased milk yield per lactating cow unit. Yields at 15,000 pounds or more of 3.5 percent butterfat milk are common during a 305 lactation period. Drylot operations are also more common than the pasture oriented large land area operations. The product from the dairy is also more uniformly wholesome than just a few years ago. Dairy herd testing programs have also significantly influenced the culling and breeding programs of the modern dairy enterprise.

In the face of the very significant progress made by the dairy industry, the question has to be: What sort of adjustments are likely to be practical or economically defensible in the next few years and in what area is it possible for the modern dairy to further accommodate changes imposed by increasing energy supply limitations or interruptions?

It is the conventional dairy system that serves as a basis for comparing the planned innovations in the proposed geothermally energized dairy operation. The techniques used are comparative and partial budgeting of the two options. That is, the conventional and unconventional dairy systems are com-

pared for costs and economic effectiveness. In the initial effort, the Master Report contains some evaluations not only of the energy substitution affect, but also management, feeding and reproduction efficiencies. The latter investigations were determined to be required by the principle investigators in order that the range of possible activities in the non-conventional dairy could be tested.

To simulate various configurations of a
controlled environment livestock production
System.

OBJECTIVE I

It is pointed out that the essential difference between the conventional dairy operation and the geothermal model is in the energy source used to operate the essential equipment and operation devices and in the substantially more controlled environment for the geothermal dairy.

The objective cited in the box above, suggested to the research team that the dairy buildings and livestock control facilities needed to be designed in a way that would appear to have both economic and technical promise when thermally assisted by the geothermal water from the Hobo Wells source. In designing the computer assisted evaluation, it became necessary to choose a herd size that would be large enough to be economically viable and also that would provide a basis for selecting buildings and equipment for inclusion in the geothermal

dairy model. The size of unit chosen was a 200 milking cow dairy. This means that buildings, equipment and facilities had to be designed to accommodate 412 animals. A breakdown of the total geothermal dairy herd is shown in Table III-1.

TABLE III-1

TYPE AND NUMBER OF ANIMALS IN AVERAGE HERD

<u>Animal Type</u>	<u>Average Number in Herd</u>	<u>Approximate Weight (lbs.)</u>
Calves:		
0 - 1.5 mo.	16	107
1.5 - 8.25 mo.	48	313
Heifers:		
8.25 - 12.5 mo.	32	611
12.5 - 17.25 mo.	34	794
17.25 - 23 mo.	44	1,004
23 - 24 mo.	8	1,135
Dry Cows:	30	1,200
Milk Cows:	<u>200</u>	1,250
Total Cows:	412	

Additionally, the research team had to make a choice as to the criteria to be used in the type of housing system (buildings) to be used in the geothermal dairy (See Appendix A). The criteria used were those that provided maximum control over environment--for the most part, environmental control meant temperature. In each of the buildings, the design attempts were to provide this range of temperature that produced the least amount of stress on the dairy animals. Stress is reflected in reduced milk production, reduced weight gain, and increased calf mortality. Depending on the class of livestock involved,

the criteria used were those recommended by the biologist and animal scientist as being most appropriate in reducing the level of stress.

To the end that cost differences and engineering sizing differences might be discerned, the flow diagram was developed (Figure I-1) as well as the six (6) barn and equipment designs (See Appendix A). From these designs it was possible to develop the digital computer simulation program capable of producing the various configurations of the dairy operation. These configurations were able to test for the energy and mass balances for the different designs. An initial intent was also to build a computer software program that could test for dynamic changes such as the daily or seasonal energy demand variations. The latter was only partially achieved; yet, sufficient encouragement was provided to the researchers to continue in their effort to achieve a full system transient mode (dynamic program). The goal of both the steady state (fixed program) and the transient (dynamic program) was the optimization of the dairy design perimeters for each of the components shown in Figure I-1 as well as the geothermal service system itself. The equipment specifications for the geothermal dairy are included in Appendix B.

An important factor influencing building and equipment design had to do with the problem of solid waste disposal and, although this research effort was to address itself mainly to direct uses of hot water or steam (geothermal energy), it be-

came essential that a definition for a higher value energy through gasification processes or other yet undetermined processes, would be evaluated. One of the objectives of this research was therefore as follows:

To investigate an integrated systems configuration engineered which will utilize livestock and crop waste, sewage system outfall (sludge), and other organic materials as nutrients for livestock feeding and fertilizer, either direct or indirect.

OBJECTIVE V

As a part of this investigation, the study group determined that the geothermal dairy waste had other potential uses. From an engineering point of view, the manure from the dairy cows is capable of providing all, or a substantial part of, the electrical energy required to energize the various sorts and kinds of equipment. The manure is processed through an anaerobic digester, which produces methane that is used to fuel a methane-fired engine and generator systems.

Efficient operation of the anaerobic digester requires seven to nine percent solid content of the waste feed. A building system which requires frequent wash-down would lead to excessive digester feed dilution. Hence, a closed system with concrete floors and mechanical manure removal (scrapers) is required.

GENERAL DESIGN CONSIDERATIONS

Types of Housing Systems- Six basic types of housing systems were considered for use in the two dairies:

1. Cold Barn Environmental System is a self contained system where all of the basic facilities are in an uninsulated structure. This is adequate for cold to moderate climates and allows for disposal of manure by scraping or wash-down.

2. Warm Barn Environmental System is a self contained system where all of the basic facilities are in an insulated structure which provides year-round protection for animals and operators in cold climates and allows for manure handling by scraping or wash-down.

3. The Roofed Free Stall System is a series of free stall rows in an open post structure which are adequate for moderately cold climates, and allows for manure handling by scraping or wash-down.

4. The Free Stall Dry Lot System is an uninsulated free stall barn with outside feed bunks which is used in moderately warm climates and has manure handling by scraping only.

5. The Roofed Free Stall Corral System is ideal for hot and dry climates. Fence line feeding will be employed. Dry manure is collected periodically.

6. Open-Air Corral System is ideal for hot and dry climates where minimum protection is required. Dry manure is collected periodically.

Environmental Considerations- The last factor to be considered in choosing the proper housing system was barn temperature:

1. Milking Cow Barn: Milking cows have been shown to produce the most milk when the barn temperature is between 15°F and 65°F. If the temperature in the barn drops below 32°F the water on the floors and in troughs, and manure in the under-floor troughs, will freeze. This is not practical for obvious reasons. Therefore, the milk barn should be kept at temperatures ranging between 32°F and 65°F. The temperatures at Hobo Wells, California, the proposed site of the geothermal dairy, for the winter months of October through March are on the average of 10°F for the low, and 68°F for a high with occasional extended periods near or below 9°F. At these temperatures the cold barn environment and the roofed free stall systems become inadequate, leaving the warm barn environment system as the most desirable for housing the milking cows.

2. Calf Barn: The best temperature for raising calves has been determined to be around 50°F. In order to maintain this inside temperature, the warm barn environment system is used.

3. Heifers and Dry Cow Barn: The heifers and dry cows have been found to withstand very cold conditions without harm and they do not require much individual attention. Their movement in the barn is substantially less than the milk cows who walk to the milking parlor every morning, and their water intake is also less than the milk cow. These factors make the

roofed free stall system feasible where icy floors and frozen watering troughs do not pose an important problem.

PROPOSED DESIGN

All of the barns are of steel construction with concrete floors and a roof system that joins all of the barns. The steel building design was chosen because of lower construction cost over other materials and the flexibility in design. The buildings may be constructed with open walls, walled-in but uninsulated, or with insulation in the walls and ceiling, depending on the application.

The milk cow and calf barns must have a warm environment, so R10 insulation was used for walls and R20 for ceiling. The milk barn requires higher inside temperatures than the cow barns to accommodate the personnel in the milking parlor, hospital or maternity ward. Usually the temperature should range between 65°F and 78°F, so R20 was selected for both walls and ceiling. The heifer and dry cow barn do not require the protection afforded by a walled structure so the metal building with only a ceiling is used. The proposed design utilizes geothermal energy to maintain the desired range of temperatures. Wind breaks are installed as required.

The concrete floor in all of the cow barns is designed to accommodate scraping as a means of removing the manure, with the exception of the milking barn. The manure is scraped by tractor and blade and moved to the bulk tank where it is held

before being pumped to the digester. The bulk tank is large enough to hold at least two days supply of manure. The milking barn manure quantity is small compared to the cow barns and is therefore flushed out through the waste water output lines.

Design Details:

A. Milking Cow Barn

1. Ventilation and Temperature- Milk cows require an inside temperature range from 35°F to 65°F and a ventilation rate of at least 100 cfm per 1000 pounds to maximize milk production. Seventy-five percent of the ventilation is provided by exhaust fans bringing in outside air and 25 percent of the ventilation is recirculated to prevent back-flow of moist air.

The geothermal milk cow barn provides ventilation and temperature control with eight unit heaters heated by geothermal water, eight 4000 cfm exhaust fans, and 26, six by eight feet sliding shutter openings in the walls of the barn which can be adjusted according to the environmental conditions.

2. Water and Feed- The barn is constructed so that an automatic feed wagon can fill the mangers on either side of the barn while driving between them.

Fresh water is supplied by automatic, level controlled water fountains located next to the manger. One fountain per 20 cows is provided.

3. Barn Layout and Stalls- The milk cow barn must be capable of housing at least 200 cows. The barn capacity was selected at 212 cows to allow for a fluctuation in herd size.

Each cow is provided with a free stall four by seven feet in size, which allows ample space for a 1250 pound cow. The free stall design was chosen because the individual resting area results in cleaner cows, less incidence of stepped-on teats, fewer udder problems and substantial savings in bedding, over stanchion or loafing barn housing.

The barn is divided into four sections containing approximately 50 cows per section. This division provides better management of the cows and insures that each cow will be milked at approximately the same time each day (See Appendix A).

4. Lighting- Lighting is provided by approximately 475 feet of double row fluorescent fixtures and ten, three by fourteen foot, sky lights.

5. General- All stall partitions, rail gates and manger restraints are made of two inch steel pipe.

B. Milking Barn

1. The Barn Layout- The milking barn was designed to house a wash area, a milking parlor, a milk storage room, utility room, a hospital, bathroom, and a maternity ward.

a. Wash Area (holding area)- The holding area has a maximum capacity of 60 cows with 50 cows being the ideal group size. This insures that even with 240 cows in the milking herd, that milking can be completed daily in four groups. There are 26 group sprayers spaced evenly five feet apart in the floor. The spray nozzles (5/32") provide a five minute soak at 4.6 gallons per

minute flow rate and a 40 PSI pressure. The group sprayer design was chosen over the automated prep stall because of the overall shorter wash time.

b. Milking Parlor- The milking parlor is designed to house a "double row sawtooth-herringbone eight-stall milker", which is capable of milking 80 cows per hour with only two operators. The sawtooth-herringbone parlor design was chosen over the diagonal stall systems because of the speed of milking, better care of the cow, and few operators.

c. Milk Room- The milk storage room houses a 3,000 gallon bulk milk tank. The tank is capable of holding two days supply of milk. Also, in the milk storage room, along with various pieces of equipment associated with the milking machine, is a large wash vat for washing and sterilizing milking equipment.

d. Utility Room and Bathroom- The utility room houses most of the equipment necessary to operate the milking portion of the dairy. Also, the utility room provides room for storage of supplies and medications needed in the hospital. Adjacent to the utility room is a small bathroom provided for the convenience of the operators.

e. Hospital- The hospital area contains eight-four by seven foot stalls equipped with conventional stanchions for holding the cow and individual mangers to

provide room to work around the cow's head. A door is located between the utility room and the hospital for convenient access to supplies. Also, a four foot outside door is provided for cows which must be taken from the hospital area.

f. Maternity Ward (maternity pens)- There are eight, 100 square foot maternity pens provided for the herd. Each pen is equipped with a water fountain and a manger. The pens are constructed of four foot high rail fences.

2. Ventilation and Temperature- The milk barn requires a temperature range of 65°F to 78°F to provide comfort and protection for all of the different activities within the same building. Adequate ventilation is also required although the demand is substantially smaller than in the cow barns.

The ventilation and temperature control is provided by a 2000 cfm exhaust fan; four unit heaters; and various sizes of windows which can be opened and closed according to the environmental conditions.

3. Water and Feed- There are small feed mangers and water fountains located at each stall in the milking parlor. Mangers and water fountains are also provided in the hospital and maternity areas.

Warm or fresh hot water is supplied to each area of the milking barn at the following temperatures:

a. Holding Area:

Water for washing cows
Temperature, 110°F

b. Milk Parlor:

Water for washing and sanitation of equipment
Temperature, 98°F and 180°F

c. Milk Storage Room:

Water for washing and sanitation of bulk tank
Temperature, 95°F and 180°F

d. Bathroom and Utility Room:

Water for general washing, etc.
Temperature, 110°F

e. Hospital:

Water for general wash-down and cleaning
of the cow
Temperature, 180°F and 110°F

f. Maternity Area:

Water for general wash-down and cleaning
of the cow
Temperature, 110°F

4. Lighting- Lighting is provided by:

a. Holding area: 92 feet of double row fluorescent fixtures

b. Milk Parlor: 40 feet of double row fluorescent fixtures

c. Milk Storage Room: 40 feet of double row fluorescent fixtures

d. Utility and Bathroom: Three, 100 watt bulbs

e. Hospital: 48 feet of double row fluorescent fixtures

f. Maternity Ward: Eight, 150 watt bulbs

g. Return Alley: 50 feet of double row fluorescent fixtures

(For further details see Figure III-2)

C. Calf Barn

1. Barn Layout and Stalls- The calf barn must be capable of housing approximately 64 calves. Each calf is provided with a free stall. The size of the stall is two feet by four feet for the one to sixteen week-old calves, and two feet, six inches by four feet for the four to six month old calves. The calves are divided up into groups of 16, 12, and 10 for their protection and ease of handling.

2. Ventilation and Temperature- The best environment for raising calves is 50°F temperature, with 0.1 cfm/lb. of calf ventilation rate. The ventilation and temperature control is provided by two unit heaters; two 2500 cfm exhaust fans; and sixteen, six foot by eight foot sliding, shuttered openings in the walls of the barn.

