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**FEASIBILITY STUDY OF
GEOTHERMAL HEATING,
MODOC LASSEN HOUSING PROJECT**

November 1981

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DAVIS ENERGY GROUP
2655 Portage Bay Avenue, Suite 1
Davis, California 95616

Mechanical Engineering
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SUMMARY

This study evaluates the feasibility of using geothermal water for space and domestic water heating systems at the elderly housing project now ready for construction at the Modoc Lassen Indian Reservation.

For the six units considered, the space heating load is four times the domestic water heating load. Since the geothermal water temperature is uncertain, two scenarios were evaluated. In the first, which assumes 160F supply temperature, the geothermal system is assumed to satisfy the entire space and domestic water heating loads. In the second, which assumes the supply temperature to be less than 120F at the wellhead, only space heating is provided.

The economics of the first scenario are quite favorable. The additional expenditure of \$15,630 is projected to save \$3522 annually at current energy costs, and the life cycle cost study projects a discounted rate of return on the investment of 44.4%. Surprisingly, the investment is even more favorable for the second scenario, due to the higher cost and lower resultant savings for the domestic water components.

Forced air space heating from geothermal is recommended. Domestic water heating is recommended pending additional information on supply water temperature.

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I. Objectives

The primary objective of the study was to evaluate the potential cost-effectiveness of using hot water from a geothermal well on the Fort Bidwell Indian Reservation to provide space heating and/or domestic water heating for housing units planned for immediate construction. A secondary objective was to compare alternate heat distribution systems within the buildings, in terms of first cost, comfort, and operating cost.

II. Background

A pilot geothermal well has recently been drilled at Fort Bidwell. While a written test report on the well is not yet available, verbal reports indicate very favorable results. The well is said to be capable of supplying 300-400 gallons per minute (gpm) of hot water on a continuous basis. However, the wellhead temperature is 160F according to one source and 116F according to another. The well is also said to be "artesian" (pressurized from the earth), eliminating the need for a pump and its accompanying energy consumption.

Construction is scheduled to begin in early November on a two building cluster containing 5 two bedroom elderly housing units and a community/clinic building located approximately 320' from the geothermal well. Building designs have been completed and include plans and specifications for electric furnaces coupled to forced air ductwork for space heating. Electric domestic water heaters are specified. Space cooling is not included in the designs.

Project Architect Cynthia Easton has requested that Davis Energy Group (DEG) evaluate the cost-effectiveness of geothermal space and domestic water heating for the elderly complex. DEG was also encouraged to consider "radiant slab" space heating, as an alternate to the specified forced air system (see Appendices A & B for additional information on DEG and radiant heating, respectively). For completeness, estimates have also been developed for a third heat distribution system, baseboard convectors, which might be used with the geothermal source.

III. Analysis

The basic analytical approach has been the following:

1. Estimate space and domestic water heating loads for purposes of sizing the geothermal water supply system.
2. Prepare conceptual designs for the proposed geothermal heat

delivery system.

3. Estimate energy savings generated by the system.
4. Estimate system initial costs based on the conceptual designs.
5. Estimate cost-effectiveness based on a life-cycle cost (LCC) analysis.

This approach has been used initially to assess the geothermal heating systems assuming the addition of components to the existing forced air design. Costs, performance, and other factors are also compared for forced air, radiant slab, and baseboard convector heat delivery alternatives.

Because of the need to draw conclusions prior to the start of construction, little time was available for completion of this feasibility study. For this reason, several design uncertainties remain. Conservative assumptions have generally been made in these cases. For example, the discharge point for water "used" by the system may be a second well, a pond, or a natural drainage area. Since the environmental impact of such features has not yet been assessed for the project, it has been assumed that the discharge will be to a natural hot spring located approximately 60 yards north of the well (more than 500' from the buildings). While this approach may be more expensive than an alternative which may be identified later, it seems relatively certain to be environmentally acceptable.

Water temperature is another major concern. While 116F water is adequate for either "forced air" or "radiant slab" space heating systems, it is too cool for either "baseboard convector" space heating or full domestic water heating. The feasibility study evaluates system economics both with and without geothermal domestic water heating.

IV. Design

Fig. 1 shows the assumed overall system schematic. A pressure reducing valve at the wellhead limits the discharge pressure to the buildings. 2" polybutylene supply and return pipes are assumed to be placed in a common trench 3' deep from the well to the buildings. The return line extends 180' north of the well to reach the hot spring. 1" supply and return lines are provided to each of the six units.

Fig. 2 shows a section of the main supply & return trench. The supply pipe is enclosed in a dry sand bed wrapped with polyethelene to provide partial insulation and protection from rocks. The return pipe is placed above the sand bed.

FIG 1 - OVERALL SYSTEM
SCHEMATIC PEAK SYSTEM
FLOW 34 GPM.

FIG 2 - SECTION
UNDERGROUND PIPING.