3. Water and Feed- The manger is constructed in a similar manner to the milk cow manger so the feeding procedure is similar. Special provisions are made for feeding the younger calves from the pail.

Fresh water is supplied by fountains located next to the manger.

4. Lighting- Lighting is provided by approximately 208 feet of double row fluorescent fixtures and two, three foot by fourteen foot sky lights.

5. General- All stall partitions, rail gates, and manger restraints are made of two inch steel pipe.

(For further details see Figure III-2)

D. Heifer and Dry Cow Barn

1. Barn Layout and Stalls- The heifer and dry cow barn is designed to house 148 animals. The cows are each provided with a free stall sized according to the age and weight of the cow. The five to fifteen month old heifers require two feet, ten inches by five foot stalls; the 14-18 month old heifers require three feet, two inches by six foot size stalls; the 16-28 month old heifers require three feet, six inches by seven foot size stalls; and the dry cows require four foot by seven foot size stalls. The cows are grouped according to age for ease in management and their own protection.

2. Ventilation and Temperature- The heifer and dry cow barn is an open structure with only a roof to provide protection from the environment. Thus, the ventilation and temperature are not controlled. There has been some consideration taken for which way the barn sits in relationship to the sun's path and prevailing winds.

3. Water and Feed- The water and feed supply are the same way as in the milking cow barn.

4. Lighting- Lighting is provided by an approximate total of 117 feet of double row fluorescent fixtures.

5. General- All stall partitions, rail gates and manger restraints are made of two inch steel pipe.

6. Window and Door Schedule-

Windows:

1) 4' X 4' Aluminum Sash

- 2) 4' X 2' Aluminum Sash
- 3) 8' X 4' Aluminum Sash
- 4) 6' X 4' Internal Glass
- 5) 8' X 6' Sliding Shutters

Doors:

- 1) 6' Double Doors, Exterior
- 2) 2'8" Internal Door
- 3) 4' External Door
- 4) 4' Rail Gate
- 5) 3' Rail Gate
- 6) 8' Double Rail Gate
- 7) 9' Double Barn Door
- 8) 7' Double Barn Door
- 9) 12' Double Barn Door
- 10) 12' Rail Gate
- 11) 10' Double Rail Gate
- 12) 8' Rail Gate
- 13) 8' Double Door

E. On-Site Power Generators-

As it was pointed out earlier in this chapter, it became necessary to include on-site power generation as a legitimate direct use of hot water from the Hobo Wells source. The justification for this is that the hot water is used to optimize temperatures for the anaerobic digester.

For this reason, an on-site power generation system has been designed for the proposed dairy. This system gene-

rates economical and reliable electrical power from the bio-gas which is produced by the anaerobic digester. The anaerobic digester utilizes energy from geothermal water for temperature control, which is critical for the production of high quality bio-gas. The power generation system produces high grade electrical energy from two low grade sources; low temperature geothermal water with a temperature of about 98°C (209°F) and cattle manure. The net amount of electrical power that can be generated by the proposed process is about 22 kw (29 hp) continuous. This would provide an economical, almost inflation free, energy source for the entire dairy operation. The equipment needed to generate this electrical power, by the proposed method, is shown in Figure III-1.

SYSTEM OPERATION

Manure is scraped from the barns twice daily and placed in the digester in-put holding bin. Since some of the constituents of the manure that will eventually become methane gas are volatile, the retention time in the holding bin should be as short as possible. The manure is continuously withdrawn from the bottom of the holding bin by a positive displacement sludge pump and transported through a pipeline to the anaerobic digester tank. The arrangement of these components is shown in Figure III-2.

In the anaerobic digester tank, the temperature of the manure is raised to, and maintained at, 35°C (95°F). This

FIGURE III-1
ON-SITE POWER PRODUCTION SYSTEM

temperature is near optimal for the production of methane gas containing a minimum concentration of carbon dioxide. Geothermal water is used to regulate the temperature of the material in the digester tank. This is accomplished by using a sludge pump to pump the manure out of a digester tank and through the geothermal water to a digester sludge heat exchanger. Sludge is removed from the digester tank at a constant rate and stored in the out-put holding bin. The sludge is removed from the out-put holding bin periodically and spread as fertilizer in a conventional manner.

The mixture of methane and carbon dioxide gas (bio-gas) produced by the digester, flows to a small cyclone scrubber where a water spray removes a large portion of the hydrogen sulfide (H_2S), a trace element in the bio-gas mixture. Approximately $3.5 \times 10^{-4} m^3/S$ (5.6 GPM) of fresh water is needed for the removal of H_2S from the bio-gas.

A single cylinder reciprocating compressor is used to raise the pressure of the bio-gas to 0.58 MN/m^2 abs (85 psia). The compressor also acts as a pump to move the bio-gas through the system. Compressing the bio-gas increases the solubility of the carbon dioxide in the scrub water.

Before entering the packed tower scrubber, the bio-gas has a carbon dioxide concentration of about 60 percent on a mass basis. This gives the fuel a lower heating value of only 20.2 MJ/kg (8700 BTU/LBm). These figures are nominal and will vary somewhat with the type of feed given the cattle, the exact

retention time in the digester and other factors.

To produce a consistently high quality fuel gas for the engine , it is necessary to remove some of the carbon dioxide from the bio-gas. This is accomplished through the use of a packed tower scrubber. The bio-gas and scrub water are passed through the packed tower under counterflow conditions. Upon leaving the packed tower, the fuel gas contains only about 23 percent carbon dioxide on a mass basis and has a lower heating value of about 38.4 MJ/kg (16520 BTU/LBm). Furthermore, the packed tower scrubber serves to remove the remaining hydrogen sulfide from the bio-gas. Thus, the packed tower scrubber increases the heating value of the fuel gas and insures that the fuel gas will be of a quality which the engine can efficiently burn, even though the anaerobic digester may produce bio-gas of variable quality and carbon dioxide content.

The carbon dioxide that is removed from the bio-gas is carried in solution with the scrub water to the flash tank where the scrub water is throttled, through a set of spray nozzles, from the packed tower operating pressure of 0.58 MN/m² abs (85 psia) to the atmospheric pressure of 0.101 MN/m² abs (14.7 psia). This throttline process removes a large part of the carbon dioxide from the scrub water. The scrub water then flows to an open tank where it remains for a few minutes to allow the remaining carbon dioxide to be released into the atmosphere. This part of the process can be likened to a carbonated beverage which is left in an open container to "go

flat". From the open tank, the scrub water enters a pump which increases the water pressure to the packed tower operating pressure of 0.58 MN/m^2 abs (85 psia).

The scrubbed bio-gas is used to fuel an internal combustion engine which drives a 220 volt, three-phase electric generator. About 27 kw (36 hp) can be generated from the manure produced by a 200 milking cow herd. Some of this power is needed to run the scrub water pump, bio-gas compressor, and the two sludge pumps. The amount of electrical power available for other uses is approximately 22 kw (29 hp). At an energy cost of 0.05 \$/kw hour this power has a value of about \$792 per month.

ENERGY UTILIZATION

This section presents a component-by-component energy accounting for the geothermal dairy on a particularly energy demanding day; the winter design day. Winter design day parameters can be found in Appendix C.

Figure III-2 shows the geothermal dairy schematic with all of the electrical and geothermal energy demand rates. The legend for this schematic is shown in Chapter I. The energy requirements are peak rates for each component. The drawing clearly illustrates the distribution of energy within the dairy.

Table III-2 is an accounting of peak energy demand categories for the major operational subdivisions in the dairy. They are:

FIGURE III-2

PEAK ENERGY DEMANDS FOR THE GEOTHERMAL DAIRY

TABLE III-2

ENERGY UTILIZATION ACCOUNTING*

Subsystem	Electrical Produced	Required Energy		
		Electrical	Geothermal	Subtotal
1. Power production	1317.5	243.1	5537.2	5780.3
2. Main pumps				
geothermal water		100.7		100.7
fresh water		77.2		77.2
3. Milk cooling		36.5	5034	5070.5
4. Milking parlor lights, fans, heating		253	2788	3041.0
milking machine (2 vacuum pumps)		55		55.0
5. Milking cow barn		438.2	8798	9236.2
6. Calf barn		131.7	1308.6	1440.3
7. Heifer and dry cow barn		66.5		66.5
TOTALS	1317.5	1401.9	23465.8	<u>24867.7</u>

* All energy rates are given in BTU/min

1. Power production (components N-Z)
2. Main water supply pumps (components K-M)
3. Milk cooling (components A-H)
4. Milking parlor (components I,J)
5. Milking cow barn
6. Calf barn
7. Heifer and dry cow barn

Table III-2 allows one to make several observations about energy utilization for this dairy model:

1. At peak load conditions, all but six percent of the electrical energy requirements are met by the methane digester/scrubber/engine-generator power production system. During most periods, the full electrical requirements of the dairy can be generated on-site.
2. About 19 percent of the electrical energy produced is required to operate the power production system, as presently designed.
3. If one assumes energy is available from the geothermal source at Hobo Wells as described in Chapter I, only about seven percent of the available geothermal energy of the artesian spring is tapped, at peak load conditions.

Some additional observations have been made regarding the energy utilization of this dairy configuration:

1. Without the digester and related power production system, the peak electrical requirement of the system would decrease by 17 percent, but the electrical energy supplied by a

public utility would increase by 93 percent.

2. Of the total peak energy requirement of the dairy, our results indicate approximately five percent is supplied by the power production system, 0.5 percent is purchased from an outside supplier, and 94.5 percent is supplied from the geothermal reservoir. This mix would be considerably different on the average day. It would be expected that no outside energy would be required, and the geothermal requirement would be considerably less. It might be found, on further investigation, that tank storage of the fuel gas to meet peak needs would be economical.

3. Without using geothermal energy, the dairy would require some 23,000 BTU/minute from other sources at peak. This is an unrealistic figure, however, since without geothermal energy the harsh mountain desert climate of the Honey Lake Valley would probably not lead to its selection as a dairy site.

Finally, these initial researches indicate that the selected dairy configuration is extremely energy efficient. It appears that it can operate with nearly complete energy independence without taxing the available energy of the named geothermal reservoir severely.

DAIRY FEEDING PRACTICES: CONVENTIONAL AND NON-CONVENTIONAL

Dairying is a business which requires highly skilled management and employees. The development of a dairy plan is

very complex because there are many alternatives in both long and short range planning. One very important analysis in considering alternatives is how to utilize the expertise of the management. An error in the planning stage, particularly an error which overburdens management, can be fatal to a developing dairy. There are several alternate ways to maximize benefits from available management abilities. For example: 1) develop a small dairy and utilize the farm forage and sell male calves at six weeks of age; 2) develop a small dairy and utilize the farm forage plus raise dairy beef calves for slaughter; and 3) develop a large dairy and purchase all feed.

Although many dairies today produce at least a portion of the forage fed to the dairy cattle, an increasing number of large dairies, particularly in the Western United States, are developing and are purchasing all forage. These large dairies specialize in milk production and purchasing the right feeds. Where this specialization exists, there must be greater amounts of milk sold per man year. The amount of milk sold per man year can vary greatly among dairies. For example, data from 731 New York dairy farms in 1966 showed an average 311,700 pounds of milk per man and the top ten percent averaged 419,000 per man while the lowest ten percent sold 222,000 pounds. And, in a Michigan study, comparative milk productivity and income per man increased with herd size. There are many individual dairy farms which are producing 500,000 pounds of milk per man.

Regardless of whether a dairy is large or small the animals

must be fed and the feed cost will usually exceed 50 percent of the cost of producing milk. Feed, then is by far the single most important cost in producing milk. Dairy livestock income was \$184 per \$100 feed expense in a Michigan study, for example. This feed expense is for providing dairy livestock with appropriate nutrients which are primarily the following items: 1) energy; 2) protein; and 3) phosphorous. It is an economic consideration whether to produce or purchase these nutrients when one has first considered management time allocations.

There are many deviations from what one may consider the average dairy operation and there may be benefits at times to have an abnormal dairy. However, for the purpose of discussing the feed requirements and costs associated with feeding dairy cattle, it is assumed that the 200 milking cow model introduced in Table III-1 is appropriate for study.

The relative number of non-milking stock on a dairy which milks 200 cows daily is also presented in Table III-3. The animals on a dairy can be broken down into 4 groups: calves, heifers, dry cows, and milking cows. Further breakdown of these classes is possible. For example, milking cows could be broken down into first and second calf heifers, but this will not be done because it would only complicate the discussions that follow.

TABLE III-3
AVERAGE YEAR-ROUND ANIMAL DISTRIBUTION
IN A 200 MILKING COW HERD

Age Range Months	Animal Classification	Animal Classification
0 - 1.5	Calves	16
1.5 - 24	Heifers	166
34 and over	Dry cows	30
24 and over	Milking cows	200

For the purpose of estimating nutrient requirements or even the amount an animal will consume daily during the period of time they are within each of the four categories, we should have an estimated average weight of each group. The weight of the animal, its age, and the general type of feed appropriate for the animal group are related to dry matter intake. Table III-4 gives the average animal weight, intake, rate of gain and time within classification.

TABLE III-4
AVERAGE ANIMAL WEIGHT, INTAKE, RATE
OF GAIN & DAYS WITHIN CLASSIFICATION

	<u>Calves</u>	<u>Heifers</u>	<u>Dry Cow</u>	<u>Milk Cow</u>
Mean Weight, lb.	108	638	1300	1275
Daily Gain, lb.	0.8	1.5	0	0.1
Days in Classification	45	675	60	365
Daily Dry Feed Intake, lb.	1.4	14.9	21.6	38.4

The mature weight of a dairy cow is quite variable and the appropriate average mature weight may be 1300 pounds ($\pm$ 100 pounds). Normally the mature weight is not achieved

until after the second lactation and for this reason some allowance for gain has been made within the milk cow category. Since most of the nutritional adjustment for gain in milking cows is made during the first lactation, little allowance has been made for tissue gain of cows in the subsequent dry period, even though these animals are usually increasing in weight due to fetal growth.