Fig. 3 shows the assumed piping configuration for each unit when both domestic water heating and forced air space heating are provided. In a manhole located outside each unit, stop valves and hose bibbs are provided to allow backflushing of both heat exchangers to remove scale. From the entry point, hot water may pass directly through an auxiliary heating coil added to the electric furnace to provide space heating. In a parallel flow path, hot water flows through a heat exchanger in the bottom of the electric water heater.

For both space heating and domestic water heating, full backup is provided by conventional components. However, the controls should be designed to prevent use of electric auxiliary unless the geothermal source cannot satisfy the load.

Fig. 4 shows the overall system schematic if either radiant slab tubing or hydronic baseboard convectors are used. Again, parallel circuits are provided for space heating and domestic water heating. Identical auxiliary heating tanks are provided for each. A circulating pump is now required for the space heating loop. In a less expensive alternate design (not shown), a tankless electric heater could be placed directly in the heating system supply line. However, this approach is less "failsafe" than that shown in Fig. 4, since space heating depends on water flow through the geothermal supply line.

For all system alternatives, flow through the domestic water and space heating heat exchangers would be controlled by electric motorized valves. The main pressure regulating valve at the wellhead would limit supply pressure to 25 psi so that motorized valves could be used.

Table 1 compares relevant design considerations for forced air, hydronic baseboard, and radiant slab systems. Generally, radiant slab systems provide greater comfort for lower initial and energy costs than forced air or hydronic baseboard. In this case, however, initial cost savings might not result for radiant slab space heating due to the addition of a tank and pump and the costs of implementing a design change. (See Section VI.)

V. Energy Savings

To assess the potential energy savings which would result from use of the geothermal source, energy demands for domestic water and space heating were estimated. Table 2 summarizes the studies of potential energy savings.

FIG.3

BUILDING INTERNAL SCHEMATIC
FORCED AIR HEATING.

FIG 4
BUILDING INTERNAL SCHEMATIC
HYDRONIC BASEBOARD OR RADIANT
SLAB HEATING

Table 1
Space Heat Alternatives

Factor	System		
	Forced Air	Radiant Slab	Hydronic Basebd
1. comfort	fair; cold floor, more air motion	excellent; warm floor	good; less air motion, cold floor
2. appearance	good; registers & grilles show	excellent; nothing shows	fair; convectors fairly visible
3. noise	noticeable	none	minimal
4. maintenance	blower & filter	none	dusting & paint
5. energy cost	highest (fan motor)	allows cooler air for fixed comfort level	low- no fan
6. cooling	easily added	easily added	not possible
7. initial cost	moderate	lowest	highest, for low supply water temp

Table 2
Projected Energy Savings

Demand Category	Units Used	mmBtu's/yr	Cost/Year
Domestic Water			
dwelling units	60 gal/day ea.	73	\$ 513
clinic/center	110 gal/day	27	190
subtotal	410 gal/day	100	\$ 703
Space Heating			
dwelling units	9120 Btu/deg.day ea	287	\$ 2018
clinic/center	18144 Btu/deg.day	114	801
subtotal	63744 Btu/deg.day	401	\$ 2819
Combined DW & SH		501	\$ 3522

Hot water usage was estimated to be 60 gallons per day at 80F temperature rise for the five dwelling units, and 110 gal/day for the clinic/center. These figures convert to energy demands of 73 and 27 million Btu's annually, for a total of 100 mmBtu's.

Space heating energy demand was estimated by calculating heat loss coefficients for use in conjunction with a "degree-day" climate rating (6300 degree-days/yr. at Ft. Bidwell). Annual space heating loads were estimated to be 287 mmBtu's for the living units and 114 mmBtu's for the clinic/center, for a total of 401 mmBtu's annually.

Current electric rates were obtained from the Surprise Valley Electric Co. in Alturas. For the quoted rate of \$0.024/kwh, the energy cost for resistance electric heat is \$7.03/mmBtu's. The estimated annual domestic water and space heating costs are \$703 and \$2819, respectively, at the current rate.

Since the well is artesian and no pump is required for either forced air space heating or domestic water heating, the entire annual heating cost will be saved if a high temperature (more than 140F) geothermal source is available. If the source temperature is less than 120F additional components required for geothermal domestic water heating may not be cost effective. For the low temperature case, projected energy cost savings are for space heating only.

VI. System Costs

Table 3 summarizes estimated costs for the geothermal heating system components. Projected costs for the wellhead connection, supply pipe, and discharge pipe are \$5790. Wellhead costs are based on conversations with Ivar Engen at EG&G Idaho, and Gene Ryan at the Geothermal Heat Center in Oregon. Excavation cost estimates are based on quotes from local excavators inflated to reflect the remote location. Project Architect Cynthia Easton indicated that subsurface rock would not be a problem where the lines would be placed.

System costs associated with the buildings themselves are separated into categories of connections, space heating, and domestic water heating. The totals for these categories are \$1940, \$3370, and \$4530, respectively. These estimates represent incremental costs over and above the conventional system costs.