There are literally thousands of feeds differing in the amount of energy, protein, or minerals that are nutritionally appropriate as contributors to dairy cattle rations. When economics are considered, this number can be reduced substantially; however, for this general discussion we can consider four feeds that can be utilized in meeting the energy requirements of all classes of dairy cattle: 1) milk (or milk replacer; 2) calf starter; 3) alfalfa hay; and 4) grain (mixed, small grains). Table III-5 contains the estimated dry feed required by the four classes of dairy cattle.

TABLE III-5

DAILY DRY MILK (OR REPLACER), CALF STARTER,
ALFALFA HAY & GRAIN (MIXTURE) REQUIRED BY
INDIVIDUAL DAIRY ANIMALS

<u>Dry Feed Type</u>	<u>Calves</u>	<u>Heifers</u>	<u>Dry Cows</u>	<u>Milk Cows</u>
Milk, 1b.	.88	---	---	---
Calf Starter, 1b.	.50	0.5	---	---
Alfalfa Hay, 1b.	---	14.4	21.6	27.0
Grain, 1b.	---	---	---	11.4
TOTAL:	1.38	14.9	21.6	38.4

These same values presented in Table III-5 extended to a yearly basis are contained in Table III-6.

TABLE III- 6

YEARLY DRY MILK (OR REPLACER), CALF STARTER,
ALFALFA HAY & GRAIN (MIXTURE) REQUIRED BY
INDIVIDUAL DAIRY ANIMALS

<u>Dry Feed Type</u>	<u>Calves</u>	<u>Heifers</u>	<u>Dry Cows</u>	<u>Milk Cows</u>
Milk, lb.	321	---	---	---
Calf Starter, lb.	183	179	---	---
Alfalfa Hay, lb.	---	5263	7884	9859
Grain, lb.	---	---	---	4172
TOTAL:	504	5442	7884	14030

The yearly dry feed requirements in Table III-6 are individual animal requirements. The dry feed requirements can be expanded to total dry feed required by all animals within each of the four animal classifications in a 200 cow year-round milking herd. This done by weighting the values of Table III-5 with the allocation of animals in Table III-6. The yearly dry feed requirements of all animals in a 200 cow year-round milking herd is given in Table III-7.

TABLE III-7

YEARLY DRY FEED REQUIREMENTS OF ALL ANIMALS
IN A 200 COW, YEAR-ROUND, MILKING HERD

<u>Feed</u>	<u>Calves</u>	<u>Heifers</u>	<u>Dry Cow</u>	<u>Milk Cow</u>
Milk, lb.	5139	---	---	---
Calf Starter, lb.	2920	29689	---	---
Alfalfa Hay, lb.	---	873708	236520	1971730
Grain, lb.	---	---	---	834390
TOTAL:	8059	903397	236520	2806120

At this point we have an estimate of various feed amounts required annually on a dry basis. These values can be converted to an estimated as-fed basis by assuming the alfalfa, grain, and calf starter to be 90 percent dry matter (DM) and milk; 12.6 percent DM (milk replacer would be about 90 percent DM). Table III-8 contains the dry and as-fed tons of each feed required in a 200 milking cow, year-round herd.

TABLE III-8

DRY AND AS-FED TONS
MILK (OR MILK REPLACER), CALF STARTER, ALFALFA HAY & GRAIN
NEEDED YEARLY FOR 200 MILKING COW, YEAR-ROUND HERD

Feed	Tons Required Yearly	
	Dry	As-Fed
Milk (Replacer)	2.57	20.40 (2.86)
Calf Starter	16.30	18.11
Alfalfa Hay	1540.98	1712.20
Grain	417.20	463.56

The main considerations made in selecting feeds are:

1) palatability of the feed; and 2) cost of the usable energy of the feed. There is no doubt that feed, unless consumed, has no value to the animal being fed. It is also important to provide feeds, particularly forages, that will be consumed in large quantities. The more feed an animal consumes the more efficient it is in converting pounds of feed into productive energy. Most dairy cattle consume between two and three times the maintenance requirement. It is the intake above maintenance requirements which allows the animal to be productive

in terms of weight gain or milk production. The second major consideration made in purchasing feed is the usable energy concentration. There are several measures used to describe usable energy. The most basic is digestible energy which is the difference between the feed gross energy consumed, and gross energy in feces. The difference between these values is a good index of the feeds gross energy that is digested and absorbed from the gastrointestinal tract. The metabolizable energy value of a feed similarly describes usable energy, but it is a lower energy value because we subtract urine and combustible gas energy in addition to fecal energy from gross energy intake for this value.

If analysis is taken one step further and subtractions are made for the energy lost in the form of heat resulting from digestion and maintenance, there is left productive energy. The breakdown of energy utility for individual animals in a dairy herd is presented in Table III-9. Table III-10 contains this same breakdown appropriate for all animals in a 200 cow, year-round milking herd.

In considering the energy values in Table III-9 and III-10, it can be observed that less than 20 percent of the gross energy offered to these animals is utilized for productive energy. About 40 percent of gross energy will be found in the manure. The remaining fraction of gross energy received by the animals will be lost in the form of heat and gas energy. The type of fuel animals receive will certainly affect these

TABLE III-9

DAILY INDIVIDUAL ANIMAL INTAKE, ENERGY UTILITY & OUTPUT

	<u>Calves</u>	<u>Heifers</u>	<u>Dry Cows</u>	<u>Milk Cows</u>
Dry Matter Intake, lb.	1.4	14.9	21.6	38.4
Mcal Energy Intake:				
Gross Energy	3.7	29.1	42.1	74.9
Digestible Energy	3.1	18.0	25.8	51.2
Metabolizable Energy	2.5	14.8	21.2	42.0
Productive Energy	0.5	2.5	3.2	16.0
Mcal Energy Output:				
Fecal Energy	0.6	11.1	16.3	23.7
Urine & Gas Energy	0.6	3.2	4.7	9.2
Heat Energy	2.0	12.3	18.0	26.0
Dry Matter Output, lb.				
Urine	0.1	1.1	1.6	2.9
Feces	0.2	5.7	8.4	12.2
Total	0.3	6.8	10.0	15.1

TABLE III-10

YEARLY ANIMAL INTAKE, ENERGY UTILITY & OUTPUT
WEIGHTED BY ALLOCATOR

	<u>Calf</u>	<u>Heifer</u>	<u>Dry Cow</u>	<u>Milk Cow</u>	<u>Total</u>
Head	16	166	30	200	412
-1000 units-					
Dry Matter Intake, lb.	8	903	237	2803	3951
Mcal Energy Intake:					
Gross Energy	21	1761	461	5466	7710
Digestible Energy	18	1090	283	3736	5127
Metabolizable Energy	15	894	232	3064	4204
Productive Energy	3	151	35	1168	1357
Mcal Energy Output:					
Fecal Energy	4	671	178	1730	2583
Urine & Gas Energy	3	196	51	672	923
Heat Energy	11	742	197	1896	2846
Dry Matter Output, lb.					
Urine	1	67	18	212	298
Feces	1	344	92	887	1324
Total	2	411	110	1099	1622

values and management could increase efficiency of gross energy utilization by feeding more grain and reduce roughage intake, but this alternative is not sound from the standpoint of current economics or the concept of best use of the grain resource. Although dairy producers have, through breeding, nutrition, animal health, and management practices, increased efficiency of both energy and labor efficiency, management still has 40 percent of the gross energy fed to dairy cattle left in the form of manure. Historically, the manure has been utilized primarily for its nitrogen content on cropland, with little value placed on this by-product of the milk or beef industry.

Two alternate uses of manure are practical; 1) methane production; and 2) livestock feed. Recent estimates of methane production from manure indicate that 3,600 cubic feet of methane can be produced per ton of manure for about \$10.

In this project it was determined at the outset that manure would be used to produce methane gas to energize the unconventional dairy (Objective V). However, the research team determined early in its research and simulation efforts, that the second alternative would, in the long run, be more profitable. It appears that the two uses could be developed to produce substantial complimentary out-puts; however, that was not part of this study.

The use of manure as livestock feed in areas with limited quantities of manure may be practical and economically feasible. Before manure can be utilized, it does require some processing

and drying. Recent research has shown that the high fiber contained in manure can be subjected to a hydrolysis process utilizing sodium hydroxide and heat. This process causes some breakdown of the fiber, and the fiber altered in this way is more digestible. The energy value of this altered material would be similar to mid-quality alfalfa or grass hay when fed to cattle, sheep or goats. There are however, two problems in using this material. First there are restrictions on the use of this material by lactating animals or animals just prior to slaughter since the altered feed may contain antibiotics, etc. The second problem is palatability of the material. Yet, the material can be disguised and fed in limited quantities; i.e., 25 - 30 percent of total feed intake.

If the dairy manure is hydrolized, dried and fed to wintering beef cattle at 30 percent of their total intake, there would be sufficient manure from a 200 cow dairy herd for 1800 beef cows. These values are based upon a 3000 pound grass hay requirement for wintering cows and the availability of 811 tons of manure dry matter from the dairy cattle. If, in addition, the manure resulting from the beef cattle could be recycled as feed, there would be available an additional 1300 tons of manure. It is perhaps apparent at this point to see that there would be no limit to the number of cows that would be fed manure at a rate of 30 percent intake.

Feeding of manure resulting from 200 dairy cows at the rate of 30 percent of dry matter intake to wintering cows,

could save 811 tons of grass hay. If the grass hay replaced by manure is valued at \$50 per ton, the producer could afford to pay \$40,000 annually for the conversion of dairy manure to wintering beef-cattle feed. Since the fiber hydrolysis process required heat, preferably steam, this process may find application on a commercial basis in areas with the geothermal energy resources.

CHAPTER IV
COMPARATIVE USES OF CONVENTIONAL vs GEOTHERMAL
ENERGY SOURCES

To compare the use of conventional energy sources with low temperature geothermal energy in this model.

This objective, aside from requiring the technical and engineering specifications for the geothermal dairy, requires a comparative evaluation of the two dairy systems. The evaluations should provide useful information for those who could be encouraged to invest in communities where geothermal resources are more or less abundant. These resources are most abundant in the western eleven United States. See Figure IV-1.

The relevant questions asked have to be, "Does it work from a dollar and cents point of view?" And also, "Is the system competitive in capturing investments--first, as compared with other non-geothermal investment opportunities, and second, with other intra-cascade investment opportunities?" In the final analysis, it is the economics of the system that will determine if the geothermally energized dairy operation is in fact a viable candidate activity for the Wendel-Amedee K.G.R.A., or for that matter, a K.G.R.A. shown in Figure IV-1.

To determine to what extent specific geothermal resources in the area of Northern California and Nevada can be used for application of this type.

FIGURE IV-1

Included here are the K.G.R.A. listed for Nevada in Figure IV-1 and the following K.G.R.A. for California: (1) Mono-Long Valley, (2) Lake City, (3) Wendel-Amedee, (4) Lassen, and (5) Glass Mountain.

The cascade concept shown in II-1 is applicable to any geothermal reservoir. The important limitations internally to the system is the amount and temperature of the hot water or steam produced for cascading through the system. Note too, that the quality of the hot water--its level of mineralization, particularly with salts that tend to effect direct use, either because of the affect on equipment or else because of its effect on products such as in food processing. As for the Wendel-Amedee K.G.R.A., some difficulty with boron and sodium has been experienced, particularly with using the cooled water for irrigation purposes. A practical end use for substantially cooled (cascade trailings) water is crop irrigation, either in greenhouses, open fields or for soil warming. Water that may be used for this purpose needs to be sufficiently free of harmful substances so that the crop can be successfully grown and sold in the market place.

For this project, the Wendel-Amedee K.G.R.A., the comparison is made between a conventional dairy operation and one in which the energy required comes mainly from a geothermal source (See Table III-2, Energy Utilization Account). The analysis consists of two parts: 1) a static single year budget, and 2) a dynamic 20-year analysis. The budgets used in this

analysis have been broken into eight sub-budgets for comparative purposes. The sub-budgets include: 1) milking parlor and hospital; 2) milk cow barn; 3) dry cow and heifer barn; 4) calf barn; 5) feed; 6) manure disposal; 7) geothermal water utilization; and 8) miscellaneous. A discussion of each sub-budget is presented along with a comparison of the costs for the conventional and proposed methods of operation.

The costs have been divided into fixed and variable costs. Fixed costs are costs that are incurred by the dairy regardless of production; e.g., payment of interest on borrowed funds, taxes, insurance, etc., and are constant for various production levels for a given scale of operation. Variable costs are those that are incurred only during production; e.g., feed, labor, electricity, maintenance. Variable costs are a function of production; the greater the production, the greater the variable costs.

In this analysis, a system of amortization has been used to obtain a yearly allocation of the fixed costs for the dairy comparisons. Amortization includes a cost for capital and ten percent has been chosen in this instance as the return to capital. The specific time period of amortization used for the various fixed costs are shown in Table IV-2. Maintenance for the various items is based on a percent of the purchase cost or construction value. A total yearly cost is derived by adding total variable costs to amortization costs. A cost per cow figure is based on total yearly costs divided by the number of cows in the milk herd.

As a point of orientation, the computer simulation and

analysis of the model dairy requires the establishment of a basing point through which the long term development might most realistically be projected. There is a need to know not only the static costs and returns, but also the likely cost changes over time. If energy costs will accelerate faster than other costs such as labor, feed, and rent, then the budget can serve to show the comparative difference over time between the conventional and non-conventional systems.

For this research, it was assumed that the dairy would be composed of 200 milking cows at all times, along with the necessary support animals. As a basing point for the research, a budget (Table IV-1) for a conventional dairy operation is presented.

Note in Table IV-1 that the total annual cost, including variable and fixed costs amounts to \$1,468.84 or \$10 per cwt of 3.5 percent milk. This is the real price against which the non-conventional dairy must ultimately compete. Note in the conventional dairy, the total costs are divided into three components as compared to only two in the computer analysis. This is to identify the actual cash flow requirements made against an operating dairy.

PART I

Static Single Year Budget

Milking Parlor and Hospital

The milking parlor and hospital are very similar for the conventional and proposed dairy systems. The milking parlor con-

sists of a double herringbone milking system with group prep, treatment and maternity area, and utility room. The differences lie in the way the building is heated and the milk cooled. The conventional milk parlor is heated by an LPG heater, while the proposed is heated by geothermal water. Milk is cooled by a vapor compressor in the conventional dairy and an absorption cooler in the proposed. Hot water for cleanup is supplied by an LPG fired hot water tank in the conventional dairy, while the proposed uses geothermal water.

Table IV-3 presents the cost structure for the milking parlor and hospital. The conventional dairy has lower fixed costs than the proposed (\$75,604 as opposed to \$80,519) while variable costs are higher for the conventional dairy due to the cost of electricity and heat.

Because the proposed dairy produces all of its required energy, the proposed milk parlor has an apparent savings of \$4,476 per year over the conventional. However, the cost for producing this energy is not included in the milking parlor and hospital budget. The manure disposal and geothermal water utilization budgets account for the total cost of energy production (See Tables IV-12 and IV-13). When this cost is allocated by energy used in the various activities, such as the milking parlor and hospital, the comparison changes.²

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²The cost of electricity produced by the proposed system is dependent upon the cost of producing methane in the digestion process and using this to fuel an engine driven generator. Since the digester uses geothermal energy, the cost of electricity is also dependent upon the geothermal water utilization budget.

TABLE IV-1

CONVENTIONAL DAIRY PRODUCTION COSTS BUDGET*

207 cows, 26% replacement, 4% cow death loss, 10% calf death loss, drylot, raise replacements, 14,127 lbs. of 3.5% milk produced per cow.

I Operating Cash Costs		<u>Value/Cow</u>
1.	Hay (8.8 tons @ \$71/ton)	\$ 624.80
2.	Concentrate (2.5 tons @ \$126/ton)	315.00
3.	Veterinary and medicine	16.00
4.	Breeding	10.50
5.	DHIA	10.80
6.	Milking supplies	5.45
7.	Utilities	23.00
8.	Milk hauling	43.01
9.	Marketing cows and calves	10.00
10.	Fuel	17.80
11.	Hired labor (milker 1b 12,000, 1 man \$7,500 ½ man \$3,750)	112.32
12.	Repairs	23.60
13.	Miscellaneous (dues, pooling, etc.)	10.00
14.	Total Operating Cash Costs	\$1,122.28
II. Fixed Cash Costs		
15.	Taxes	\$ 21.80
16.	Insurance	6.00
17.	Total Fixed Cash Costs	27.80
III Non-Cash Costs		
18.	Depreciation	
a.	Buildings	13.00
b.	Machinery and equipment	42.00
19.	Death loss	12.32
20.	Operator labor (\$12,000/year)	57.97
21.	Opportunity cost of capital (8% x \$241,863) ÷ 207)	93.47
22.	Total Non-Cash Costs	\$ 218.76
23.	Total Costs	\$1,468.84
24.	Cost Per Hundred Pounds of Milk	\$ 10.40

*The above budget, Dairy Production Costs, is available from the Nevada Cooperative Extension Service. It was developed by Mr. Gordon L. Myer, Extension Agriculture Specialist in Farm Management and Marketing.

TABLE IV-2
AMORTIZATION AND MAINTENANCE SCHEDULE

<u>Fixed Costs</u>	<u>Amortization at 10% (number of years)</u>	<u>Maintenance (% of purchase cost or construction value)</u>
Buildings	20	2
Ventilation	20	3
Heating	20	3
Milk Tank	15	3
Milking Equipment	15	3
Treatment Stalls	20	2
Maternity Pens	20	2
Absorption Cooler	20	3
Cooling Tower	20	3
Vapor Compressor	15	3
Hot Water Tank	15	3
Pipe and Insulation	20	3
Freestalls	15	2
Waterers	15	2
Calf Pens	10	2
Grass Growth Chambers	20	2
Concentrate Storage	20	2
Feed Wagon	10	3
Disgester Tank	20	2
Heat Exchanger	20	3
Pumps	15	3
Safety Equipment	20	2
Flash Tank	20	2
Make-up Tank	20	2
Water Pump	15	3
Scrubber	20	2
Compressor	15	3
Water Dripleg	20	2
Engine	10	3
Generator	10	3
Tractor Scraper	10	3
Hot Water Storage Tank	20	2
Fence	10	3

TABLE IV-3

DAIRY BUDGET

Milking Parlor and Hospital

<u>Sunk Costs (Investment)</u>	<u>Conventional Dairy</u>	<u>Proposed Dairy</u>
Building	\$ 44,000	\$ 44,000
Ventilation	241	241
Heating	280	800
Milk Tank	16,000	16,000
Milking Equipment	10,155	10,155
Treatment Stalls	270	270
Maternity Pens	350	350
Absorption Cooler	---	6,656
Cooling Tower	---	1,548
Vapor Compressor	3,658	---
Hot Water Tank	650	444
Pipe and Insulation	---	55
TOTAL:	\$ 75,604	\$ 80,519
 <u>Variable Costs (Operation)</u>		
Milking Supplies	\$ 1,090	\$ 1,090
Electricity	3,680	---
Heat	1,500	---
Labor	12,000	12,000
Veterinary and Medicine	3,200	3,200
Maintenance	1,655	1,758
TOTAL:	\$ 23,125	\$ 18,048
Amortization Costs:	\$ 9,352.99	\$ 9,953.86
Total Yearly Costs:	\$ 32,478	\$ 28,001.9
Cost/Cow:	\$ 162.39	\$ 140.009

Milk Cow Barn

The conventional milk cow barn consists of a "cold" free stall barn. This is often of pole-type construction with one side of the barn being left open for ventilation. The proposed milk cow barn consists of a "warm" environmental barn. The walls and ceiling are insulated and mechanical ventilation is provided. Barns are insulated to reduce stress on the cows.

When a cow is subjected to stress it releases an adrenocorticotrophic hormone (ACTH). Because high levels of ACTH cause milk production to decrease, stress should be minimized to assure maximum milk production. There are two types of temperature related stress, cold stress and heat stress. Cold stress affects milk production in that more energy is required to keep the cow warm, so less is available for milk production. In a cold stress situation, for a given quantity of feed, less milk will be produced or, to maintain a given milk production, more feed will be required. Heat stress affects milk production in that less feed is consumed by the cow when she is hot. Since milk production is a function of feed intake, less milk is produced during a heat stress situation. Due to the cool summers in the Susanville area, heat stress doesn't present a serious problem, so it was not considered in this analysis. Cold stress generally occurs at temperatures below 5°F (See Figure IV-2).

There are various opinions as to when a warm barn is economically justified. Speicher (1967) states that warm barns

FIGURE IV-2

MILK PRODUCTION AND
THE EFFECTS OF COLD STRESS

can be justified when the average minimum daily temperature is 5°F or colder for the 120 day winter period. Speicher and Brown (1970) concluded that warm barns are not justified except for dairies, in the northern portions of the United States, where average temperatures are 10°F or lower for extended periods of time. Table IV-4 shows the minimum temperature in the Susanville area for the five coldest months to average in the 20's, indicating that a warm barn would not be justified in this case.

The milk cow barn budget (Table IV-5) is based on the conventional dairy utilizing a cold freestall barn costing \$6 per square foot with natural ventilation, heated waterers and fenced exercise area. The proposed dairy has a warm environmental barn costing \$12 per square foot with mechanical ventilation, heating and non-heated waterers. Total yearly costs are \$18,419 for the conventional and \$34,513 for the proposed. Savings will accrue to the proposed dairy in the form of either feed savings or increased milk production. Feed savings will be used in this instance for comparative purposes. A feed savings of ten percent for the four month winter period is used based on personal communication with the dairy farmers in the Susanville area. This amounts to a total yearly savings of \$5,356 (See Table IV-10). The warm barn costs an additional \$16,094 per year, and saves only \$5,356 in feed. Again, it should be emphasized that the budget doesn't reflect the costs for energy. In this case it is a very small figure due to the small amount of heating and lighting required for the milk cow barn.

TABLE IV-4

AVERAGE MINIMUM DAILY TEMPERATURE
FOR FIVE COLDEST MONTHS IN SUSANVILLE AREA
(Degrees Fahrenheit)

	<u>November</u>	<u>December</u>	<u>January</u>	<u>February</u>	<u>March</u>
Average*	28.2	22.7	20.7	24.2	28.7
Lowest*	1	-10	-22	-23	- 4

Source: National Weather Service

*For 52 years of record

TABLE IV-5
MILK COW BARN

<u>Sunk Costs (Investment)</u>	<u>Conventional Dairy</u>	<u>Proposed Dairy</u>
Building	\$118,944.00	\$237,888.00
Ventilation	---	2,176.00
Heating	---	1,985.00
Free stalls	6,000.00	6,000.00
Waterers	350.00	150.00
Pipe and insulation	---	360.00
Fence	<u>1,470.00</u>	<u>---</u>
TOTAL:	\$126,764.00	\$248,559.00
 <u>Variable Costs (Operation)</u>		
Maintenance	\$ 2,550.00	\$ 5,018.00
Electricity	<u>708.00</u>	<u>---</u>
TOTAL:	\$ 3,258.00	\$ 5,018.00
Amortization Costs:	\$ 15,161.4	\$ 29,495.3
Total Yearly Cost:	\$ 18,419.4	\$ 34,513.3
Cost per Cow:	\$ 92.10	\$ 172.57

Dry Cow and Heifer Barn

The dry cow and heifer barn are essentially the same for both the conventional and the proposed systems. Stress is not as critical with dry cows as compared to milking cows because they are not producing milk and a maintenance ration is all that is being fed. The heifers may gain less weight during stress situations, but this weight difference is usually made up during other periods. The costs for both systems are presented in Table IV-6.

Calf Barn

The conventional system has no calf barn as such. The system consists of individual sheltered calf pens. The calves are moved to a fenced area after 1.5 months and remain there until they enter the dry cow and heifer barn at age eight months. The proposed system consists of a warm barn that houses all calves and young heifers until they enter the dry cow and heifer barn.

The conventional system costs \$3,166 as compared to a cost of \$36,907 for the proposed system (See Table IV-7). The savings for the proposed system will be reflected in less calf and heifer death loss. This amounts to an annual savings of \$4,280. This figure is based on a cow cull rate of 30 percent for both systems, a calf loss of seven percent for the proposed, and a calf loss of 18 percent for the conventional; cull cow value of \$297, calf value of \$20, and a heifer value of \$408. The total yearly cost difference between the conventional and pro-

TABLE IV-6

DRY COW AND HEIFER BARN

<u>Sunk Costs (Investment),</u>	<u>Conventional Dairy</u>	<u>Proposed Dairy</u>
Building	\$ 68,544.00	\$ 68,544.00
Free stalls	4,440.00	4,440.00
Waterers	700.00	700.00
Fence	<u>1,165.00</u>	<u>1,165.00</u>
TOTAL:	\$ 74,849.00	\$ 74,849.00
<u>Variable Costs (Operations)</u>		
Maintenance	\$ 1,509.00	\$ 1,509.00
Electricity	<u>304.00</u>	<u>---</u>
TOTAL:	\$ 1,813.00	\$ 1,509.00
Amortization Costs:	\$ 8,938.44	\$ 8,938.44
Total Yearly Cost:	\$ 10,751.4	\$ 10,447.4
Cost per Cow:	\$ 53.76	\$ 52.24

TABLE IV-7

Calf Barn

<u>Sunk Costs (Investment)</u>	<u>Conventional Dairy</u>	<u>Proposed Dairy</u>
Building	\$ ---	\$ 33,696.00
Heating	---	395.00
Ventilation	---	496.00
Calf pens	2,400.00	800.00
Free stalls	---	1,440.00
Pipes and insulation	---	80.00
Fence	<u>766.00</u>	<u>---</u>
TOTAL:	\$ 3,166.00	\$ 36,907.00
<u>Variable Costs (Operations)</u>		
Maintenance	\$ 71.00	\$ 748.00
Electricity	<u>---</u>	<u>---</u>
TOTAL:	\$ 71.00	\$ 748.00
Amortization Costs:	\$ 405.51	\$ 4,368.77
Total Yearly Costs:	\$ 476.51	\$ 5,116.77
Cost per Cow:	\$ 2.38	\$ 25.58

posed is \$4,640. Based on these cost comparisons it appears that the calf barn is not feasible.

Feed

The conventional feed ration consists of a hay/grain combination with all feed being purchased. The proposed ration consists of a grass/roughage/grain combination with the grass being grown on farm with growth chambers, and the other feeds purchased.

The conventional dairy feed costs are based on fifty pounds per day milk production per cow, hay \$65 per ton, grain \$110 per ton, milk replacer \$16.50 per fifty pounds, calf starter \$194 per ton. The amount of feed required for the dairy operation is presented in Chapter 2. The proposed dairy feed costs are based on fifty pound per day milk production per cow, with grass at \$49.14 per ton (See Table IV-8), straw \$27 per ton, grain \$110 per ton, milk replacer at \$16.50 per fifty pounds, and calf starter at \$194 per ton. The amount of feed required for the proposed dairy is based on a grass/straw combination replacing hay for an equivalent energy value. Table IV-9 presents the comparative costs for the two systems with grass at 33 percent dry matter. It can be seen that the proposed feed ration costs \$56,855 per year more than the conventional ration, or \$284 more per cow.

Table IV-10 gives the comparative value of grass when compared to hay and grain. With grass costing \$49.14 per ton, hay would have to cost over \$91 per ton before the grass would be substituted for hay, based on a total digestable nutrient (TDN) comparison.

TABLE IV-8
COST PER TON FOR SPRINGFEED GRASS

Sunk Costs: (Investment)

Growth Chamber	\$15,500.00
Model 24	
Capacity, 146 tons per year	
TOTAL:	\$15,500.00

Variable Costs: (Operations)

Seed	
260 pounds @ \$7.65 per cwt	\$ 19.89
Chlorine	.50
Nutrient	1.78
Electricity	5.00
Maintenance	.50
Labor	
3 hours @ \$3 per hour	9.00
TOTAL:	\$ 36.67

Amortization: 20 years @ 10%	\$ 12.47
TOTAL cost per ton:	\$ 49.14

Source: Commercial Firm (not identified)

TABLE IV-9

F E E D

<u>Sunk Costs (Investment)</u>	<u>Conventional Dairy</u>	<u>Proposed Dairy</u>
Grass growth chamber	\$ ---	\$341,000.00
Concentrate storage	2,862.00	2,862.00
Feed wagon	4,500.00	4,500.00
TOTAL:	\$ 7,362.00	\$348,362.00
<u>Variable Costs (Operations)</u>		
Nutrient	\$ ---	\$ 5,381.00
Seed	---	60,127.00
Roughage	---	13,440.00
Concentrate	53,196.00	51,480.00
Hay	112,840.00	1,755.00
Maintenance	192.00	7,012.00
Labor	---	27,207.00
Electricity	---	15,115.00
Chlorine	---	1,512.00
Milk replacer	1,737.00	1,737.00
Calf starter	3,162.00	3,162.00
TOTAL:	\$171,127.00	\$187,928.00
Amortization Costs:	\$ 864.74	\$ 40,918.6
Total Yearly Costs:	\$171,992.00	\$228,847.00
Cost Per Cow:	\$ 859.96	\$ 1,144.23

NOTE: Grass requirements are figured at 33% dry matter.

TABLE IV-10

COMPARISON OF SELECTED FEEDS
WITH SPRINGFEED GRASS
EQUIVALENT VALUE

Feed	Dry Matter %	TDN		Cost/Ton		Grain		Hay	
		ASFED	Dry	ASFED	Dry	ASFED	Dry	ASFED	Dry
Barley Grain	89	71.9	80.8	91.00	102.25	91.00	102.25	95.18	106.80
Alfalfa Hay	91.4	49.1	53.8	65.00	71.12	62.14	68.00	65.00	71.12
Springfeed Grass	33	26.4	80.0	49.14	148.90	33.41	101.24	34.95	105.75
Springfeed Grass	25	20.0	80.0	49.14	196.56	25.31	101.24	26.48	105.75
Springfeed Grass	20	16.0	80.0	49.14	245.70	20.25	101.24	21.18	105.75
Springfeed Grass	15	12.0	80.0	49.14	327.60	15.19	101.24	15.88	105.75

Feed	Dry Matter %	Grass 33%		Grass 25%		Grass 20%		Grass 15%	
		ASFED	Dry	ASFED	Dry	ASFED	Dry	ASFED	Dry
Barley Grain	89	133.83	150.40	176.66	198.52	220.82	248.16	294.43	330.87
Alfalfa Hay	91.4	91.39	100.13	120.64	131.51	150.80	165.23	201.06	220.31
Springfeed Grass	33	49.14	148.90						
Springfeed Grass	25			49.14	196.56				
Springfeed Grass	20					49.14	245.70		
Springfeed Grass	15							49.14	327.60

Note: Various dry matter contents were analyzed for the springfed grass due to the uncertainty of the actual dry matter content of the grass.

Similarly, grain would have to cost \$134 per ton before a substitution would be made, grass for grain. With lower dry matter contents for the grass, the price of hay and grain would have to increase substantially before a substitution would be made.

Table IV-11 presents the savings if conventional feed were used in the proposed system. A savings of \$26.77 per cow would accrue to the proposed dairy with conventional feed due to the feed savings in the winter. This savings is due to a reduction of cold stress as discussed earlier.

Manure Disposal

Manure can be thought of in terms of a disposal problem with little or no value, or of a byproduct with potential value. There are many manure handling systems being used today by dairy farmers, but for this analysis two systems will be compared. The conventional system consists of a tractor-scraper that collects the manure and stockpiles it. The proposed system uses a similar collection system but instead of stockpiling, the manure is processed through a digester. The digester produces bio-gas and sludge. The bio-gas is used to generate electricity. The sludge can be used as a fertilizer.

The costs for the two systems are presented in Table IV-12. The conventional system has a total cost of \$1,420 per year. This compares to a cost of \$11,047 for the proposed system.

The raw manure collected in the conventional system has some value as a fertilizer, but since the conventional dairy buys

TABLE IV-11
FEED BUDGETS WITHOUT GRASS GROWTH CHAMBERS

	Conventional Dairy	Proposed Dairy
<u>Sunk Costs: (Investment)</u>		
Grass Growth Chamber	\$ --	\$ 0
Concentrate Storage	2,862.	2,862.
Feed Wagon	<u>4,500.</u>	<u>4,500.</u>
Total:	\$ 7,362.	\$ 7,362.
<u>Variable Costs: (Operations)</u>		
Nutrient	\$ --	\$ 0
Seed	--	0
Roughage	--	0
Concentrate	53,196.	51,480.
Hay	112,840.	109,200.
Maintenance	192.	192.
Labor	--	0
Electricity	--	0
Chlorine	--	0
Milk Replacer	1,737.	1,737.
Calf Starter	<u>3,162.</u>	<u>3,162.</u>
Total:	\$171,127.	\$165,771.
Amortization Costs:	\$ 864.74	\$ 864.74
Total Yearly Costs:	\$171,992.	\$166,636.
Cost/Cow:	\$ 859.96	\$ 833.18

TABLE IV-12

MANURE DISPOSAL

<u>Sunk Costs (Investment)</u>	<u>Conventional Dairy</u>	<u>Proposed Dairy</u>
Digester tank	\$ ---	\$ 39,000.00
Heat exchanger	---	15,000.00
Sludge pumps	---	3,000.00
Safety equipment	---	1,000.00
Flash tank	---	2,000.00
Make-up tank	---	100.00
Water pump	---	442.00
Scrubber	---	1,000.00
Compressor	---	650.00
Water dripleg	---	100.00
Engine	---	2,480.00
Generator	---	1,433.00
Tractor-scraper	<u>9,621.00</u>	<u>9,621.00</u>
TOTAL:	\$ 9,621.00	\$ 75,826.00
<u>Variable Costs (Operations)</u>		
Maintenance	\$ 290.00	\$ 1,864.00
Electricity	<u>---</u>	<u>---</u>
TOTAL:	\$ 290.00	\$ 1,864.00
Amortization Costs:	\$ 1,130.08	\$ 9,183.32
Total Yearly Costs:	\$ 1,420.08	\$ 11,047.83
Cost per Cow:	\$ 7.10	\$ 55.24

all of its feed, the manure will have to be sold off-farm. For this analysis it was assumed that the off-farm value would be offset by the transportation and marketing expense. Therefore, the manure will have a zero value. In the proposed system, the products to be analyzed for value consist of electricity and the sludge left from the digestion process. The value of the electricity could be expressed as the savings in conventional energy costs, but since the conventional dairy uses less energy than the proposed, the electricity costs for the conventional dairy cannot be used. The exact electricity consumption for the proposed system is not known due to the uncertainty of how long various pieces of equipment would run for an average year. Considering this, an analysis will be based on the maximum amount of electricity that the system can produce. The system consists of a 30 kw generator producing 25 kw's on a continuous basis. If it is assumed to run continuously with a ten percent down time, then a total of 197,100 kwh is produced per year $((25 \times 24 \times 365) - 10\% = 197,100)$. An average value of \$.042 per kwh was used, based on the total number of kwh's produced and the price of electricity in the Susanville area. This gives a total value of \$8,314.37 per year for electricity produced. The sludge from the digester has an unknown value due to the scarcity of the product. Basing the value of the sludge on the nitrogen contained in it and comparing this to another source of nitrogen, urea, a yearly value of \$2,886.95 is derived. This is based on 8 tons³ of nitrogen

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³This figure is based on results obtained by a similar size dairy bio-gas system at the State Reformatory Honor Farm, Monroe, Washington.

being produced, and a cost for urea of \$166 per ton, urea being 46 percent nitrogen ($8 \times 166 / .46 = \$2,886.95$). The total yearly value of the combined products is \$11,201.33 with a total yearly cost for the system of \$11,047.30. Therefore, the net savings is \$154.03 per year. The actual cost will be slightly higher depending on the allocation of the miscellaneous geothermal water equipment. If the miscellaneous geothermal water cost allocation exceeds the \$154 per year, it will do so by a small margin, so the system should be at, or near, break-even for the first year.

Geothermal Water Utilization

The miscellaneous geothermal water utilization equipment is included in this budget (See Table IV-13) due to the fact that it would be inappropriate to group these costs with one specific activity. The total yearly cost of \$626 is considered in the total budget, but the allocation of these costs among specific uses cannot be estimated at this time. In order to allocate these costs the simulation would have to be run for the various temperatures expected during the average year. This would require a minimum of 12 runs if average monthly data was used, or to be more accurate, 365 runs if daily data was used. There was not enough time to run this data, so specific allocation of these costs was not considered.

Miscellaneous

The miscellaneous budget includes all items required by the dairy systems not included in other budgets. Table IV-14

TABLE IV-13

GEOTHERMAL WATER UTILIZATION

<u>Sunk Costs (Investment)</u>	<u>Conventional Dairy</u>	<u>Proposed Dairy</u>
Hot water storage tank	\$ ---	\$ 714.00
Pump-well	---	1,170.00
Pump-tank	---	733.00
Pipes	---	1,237.00
Insulation	---	254.00
TOTAL:	\$ ---	\$ 4,108.00
<u>Variable Costs (Operations)</u>		
Maintenance	\$ ---	\$ 117.00
Electricity	---	---
TOTAL:	\$ ---	\$ 117.00
Amortization Costs:	\$ ---	\$ 509.19
Total Yearly Costs:	\$ ---	\$ 626.19
Cost per Cow:	\$ ---	\$ 3.13

TABLE IV-14

MISCELLANEOUS

<u>Fixed Costs</u>	<u>Conventional Dairy</u>	<u>Proposed Dairy</u>
Insurances	\$ 1,200.00	\$ 2,150.00
Taxes	<u>4,360.00</u>	<u>4,360.00</u>
TOTAL:	\$ 5,560.00	\$ 6,510.00
 <u>Variable Costs (Operations)</u>		
Milk hauling	\$ 22,875.00	\$ 22,875.00
Breeding	4,000.00	4,000.00
CHIA	2,160.00	2,160.00
Dues, pooling, etc.	2,000.00	2,000.00
Fuel	3,560.00	3,560.00
Marketing cows and calves	2,000.00	2,000.00
Labor	<u>23,250.00</u>	<u>23,250.00</u>
TOTAL:	\$ 59,845.00	\$ 59,845.00
 Total Yearly Costs:	 \$ 65,405.00	 \$ 66,355.00
 Cost per Cow:	 \$ 327.03	 \$ 331.78

presents these costs for the two systems. Costs are very similar except that insurance costs are greater for the proposed system because of the increased capital investment.

Total Yearly Costs

The total yearly costs for both systems are given in Tables IV-15 and IV-16. Table IV-16 shows the cost with the grass growth chambers included; Table IV-15 without. The grass adds an additional \$2.23 to the proposed system and is not feasible at this time. A construction allowance has been included in the cost figures to allocate the expense of building the total system (the budgets are largely comprised of material and equipment costs). A figure of 15 percent of fixed costs was used as the construction allowance. This also allows for unforeseen expenses that might accrue. The cost per cwt for the conventional system is \$8.93 $((300,719 - 28,436) \div 30,500)$. The proposed system is calculated in a similar fashion and yeilds a \$9.58 cost per cwt without the digester sludge valued. When a value is given to the digester sludge, the cost per cwt decreases to \$9.49 $((325,144 - 32,716 - 2,886.95) \div 30,500)$.

PART II

Twenty-Year Analysis

To more fully compare the feasibility of the proposed dairy system to the conventional sytem, a twenty-year analysis was performed. The analysis consists of projecting the costs for the two systems over a twenty-year period. Predicting how production

TABLE IV-15

TOTAL YEARLY COSTS

	<u>Conventional</u>	<u>Proposed</u>
Total Sunk Costs	\$302,926.00	\$534,640.00
Construction Allowance	45,438.90	80,196.00
Total Variable Costs	259,529.00	252,920.00
Total Amortization Costs	35,853.20	62,804.40

#####

	<u>Conventional</u>	<u>Proposed</u>
Total Yearly Costs	\$300,719.00	\$325,144.00
Less Livestock Sales	28,436.00	32,716.00
Cost per cwt:*	\$ 8.93	\$ 9.58
Cost per Cow:	\$ 1,361.42	\$ 1,462.14
Milk Production:	30,500 cwt	30,500 cwt

*1 cwt = 45.36 kg

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TABLE IV-16

TOTAL YEARLY COSTS

	<u>Conventional</u>	<u>Proposed*</u>
Total Sunk Costs	\$302,926.00	\$393,363.00
Construction Allowance	45,438.90	131,346.00
Total Variable Costs	259,529.00	275,077.00
Total Amortization Costs	35,853.20	102,858.00

#####

	<u>Conventional</u>	<u>Proposed</u>
Total Yearly Costs	\$300,719.00	\$393,363.00
Less Livestock Sales	28,436.00	32,716.00
Cost per cwt:	\$ 8.93	\$ 11.82
Cost per Cow:	\$ 1,361.42	\$ 1,803.24
Milk Production:	30,500 cwt	30,500 cwt

*Proposed system includes grass/straw ration which has been excluded due to high cost.

costs and product prices are going to change over time with accuracy is difficult, but an attempt has been made. Since fixed costs are constant for a given scale of operation there is an equal yearly allocation to total operating cost. Variable costs, however, may change depending on interactions of the economy. With this in mind, it was assumed the only costs that would affect total operating costs in the future would be variable costs. The question becomes, "How these costs increase, and at what rate?" Two cost schemes have been devised to be as flexible and realistic as possible. They consist of a linear cost increase and a percent per year cost increase (non-linear). The variable costs were divided into four categories: 1) feed, 2) labor, 3) energy, and 4) other. Cost increases were based on past cost trend data, an index of prices paid and received by farmers. Based on this data, it was assumed that feed costs would increase by ten percent, labor by ten percent, energy by 15 percent or 25 percent (the higher figure is included to analyze the sensitivity of milk production costs to energy cost increases), and other by 11 percent. The variable costs for the conventional dairy can be broken down into percentages of total production costs with feed comprising 56.8 percent of total costs, labor 11.7 percent, energy two percent, and other 15.7 percent. The remainder consists of the fixed cost allocation. The variable costs for the proposed system may be divided into feed which is 51 percent of total costs, labor is 10.8 percent, and other 15.9 percent. Energy is not included because the proposed system produces all of the energy required, and

the costs associated are included in the fixed cost allocation and the other category.

Based on these assumptions, a figure of 8.887 percent (9.08 percent for 25 percent energy increase) is used to predict production cost increases for the conventional dairy while 7.93 percent is used for the proposed dairy. The results are given in Table IV-17 for non-linear increase, while Table IV-18 shows the linear increase. The proposed costs are figured with sludge valued, and not valued as discussed earlier. One can see that it takes ten years (9 years with sludge valued) to reach a break-even point between the two systems with a non-linear cost increase. With the higher energy cost (25 percent), the break-even point takes place at eight years (7 years with sludge valued). This small change in the break-even point is probably due to the small percent of production costs represented by energy. With a linear cost increase and 15 percent rise in the cost of energy, the proposed never reached a break-even point with the conventional. With the sludge valued for the proposed system, the break-even point is at 16 years. At 25 percent energy cost increase, the break-even point is reached in 14 years (11 years for the sludge valued). A graphical representation of both schemes are presented in Figures IV-3 and IV-4.

Milk prices were also predicted using similar pricing schemes for an 8.5 percent, 9 percent, and 10 percent yearly increase in price. Tables IV-19 and IV-20 present the results. A graphical representation is given in Figures IV-5 and IV-6. The

FIGURE IV-3
MILK PRODUCTION COSTS
Non-Linear Increase

FIGURE IV-4
MILK PRODUCTION COST
Linear Increase

FIGURE IV-5
MILK PRICE
Non-Linear Increase

FIGURE IV-6

MILK PRICE
Linear Increase

TABLE IV-17

TWENTY YEAR PRODUCTION COST ANALYSIS
Non-Linear Increase

	15% Energy Conventional Cost/Cwt.	25% Energy Conventional Cost/Cwt.	Proposed Cost/Cwt.	Sludge Valued Proposed Cost/Cwt.
Year 1	\$ 8.93	\$ 8.93	\$ 9.58	\$ 9.49
Year 2	9.72	9.74	10.34	10.24
Year 3	10.58	10.63	11.16	11.05
Year 4	11.52	11.59	12.04	11.93
Year 5	12.55	12.65	13.00	12.88
Year 6	13.66	13.79	14.03	13.90
Year 7	14.87	15.05	15.14	15.00
Year 8	16.19	16.42	16.34	16.19
Year 9	17.62	17.91	17.64	17.47
Year 10	19.19	19.53	19.04	18.86
Year 11	20.89	21.31	20.55	20.36
Year 12	22.74	23.25	22.18	21.97
Year 13	24.76	25.36	23.94	23.71
Year 14	26.96	27.66	25.84	25.59
Year 15	29.35	30.18	27.88	27.62
Year 16	31.95	32.92	30.10	29.81
Year 17	34.78	35.91	32.48	32.18
Year 18	37.87	39.17	35.06	34.73
Year 19	41.23	42.73	37.84	37.48
Year 20	44.89	46.62	40.84	40.45

TABLE IV-18
 TWENTY YEAR PRODUCTION COST ANALYSIS
 Linear Increase

	15% Energy Conventional Cost/Cwt.	25% Energy Conventional Cost/Cwt.	Proposed Cost/Cwt.	Sludge Valued Proposed Cost/Cwt.
Year 1	\$ 8.93	\$ 8.93	\$ 9.58	\$ 9.49
Year 2	9.72	9.74	10.34	10.24
Year 3	10.51	10.55	11.10	11.00
Year 4	11.31	11.36	11.86	11.75
Year 5	12.10	12.18	12.62	12.50
Year 6	12.89	12.99	13.38	13.25
Year 7	13.68	13.80	14.14	14.01
Year 8	14.47	14.61	14.90	14.76
Year 9	15.27	15.42	15.66	15.51
Year 10	16.06	16.23	16.42	16.26
Year 11	16.85	17.04	17.18	17.02
Year 12	17.64	17.86	17.94	17.77
Year 13	18.44	18.67	18.70	18.52
Year 14	19.23	19.48	19.46	19.27
Year 15	20.02	20.29	20.22	20.03
Year 16	20.81	21.10	20.98	20.78
Year 17	21.60	21.91	21.74	21.53
Year 18	22.40	22.73	22.49	22.28
Year 19	23.19	23.54	23.25	23.04
Year 20	23.98	24.35	24.01	23.79

TABLE IV-19

TWENTY YEAR MILK PRICE ANALYSIS
Non-Linear Increase

	8.5% Milk Price	9% Milk Price	9.5% Milk Price	10% Milk Price
Year 1	\$ 9.5	\$ 9.5	\$ 9.5	\$ 9.5
Year 2	10.31	10.36	10.40	10.45
Year 3	11.18	11.29	11.39	11.50
Year 4	12.13	12.30	12.47	12.64
Year 5	13.17	13.41	13.66	13.91
Year 6	14.28	14.62	14.96	15.30
Year 7	15.50	15.93	16.38	16.83
Year 8	16.82	17.37	17.93	18.51
Year 9	18.25	18.93	19.64	20.36
Year 10	19.80	20.63	21.50	22.40
Year 11	21.48	22.49	23.54	24.64
Year 12	23.31	24.51	25.78	27.10
Year 13	25.29	26.72	28.23	29.82
Year 14	27.44	29.13	30.91	32.80
Year 15	29.77	31.75	33.85	36.08
Year 16	32.30	34.60	37.06	39.68
Year 17	35.04	37.72	40.58	43.65
Year 18	38.02	41.11	44.44	48.02
Year 19	41.25	44.81	48.66	52.82
Year 20	44.76	48.85	53.28	58.10

TABLE IV-20

TWENTY YEAR MILK PRICE ANALYSIS
Linear Increase

	8.5% Milk Price	9% Milk Price	9.5% Milk Price	10% Milk Price
Year 1	\$ 9.5	\$ 9.5	\$ 9.5	\$ 9.5
Year 2	10.31	10.36	10.40	10.45
Year 3	11.12	11.21	11.31	11.4
Year 4	11.92	12.07	12.21	12.35
Year 5	12.73	12.92	13.11	13.3
Year 6	13.54	13.78	14.01	14.25
Year 7	14.35	14.63	14.92	15.2
Year 8	15.15	15.49	15.82	16.15
Year 9	15.96	16.34	16.72	17.1
Year 10	16.77	17.20	17.62	18.05
Year 11	17.58	18.05	18.53	19.
Year 12	18.38	18.91	19.43	19.95
Year 13	19.19	19.76	20.33	20.9
Year 14	20.00	20.62	21.23	21.85
Year 15	20.81	21.47	22.14	22.8
Year 16	21.61	22.33	23.04	23.75
Year 17	22.42	23.18	23.94	24.7
Year 18	23.23	24.04	24.84	25.65
Year 19	24.04	24.89	25.75	26.6
Year 20	24.84	25.75	26.65	27.55

production costs for the proposed dairy exceed the milk price for the first two years of analysis with the non-linear production increase and an 8.5 percent milk price increase (Tables IV-17 and IV-18). At other milk price increases, there is a loss for only the first year. With the sludge valued, the production costs are less than the milk price in all cases. With a linear increase in production costs and milk prices, there are similar results (Table IV-19 and IV-21). The conventional dairy production costs are less than the milk price in all cases except for: 1) non-linear production cost increase, energy cost increases 25 percent, and milk price increases 8.5 percent (Tables IV-19 and IV-20), then production costs exceed milk price at year 13 and after; and 2) non-linear production cost increase, energy cost increases 15 percent, and milk price increases 8.5 percent, then production costs exceed milk price at year 20.

Present Worth Analysis

The feasibility of the proposed system cannot be totally analyzed unless a method of equating future prices to the present is used. In order to do this, a present worth analysis was conducted for all the cost-price schemes previously discussed. The results are shown in Tables IV-21 and IV-22 for the production costs, while Table IV-23 and IV-24 give the milk price results. For the production cost analysis, a smaller total is better. The totals for the proposed system are higher than the totals for the conventional system with linear cost increase (Table IV-18). With

TABLE IV-21

PRODUCTION COST
Present Worth Analysis
Linear Increase

	15% Energy Conventional Present Worth	25% Energy Conventional Present Worth	Proposed Present Worth	Sludge-Valued Proposed Present Worth
Year 1	\$ 8.12	\$ 8.12	\$ 8.71	\$ 8.63
Year 2	8.03	8.05	8.55	8.46
Year 3	7.90	7.93	8.34	8.26
Year 4	7.72	7.76	8.10	8.02
Year 5	7.51	7.56	7.84	7.76
Year 6	7.28	7.33	7.55	7.48
Year 7	7.02	7.08	7.26	7.19
Year 8	6.75	6.82	6.95	6.88
Year 9	6.47	6.54	6.64	6.58
Year 10	6.19	6.26	6.33	6.27
Year 11	5.91	5.97	6.02	5.96
Year 12	5.62	5.69	5.72	5.66
Year 13	5.34	5.41	5.42	5.36
Year 14	5.06	5.13	5.12	5.08
Year 15	4.79	4.86	4.84	4.79
Year 16	4.53	4.59	4.56	4.52
Year 17	4.27	4.34	4.30	4.26
Year 18	4.03	4.09	4.05	4.01
Year 19	3.79	3.85	3.80	3.77
Year 20	3.56	3.62	3.57	3.54
TOTAL:	\$119.91	\$120.99	\$123.65	\$122.49

TABLE IV-22

PRODUCTION COST
Present Worth Analysis
Non-Linear

	15% Energy Conventional Present Worth	25% Energy Conventional Present Worth	Proposed Present Worth	Sludge-Valued Proposed Present Worth
Year 1	\$ 8.12	\$ 8.12	\$ 8.71	\$ 8.63
Year 2	8.03	8.05	8.55	8.46
Year 3	7.95	7.98	8.38	8.31
Year 4	7.87	7.92	8.23	8.15
Year 5	7.79	7.85	8.07	8.00
Year 6	7.71	7.79	7.92	7.85
Year 7	7.63	7.72	7.77	7.70
Year 8	7.55	7.66	7.62	7.55
Year 9	7.47	7.59	7.48	7.41
Year 10	7.40	7.53	7.34	7.27
Year 11	7.32	7.47	7.20	7.13
Year 12	7.25	7.41	7.07	7.00
Year 13	7.17	7.35	6.93	6.87
Year 14	7.10	7.28	6.80	6.74
Year 15	7.03	7.22	6.68	6.61
Year 16	6.95	7.16	6.55	6.49
Year 17	6.88	7.10	6.43	6.37
Year 18	6.81	7.05	6.31	6.25
Year 19	6.74	6.99	6.19	6.13
Year 20	6.67	6.93	6.07	6.01
TOTAL:	\$147.45	\$150.18	\$146.29	\$144.92

TABLE IV-23

MILK PRICE
Present Worth Analysis
Linear Increase

	8.5% Milk Present Worth	9% Milk Present Worth	9.5% Milk Present Worth	10% Milk Present Worth
Year 1	\$ 8.64	\$ 8.64	\$ 8.64	\$ 8.64
Year 2	8.52	8.56	8.60	8.64
Year 3	8.35	8.42	8.49	8.56
Year 4	8.14	8.24	8.34	8.44
Year 5	7.90	8.02	8.14	8.26
Year 6	7.64	7.78	7.91	8.04
Year 7	7.36	7.51	7.65	7.8
Year 8	7.07	7.22	7.38	7.53
Year 9	6.77	6.93	7.09	7.25
Year 10	6.46	6.63	6.79	6.96
Year 11	6.16	6.33	6.49	6.66
Year 12	5.86	6.02	6.19	6.36
Year 13	5.56	5.72	5.89	6.05
Year 14	5.27	5.43	5.59	5.75
Year 15	4.98	5.14	5.30	5.46
Year 16	4.70	4.86	5.01	5.17
Year 17	4.44	4.59	4.74	4.89
Year 18	4.18	4.32	4.47	4.61
Year 19	3.93	4.07	4.21	4.35
Year 20	3.69	3.83	3.96	4.10
TOTAL	\$125.62	\$128.25	\$130.88	\$133.52

TABLE IV-24

MILK PRICE
Present Worth Analysis
Non-Linear Increase

	8.5% Milk Present Worth	9% Milk Present Worth	9.5% Milk Present Worth	10% Milk Present Worth
Year 1	\$ 8.64	\$ 8.64	\$ 8.64	\$ 8.64
Year 2	8.52	8.56	8.60	8.64
Year 3	8.40	8.48	8.56	8.64
Year 4	8.29	8.40	8.52	8.64
Year 5	8.17	8.33	8.48	8.64
Year 6	8.06	8.25	8.44	8.64
Year 7	7.95	8.18	8.40	8.64
Year 8	7.84	8.10	8.37	8.64
Year 9	7.74	8.03	8.33	8.64
Year 10	7.63	7.95	8.29	8.64
Year 11	7.53	7.88	8.25	8.64
Year 12	7.43	7.81	8.21	8.64
Year 13	7.32	7.74	8.18	8.64
Year 14	7.22	7.67	8.14	8.64
Year 15	7.13	7.60	8.10	8.64
Year 16	7.03	7.53	8.07	8.64
Year 17	6.93	7.46	8.03	8.64
Year 18	6.84	7.39	7.99	8.64
Year 19	6.75	7.33	7.96	8.64
Year 20	6.65	7.26	7.92	8.64
TOTAL:	\$152.08	\$158.59	\$165.47	\$172.73

a non-linear cost increase, the proposed systems are lower than the conventional system (Table IV-17). The differences lie in the fact that the savings are greater in the latter years for the proposed system, and a non-linear cost increase tends to amplify these savings.

So, with a linear cost increase, the conventional becomes the least cost system. If milk prices are brought into the analysis (Tables IV-23 and IV-24), then both systems become feasible, the total present worth of milk prices always exceeding the present worth of production costs in both systems.

Summary and Conclusion

Two dairy production systems have been compared in the preceding analysis. The systems were compared in the static sense, single-year budget, and dynamic sense, twenty-year analysis, and present worth analysis.

For the single-year budget, the conventional system cost \$8.93 per cwt of milk produced. This compared to a cost of \$9.58 for the proposed system with conventional feed and no value for the digester sludge. This cost was reduced to \$9.49 per cwt if sludge was valued on the amount of nitrogen present in it. With the proposed system and grass in the feed ration, a cost of \$11.82 per cwt was obtained with a conclusion that the grass ration was not feasible.

In the dynamic analysis, two possible conclusions were reached. With non-linear price increases, the proposed system

was the least cost system for the twenty year period of operation.

If linear price increases are expected, then the least cost system is the conventional system.

CHAPTER V

TECHNICAL DATA SUMMARY

The master document contains seventeen chapters of the detailed technical engineering data which would be required to build a geothermal dairy system. The purpose here is to summarize this complex document into a more simplistic and understandable report. The authors feel that each chapter is of enough specific importance for a separate summarization.

DIGESTER DESIGN

Objective: The objective of this analysis was to design a anaerobic digester capable of containing the daily waste produced by a dairy herd of 412 animals and processing this waste efficiently into bio-gas.

Design: The proposed digester is constructed of concrete and reinforced steel. The tank is built in the shape of an octagon, each side being 15 feet, 7 inches in length, and 1 foot thick, and 20 feet high (10 feet above ground and 10 feet below) to take advantage of the natural insulation provided by the soil.

The design shape was chosen because of the lower cost in construction as compared to the circular tank design. The dead spaces encountered in a square tank design are practically eliminated.

The digester as designed, will produce 14,420 cubic feet of methane gas per day.

Geothermal Application: The ideal gas flow was used assuming

atmospheric pressure and a digester operating temperature of 95°F. Heat is added to the digester to maintain this inside temperature by circulating the sludge through a heat exchange which is heated with geothermal water.

CARBON DIOXIDE SCRUBBER DESIGN

Objective: The objective of this section is to outline an approximate approach to the design of the packed tower scrubber system.

Purpose: This equipment is used to remove carbon dioxide from the bio-gas which is produced by the anaerobic digester.

Process: The CO₂ removal technique to be used is nothing more than a common carbonating process. The solubility of carbon dioxide in water increases markedly with increase in pressure, hence, the methane will be compressed using a single cylinder reciprocating compressor and flowed through a packed tower, counter current to a stream of water. The water absorbs the CO₂ into solution and carries it from the packed tower.

Chapter nine of the master document specifies the engineering design.

GEOHERMAL WATER SUPPLY SYSTEM

Geothermal Water Pumps: The geothermal water pumps have been sized for a 100 GPM flow rate. Since the proposed dairy has a maximum geothermal water demand of about 80 GPM, this should be adequate.

The Hobo Wells site geothermal resource is an artesian spring. Therefore, the installation of a turbine type pump would

be a relatively simple matter. This pump would be used to lift the geothermal water from the artesian well to the storage tank. Since the pump needs to be sized only to raise the water a small elevation, the power demand is low. The pump is controlled by a geothermal water level controller in the storage tank.

Although the temperature of the geothermal water is near the saturation temperature, problems with cavitation are avoided by submerging the pump turbine into the hot geothermal water six feet or more. This provides enough net positive suction head (NPSH) so that cavitation can be avoided and thus, the pump can operate efficiently.

A fiberglass insulated 1,000 gallon tank is used to store the geothermal water. Another pump is used to pump the water up to the supply pressure. While this pump has been sized to deliver 100 GPM at a pressure of 50 psig, a much lower supply pressure could be used since none of the equipment in the geothermal water system requires a high supply pressure. A lower supply pressure would reduce the power input required at the supply pump. The system is illustrated in Figure V-1.

Geothermal Water Pipes: The geothermal water piping system was designed using the technique of thermodynamic availability accounting which is discussed later.

FRESH HOT WATER HEATING SYSTEM

The proposed dairy uses hot geothermal water to heat fresh water. Hot fresh water is required for wash-down and sanitizing of the milking equipment.

FIGURE V-1

GEOHERMAL WATER SUPPLY SYSTEM

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FIGURE V-2

FRESH WATER HEATING SYSTEM

A 200 milking cow dairy operation requires about 500 gallons of fresh hot water daily. The temperature of this water must be at least 82°C (180°F) to comply with legal requirements. Geothermal water cannot be used directly for washing-down or for sanitizing the milking equipment due to the legal requirement that water of potable quality be used for this purpose.

Equipment: The fresh water heating system is composed of a geothermal water-to-fresh-water heat exchanger, an insulated storage tank, and an automatic control system. Two types of automatic control are required; pressure control and temperature control.

The temperature controller regulates the geothermal water flow rate so that the fresh water entering the storage tank is at a temperature of 85°C (185°F). The pressure controller regulates the fresh water flow into the storage tank so that fresh water is always available at a pressure of between 40 psig and 60 psig. This pressure is required for the wash-down of the milking equipment.

The fresh hot water usage rate is approximately periodic. The greatest usage is immediately before and after milking. An insulated storage tank of 350 gallon capacity is used. This size is a good compromise between reserve capacity and excessive heat loss through the insulated tank wall resulting from long retention time in the storage tank. Based on a computer analysis of the storage tank and heat exchanger system, the tank size of 350 gallons will function adequately. The system is illustrated in Figure V-2.

BUILDING THERMAL ANALYSIS

Most standard building thermal analysis programs now available are not fully applicable to the design of air conditioning systems for dairy buildings. The main intent of such programs is to aid in the design of comfortable air conditioning systems for office and commercial buildings. Thus, standard programs do not usually consider the large variation of the parameters required in a dairy operation.

The building model has been designed to determine the heat and moisture transfer rate required of an air conditioning system to maintain prespecified environmental conditions within a building which is subject to a specified set of external conditions.

Analysis: The master document examines the four main components of the thermal load on a building. These components are: 1) energy transmission through walls and roof areas; 2) energy transmission through windows; 3) energy transmission due to air infiltration or forced air ventilation; and 4) miscellaneous energy sources within the building.

This section of the base document develops the input equations for the computer program. Refer to chapters 12 and 22 of the master document for specific details.

ENGINE/GENERATOR SET

An internal combustion engine is used to burn the scrubbed methane or methanol and provide the power input to the alternating current generator. The system is illustrated in Figure V-2. This

on-site generated electrical power can then be used to power the geothermal and fresh water pumps, vacuum pumps for the automatic milking machines, ventilating fans, and to provide lighting for the barns, milk parlor, and other areas. If the amount of on-site generated power is insufficient to meet all the electrical power demands of the dairy, supplemental power can be purchased from the local power company. It should be observed that the anaerobic digester, which uses geothermal water for temperature control; the packed tower scrubber system; and the methane engine/generator set, in combination, provide high grade electrical energy from a normally wasted material, cattle manure.

Program Limitation: The engine model uses a fixed efficiency value of 0.275. This value was obtained from the manufacturer's data for the engine and is based on a particular fuel heating value with a particular fuel flow rate (full throttle). A significant improvement in the engine model would result if these variables were used to determine engine efficiency. The generator efficiency was set at 0.95, which is reasonable and would be quite constant.

The lower heating value of the engine fuel is determined by the scrubber tower design.

ABSORPTION COOLER THERMAL ANALYSIS

Purpose: The absorption cooler thermal analysis determines the energy required by the absorption refrigeration unit and the amount of heat that the system must reject to the cooling tower. From these energies the mass flow rates of cooling water from the

cooling tower and geothermal water required at the absorpition cooler generator can be determined.

Introduction: A lithium bromide and water (LiBr/H₂O) absorption refrigeration system is ideal for converting low grade heat sources such as solar or low temperature geothermal water (approximately 205°F) into useful refrigeration. Since the dairy required refrigeration only for milk-chilling and possible air conditioning, the temperatures required are moderate, within the range of 3°C to 7°C (37°F to 45°F). Thus, the fact that water is the refrigerant in the absorption system, which limits practical operation to temperatures above about 3°C (37°F), is no disadvantage for this application.

The electrical energy used in a vapor compression refrigeration system is much greater than that required by an absorption system of the same capacity. Geothermal water provides a cheap, low temperature energy source to heat the generator section of the absorption cooler. Very little high grade shaft work, usually provided by electrical power, is needed by an absorption system. This LiBr/H₂O absorption system is ideal for utilizing geothermal energy to produce useful refrigeration.

FLASH TANK GEOTHERMAL ENERGY REQUIREMENT

Purpose: This formulation calculates the heat transfer rate required to maintain an acceptable operating temperature for the process water which is used to scrub the carbon dioxide (CO₂) from the bio-gas produced by the anaerobic digester. Temperature control for the scrub water system is obtained by using geothermal

water to heat the flash tank in cold weather. The addition of heat at the flash tank also aids in the driving off of the CO_2 from the process water (See Figure V-3).

FIGURE V-3
PRELIMINARY DESIGN OF THE
FLASH TANK

SUMMARY

Chapter V describes the component parts of the geothermally energized dairy system. Each component was engineered to meet the energy demands of the dairy which were met through the use of geothermal brines directly heating and cooling the system, as well as providing the energy required in the anaerobic digester to produce methane or methanol.

CHAPTER VI

SUMMATION

The C.L.R. project titled "Controlled Environment, Livestock Production System, Computer Simulation and Analysis (Dairy)" was an attempt at exploring practical ways for using low heat geothermal brines in the operation of a livestock enterprise. The underlying objective for this project, as well as for projected future work, is to achieve some optimum level of fossil fuel energy independence in various agricultural and food processing activity. There were numerous livestock or farming activities considered at the outset of the project; however, it was determined by the C.L.R. investigators that the modern dairy enterprise would be the most manageable for simulation. The reason that the dairy enterprise would work well as the candidate activity is the fact that there is significant control over both inputs and outputs. This characteristic for control had to exist for both engineering and economic feasibility analysis. In effect, the candidate activity had to have a high level of measurability (Quantification) when operated under traditional or non-traditional methods of dairying. From the economic point of view, the procedure for investigation was to make simple activity cost comparisons as part of the total analysis--a sort of partial budgeting.

The commercial dairy operation has other characteristics that made it attractive to the research team. Modern dairy farming is highly concentrated, which means that land resources re-

quired are small when compared with most other livestock enterprise activity; also, the practical substitution of machines for human labor is continuous and is currently rather substantial. The introduction of new or innovative technology seems more possible with the dairy operation as compared with cattle or hog operations. For example, it would be a good deal more difficult to introduce the practice of super-ovulationg high yield animals in the commercial beef operation, yet, in the modern commercial dairy, this practice could produce substantial economic gains. It has become increasingly clear that future gains in dairy efficiency are tied to germ plasm management. Included are almost all of those traits that contribute to increased economic returns such as increased milk yield, high fat test, and increased milk fat production. Not so obvious, but also contributing to economic benefits and also related to dairy genetics, is efficiency in feed conversion, disease resistance, longevity, and other characteristics that contribute to technical and economic efficiency.

From an engineering point of view, the dairy enterprise also presented some advantages over other livestock activity. The dairy operation lends itself to quantification. That is, "the numbers" are known and can be related to considerations of space, structural or building needs, and, above all, to energy demands. It was the opinion of the research team that if the dairy simulation could be made to function, it would serve as a useful method for investigations involving other animal agricultural activities. (see Figure II-1-Geothermal or Waste Heat Flow System (Energy Cascade)-Model A)

The simulation approach to economic and engineering analysis has obvious advantages. It makes possible the determination of feasibility of high capital and operationally expensive production activities at fairly low costs. Simulation is an effective partial substitute for what would otherwise involve substantial capital cost for scale development of a suitable dairy model for testing alternative operation techniques and practices. In this study, the simulation method was used to investigate the peak, steady energy utilization of a geothermal energy supported dairy.

It was also intended that a dynamic simulation program would be written to determine the variable energy demand for the model dairy. However, the final outcome was a fairly limited application of the dynamic simulation program. It provides simulation for purposes of design of water storage tanks under diurnal transient loading. A digital computer program was also written to assess the lifetime economics of the dairy operation and a 20-year cycle was used.

SIMULATION FINDINGS

The model dairy used in the study is unique, but consists of conventional and readily available equipment. In the model dairy, the waste materials are used to generate methane and carbon dioxide by anaerobic digestion. Some carbon dioxide is removed from the gas stream with a pressurized water scrubber to raise the heating value of the scrubbed methane gas. The methane gas produced is burned in a spark ignition engine connected to an electric generator. The electric power generated is used to operate

fans, pumps, lights, milking machines, and other essential equipment in the dairy.

The steady state computer simulation designs (sizes) much of the equipment in the dairy based on herd size. (See Plot Design A - E). A building thermal analysis of all barns (out-buildings) is performed based on users-controlled climate and building heat transfer parameters. Fluid transmission piping is sized and insulated thickness is selected for hot water pipes, using an optimization approach based on thermodynamic availability. The user has control of pipe length, flow rates, temperatures and the model network of pipes used.

In the steady state simulation, computer runs were made for a 200 milking cow dairy operation. Total animals in dairy operations is 412. A winter run was used to size pipes and some other equipment. A summer run shows the energy used by the model dairy under summer climatic conditions.

The outcome, for the engineering design as determined by simulation is that under peak load conditions, there was no essential energy limitation in the model (non-conventional) dairy. A goal of the study was to identify, and model, for a computer-aided simulation, a configuration of a dairy system which appeared to have economic and technical promise, when thermally assisted by geothermal water from a particular reservoir. The specific geothermal site where temperatures and chemical characteristics affected this design was the Hobo Wells site near Wendel, California. It is an artesian hot spring with flow of approximately 1200 liters

per minute (317 gallons per minute) and a temperature at point of eruption of 99°C (209°F.).

As a point of reference, based on an ambient condition of 27°C (80°F), this is an energy flow of 3.6×10^5 KJ/min (3.4×10^5 BTU/min) using current electricity costs in the Wendel, California area of about 0.05 \$/kw/hour. This energy has a value of about \$/minute, or 7,000 \$/day. Basing the value of a low grade energy source on the cost of a high grade energy is not normally correct, but if all heating and cooling were to be done with electricity (along with all the usual electric power applications, such as lights, pumps, and fans) with conversion efficiencies of 100 percent, this procedure would be correct. However, one determines a value for geothermal internal energy and it is apparent that it is worth investigating applications for it.

In any event, the geothermal dairy required only a small fraction of the available energy flow from the Hobo Wells spring source. The direct application (See Plot Plan A-1) of geothermal fluids along with the geothermally assisted methane production for electricity generation makes the model dairy essentially energy independent.

The engineering and economic concept of "Controlled Environment" conveyed to the investigators the idea that two distinct functions are involved; first, that the physical environment could, in some measure, be controlled to enhance the production of milk, meat and replacement animals; and second, that resources flowing into the system could be managed with the same

output goals, but that the inputs could be from different or non-conventional sources. For example, as is pointed out above, the model commercial dairy operation is made energy independent of outside gas and electricity by the geothermally assisted methane generation system and by direct application of geothermal fluid.

From the economic point of view, the benefits accruing are of three sorts: first, the substitution of a currently under-employed energy resource (conservation) for an energy resource that is becoming increasingly more valuable and scarce; second the quality of the environment is favorably and most directly effected by the conversion of the dairy manure to a non-offensive organic soil builder, that does not attract flies, rodents, and other nuisances. The latter is one of the very attractive spin-offs considering the location and technically concentrated nature of the dairy operation; third, the residue produced from methane operations have potential uses or inputs to selected complimentary activities. For example, organic waste produced by the digestion process could be used in the production of greenhouse products as a growing media--a greenhouse tie-in to the dairy may be economically very attractive.

The question of value of the digestion waste becomes important when waste disposal costs, and possible alternative uses are considered. It is likely that the processed manure would be an acceptable consumer product for garden soils uses or other uses. These issues are still to be resolved. It needs to be kept in mind that the manure from the dairy has other uses than to gen-

erate methane gas. The selection of the methane activity is simply a choice of one of several alternative uses for the manure in the model configuration. For example, some researchers have indicated that with certain treatment, dairy manure can be used as feed. It has been suggested that as much as one-half of the total ration in some feeding routines could be from the manure source. The economic and engineering questions raised by this alternative are important from the point of view of both technical and economic efficiency. Which of the several alternatives produces the best returns in energy and dollar revenue?

For example, assuming that one-half of the feed for dairy cows could be from manure of the milking herd, and assuming that about 6,000 pounds of feed is required per non-milking dry cow, then it is possible to value the trade-offs between alternatives. The following uses, current alfalfa hay prices as the basis for calculation of the trade-off:

- a) Alfalfa hay - delivered: \$75 per ton
- b) Amount of roughage feed required per day, non-milking cow: 6,000 pounds

Total manure 1.5 ton equivalent (ensilaged)   \$ 75.00

Total alfalfa hay 1.5 ton equivalent (delivered) \$112.50

\$187.50

Value of transport: \$ 22.50

TOTAL: \$210.00

Under this arrangement, manure would have a value near or equal to transported alfalfa hay. Processing of manure would add some cost. However, since geothermal water is abundantly

available, the material could be dried and stored probably at very competitive costs. It suffices to point out here that the digester operation to be competitive would need to produce about \$65 worth of power per ton of 90 percent dry manure.

As stated earlier, an advantage of investigating a geothermal energy-controlled dairy is that much reliable economic information is readily available for conventional operations. It was recognized early in the analysis (comparisons) that the significantly large capital investment requirement of the non-conventional dairy would influence, or perhaps completely offset any gains made by the energy substitution. The economic benefits also might be small enough that the dairy activity would not be the first activity to be developed by potential investors when compared with some of the alternatives included in Figure 1. However, this in no way detracts from the use of the dairy model in the simulation. In fact, the computer program generated information that shows the dairy to recover all costs in the second year of operation; however, in comparing the model with the conventional dairy, cost and return equality is not achieved before about the seventh year.

CONCLUSIONS

The research by C.L.R. clearly indicates that computer simulation has potentials for making significant contributions in the design and planning of candidate activities in an energy cascade such as shown in Figure 1. It is also evident that even though the current computer simulation programs work, there is a con-

tinuing need for simplification and standardization. There is also the need to adapt the computer simulations to different technical configurations. The adaptations should be developed for additional activity in the model (non-conventional) dairy, but should also be extended to include the various geothermal assisted activities shown in Figure 1.

The on-site geothermal technology is designed to accommodate currently available on-shelf hardware. The system is designed to energize the non-conventional dairy, using geothermal fluids. It was determined by simulation programming that the dairy can be energy independent of outside fossil fuel resources. The geothermal fluid was also determined to be effective energy for optimizing temperatures on the anaerobic digester. The digester is capable of producing enough high quality bio-gas (methane) to generate about 29 H.P. continuously. The combined geothermal and bio-gas resource would insure energy for the model dairy. The latter would not be effected by delivery curtailments, inflation, or power failures in the commercial delivery systems.

The simulation runs indicate the following technical outcomes:

1. At peak load conditions, all but six percent of the electrical energy requirements are met by the methane digester/scrubber/engine-generator power production system. During most of the operations time, the full electrical requirements of the model dairy are met by the on-site energy system.

2. About 19 percent of the electrical energy produced by the on-site engine-generator is required to operate the power production system, as currently designed.

3. The current Hobo Wells (specific reservoir) production is capable of providing enough thermal fluids to operate 15 dairies of the size and configuration as described.

The dairy requires between six and seven percent of current artesian flow, and this at peak energy load conditions.

4. Calculations indicate that without the digester and related power production system, the peak electrical requirements of the system would decrease by 17 percent, but the electrical energy supplied by a public utility would increase by 93 percent.

5. Total peak energy demands of the model dairy are supplied as follows: Five (5) percent is from the power generating system, one-half of one (.5) percent purchased from outside suppliers, and ninety-four and one-half (94.5) percent is supplied direct from the geothermal reservoir. This mix would be considerably different on an average day. It might be expected that normally no outside energy would be required and the geothermal demand would also be much less. Further investigation might indicate that stand-by power for peak periods or other energy demand overload could be met with tank stored fuel gas.

6. Without the geothermal resource, the dairy would require 23,000 BTU's per minute from commercial or other sources at peak periods. It is likely that without the geothermal energy, the Hobo Wells or any other Honeylake geothermal site, would not be used for dairy production.

The comparative economic analysis indicates the following results:

1. The conventional dairy operation is able to produce 100 pounds (45.36 kg) of milk for \$8.93, and \$9.49 for the non-conventional system. The 56 cents difference in the first year is probably sufficiently large to discourage investment. This suggests that if new or innovative systems are to be established in any enterprise with the objective of conserving scarce fossil fuels, a system of investment credit allowances will have to be made to provide sufficient incentives for conversion and investment in the new technology.

2. In the dynamic analysis, two possible conclusions were reached:

a. With non-linear price increases, the proposed (non-conventional) system was the least cost system for the 20-year period of operation.

b. If linear price increases are expected, then the least cost system is the conventional dairy operation.

3. The investment requirement (excluding livestock) for the non-conventional dairy is established to be about 77 percent greater than for the conventional dairy--\$535,000 as compared to \$303,000.

4. Operations cost per cow are of two sorts: fixed and variable. The total cost for the conventional dairy was determined to be \$301,000 per year, and \$325,000 for the non-conventional dairy.

5. The two dairies become cost equal in about the seventh year of operation. In the seventh year, it is projected that costs for producing 45.36 kg of milk will be about \$15. In that same year, net revenue is estimated to be between \$0.50 and \$1.83 per 45.36 kg.

6. It is determined by separate linear programming that for both dairy operations the major operations cost variable is feed. The analysis indicates that there is sufficient justification for further research with the objective of finding useful solutions to:

a. Waste disposal--manure and other waste.

b. Efficient feed energy utilization. There is some good evidence that dairy manure can be processed to be used as a feed substitute (roughage)--currently as much as 50 percent of the ration could be from this source.

7. The current analysis is limited in the number of activities that could properly be included as either complimentary or parallel activity. It is likely that some activities, such as greenhouse operations, could contribute to a substantially different revenue production between the conventional and non-conventional dairies.

APPENDIX A

GEOTHERMAL LIBRARY BIBLIOGRAPHY

GEOHERMAL LIBRARY

The principal investigator and the Consortium's Board of Directors, agreed from the on-set to record and document in detail all portions of the project. The documentation and all primary source documents would be made public through a special section of the Lassen College Library. This collection has become known as the "C.L.R. Geothermal Library".

The C.L.R. Geothermal Library is housed in a four drawer steelcase vertical file. The library is indexed by author and title entries. Each item is given an assession number and can be found by this number.

The C.L.R. Geothermal Library has expanded beyond this current project. All subject areas that the C.L.R. Consortium has explored are included. The library includes all documents published by the Geothermal Resource Council and contains proceedings of some of the Council's conferences.

The most current entry is Lawerance Berkley Labatory's "Compilation of Geothermal Information; Exploration".

Appendix II is a bibliography of the geothermal articles the library contains as of summer 1978; however, additional items have become availabe and cataloged since this bibliography was written.

The C.L.R. Consortium's Board of Directors desired that this library be available to scholars, engineers, and the general public--farmer, rancher, and other interested citizens.

At present, the C.L.R. Geothermal Library is small in volume, but will continue to grow as the industry's knowledge as it applies to low temperature uses of geothermal energy grows.

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APPENDIX B

GEOTHERMAL DAIRY

PLOT PLAN

EQUIPMENT LAYOUT

FLOOR PLAN: MILKING BARN

FLOOR PLAN: MILKING COW BARN

FLOOR PLAN: CALF, HEIFER & DRY COW BARN

SECTION A-A

SECTION B-B

LEGEND:
 GEOTHERMAL WATER
 FRESH COLD WATER
 FRESH HOT WATER
 SLUDGE
 WASTE WATER

NOTE:
 1 FT. = 0.3048 METERS
 1 IN. = 0.0254 METERS

GEOTHERMAL DAIRY		
DATE: 8-16-77	APPROVED BY:	DESIGN PLANNING:
PLOT PLAN		
E.R.D.A. PROJECT		A1

- LEGEND:**
- A SLUDGE HEAT EXCHANGER
243000 BTU/HR. V(SLUDGE) 1/4 GAL/MIN.
DOGG-OLIVER NO. 38
  - B FLASH TANK
4'-0" x 6'-0" x 1'-6"
  - C SCRUB WATER PUMP
GOULDS MOD. 3199 SIZE 1 1/2 x 6 25 GAL/MIN
1/2 HP, 3 PHASE, 220 V. MOTOR
  - D SCRUB WATER MAKE-UP TANK
100 GAL.
  - E FRESH WATER/GEO WATER MIXING VALVE
  - F PACKED TOWER CO₂ SCRUBBER
1'-6" DIA. 8' OF PACKING
  - G SLUDGE RECIRCULATION & EFFLUENT PUMP
MOYNO MOD. ILB 5 HP, 3 PHASE, 220 V. MOTOR
  - H METHANE ENGINE
WAUKESHA MOD. VRG232U
  - I GENERATOR
KATO 30 KV 220 V. 3 PHASE
  - J BIO-GAS COMPRESSOR
10 SCFM OUTPUT PRESSURE = 80 PSIG

- LEGEND:**
- K CHILLED WATER CIRCULATION PUMP #1
  - L CHILLED WATER STORAGE TANK
500 GAL.
  - M CHILLED WATER CIRCULATION PUMP #2
15 GAL/MIN
  - N COOLING TOWER
DELTA TECH. MOD. DT-10 10 TON
1 HP, 3 PHASE, 220 V. MOTOR
  - O ABSORPTION COOLER #1
ARKLA SOLAIRE 3/4 3 TON
  - P ABSORPTION COOLER #2
ARKLA SOLAIRE 3/4 3 TON
  - Q COOLING WATER CIRCULATION PUMP
24 GAL/MIN
  - R GEO. WATER PUMP #1
GOULDS MOD. 3196 ST SIZE 1 1/2 x 6 100 GAL/MIN
5 HP, 3 PHASE, 220 V. MOTOR
  - S GEO. WATER STORAGE TANK
1000 GAL.
  - T GEO. WATER PUMP #2
GOULDS MOD. 3171 ST SIZE 1 1/2 x 6 100 GAL/MIN
1 HP, 3 PHASE, 220 V. MOTOR
  - U SLUDGE INFLUENT PUMP
MOYNO MOD. ILB 1/2 HP, 3 PHASE, 220 V. MOTOR
  - V FRESH HOT WATER TANK
350 GAL.
  - W FRESH HOT WATER HEAT EXCHANGER
V(FRESH WATER)=1.06 GAL/MIN. 66000 BTU/HR

GEO. WATER
FRESH WATER
SLUDGE
CO₂
CO₂ - CH₄ (BIO-GAS)
CO₂ - FRESH WATER
CH₄

NOTE:
1 TON (REFG) = 3517 WATTS
1 PSI = 6894 NEWTON/METER²
1 HP = 745.8 WATTS
1 GAL = 0.003785 METER³
1 FT = 0.3048 METER
IN. = 0.0254 METER

GEOTHERMAL DAIRY			
NAME: NONE	DATE: 8-16-77	DESIGNED BY: A.P.E.Z.	DATE: 8-16-77
EQUIPMENT LAYOUT			
E.R.D.A. PROJECT			A2

FLOOR PLAN.

GEOTHERMAL DAIRY	
DATE: 8-16-77	DESIGNED BY:
MILKING BARN	
ERDA PROJECT	

FLOOR PLAN

FLOOR PLAN

GEOTHERMAL DAIRY	
DATE: 8-16-77	DESIGNED BY: [blank]
CALF, HEIFER & DRY COW BARN	
E.R.D.A. PROJECT	51

SECTION A-A

SECTION B-B

NOTE:
1 FT. = 0.3048 METERS
1 IN. = 0.0254 METERS

GEOTHERMAL DAIRY	
DATE: 5-10-77	DESIGNED BY: [blank]
SECTIONS AA & B-B	
ERDA PROJECT	E1