Table 4 summarizes the cost estimates for the alternate space heat distribution systems. Normally, the radiant slab design

Table 3
Estimated Initial Costs

Item	Installed Cost
A. External	
1. wellhead connection	
a. tapping/fittings	\$ 1200
b. pressure reducing valve	350
2. buried pipe	
a. trench & backfill (550')	700
b. dry sand & poly wrap	590
c. 2" polybutylene pipe (900')	2100
3. design	850
4. subtotal	\$ 5790
B. Building Connections	
1. trenching & backfill	\$ 150
2. 1" polybutylene 480'	440
3. manholes, fittings, valves	1100
4. design	250
5. subtotal	\$ 1940
C. Space Heating (Forced Air)	
1. 6 heating coils	\$ 1500
2. motorized valves & wiring	750
3. isolation valves & piping	670
4. design	450
5. subtotal	\$ 3370
D. Domestic Water Heating	
1. water heaters with exchangers	\$ 4100
2. credit for conventional units	(1950)
3. motorized valves	850
4. auxiliary thermostats	270
5. isolation valves & piping	760
6. design	500
7. subtotal	\$ 4530
E. Total w/Domestic Water (incl. design)	\$ 15630
F Total w/Space Heat Only (incl. design)	\$ 11100
G. Total Design w/Domestic Water	2050
H Total Design w/Space Heat Only	1550

Table 4
Alternate Space Heating System Costs

<u>System & Components</u>	<u>Installed Cost</u>
1. Forced Air (itemized in Table 3)	\$ 3370
2. Radiant Slab	
a. storage tanks w/exchangers	\$ 5000
b. slab tubing (6500' 1/2" polybut.)	1950
c. pumps, manifolds, & piping	2750
d. motorized valve & controls	2550
e. design	1250
f. credit for forced air system replaced	(8660)
Radiant Slab Total	\$ 4840
3. Hydronic Baseboard (sized for 140F water)	
-costs same as for radiant slab, except:	
a. credit for slab tubing	\$(1950)
b. 650 lf Embassy KPT-D baseboard	5200
c. radiant slab total	4840
Hydronic Baseboard Total	\$ 8090

Using polybutylene tubing will be more economical to install than either forced air or hydronic baseboard. However, the assumption that "stand alone" auxiliary heating is needed eliminates the cost advantage of the radiant slab in this case, at least for the design configuration shown in Fig. 4.

VII. Economic Analysis

A 20 year life cycle cost study is shown in Table 5. Assumptions for the analysis are in agreement with those recommended by HUD for cost studies of geothermal projects (see Appendix C). The present worth of the cumulative savings for the \$15,630 investment (assuming both space and domestic water heating) is \$114,855, and the discounted rate of return on the investment is projected to be 44.4%.

If water temperature is less than 120F, and only space heating is provided from the system, the life cycle cost picture is even better than that shown in Table 5. This result is obvious from a review of savings/cost ratios for the two alternatives. For space heat only (including all external and building connection costs) the initial system cost is \$11,310 and projected annual savings are \$2819 ($S/C=0.249$). The incremental cost of adding geothermal domestic water heating to the geothermal space heating system is \$4530, and projected annual savings are \$703 ($S/C=.154$).

Although the potential return for domestic water heating is lower than for space heating, its "direct time payback" of 6+ years represents a very favorable investment compared to many other potential energy conservation measures.

Table 5
Life Cycle Cost Analysis

INITIAL COST OF GEOTHERMAL SYSTEM = \$ 15630.
PROJECTED ANNUAL SAVINGS = \$3522
INITIAL FUEL COST = \$7.03/MMBTU (\$.024/KWH)
FUEL COST ESCALATION RATE = 18% PER YEAR
MARKET DISCOUNT RATE = 12%
ANNUAL INSURANCE, MAINTENANCE COSTS = 1% OF INVEST./YEAR

YR	INTRST PAID	END OF YR PRINC	DEPRC DEDUCT	PROP TAX PAID	INC TAX SAVED	BACKUP FUEL COST	INSUR, MAINT COST	COST WITH GEOTH.	SAVNGS WITH GEOTH.	PW OF GEOTH. SAVNGS
0	0	0	0	0	0	0	0	15630	-15630	-15630
1	0	0	0	0	0	0	156	156	4155	3710
2	0	0	0	0	0	0	165	165	4922	3924
3	0	0	0	0	0	0	175	175	5828	4148
4	0	0	0	0	0	0	186	186	6898	4384
5	0	0	0	0	0	0	197	197	8163	4631
6	0	0	0	0	0	0	209	209	9656	4892
7	0	0	0	0	0	0	221	221	11419	5165
8	0	0	0	0	0	0	235	235	13501	5453
9	0	0	0	0	0	0	249	249	15959	5755
10	0	0	0	0	0	0	264	264	18862	6073
11	0	0	0	0	0	0	279	279	22289	6407
12	0	0	0	0	0	0	296	296	26335	6759
13	0	0	0	0	0	0	314	314	31111	7129
14	0	0	0	0	0	0	333	333	36749	7519
15	0	0	0	0	0	0	353	353	43403	7929
16	0	0	0	0	0	0	374	374	51259	8361
17	0	0	0	0	0	0	397	397	60530	8815
18	0	0	0	0	0	0	420	420	71473	9294
19	0	0	0	0	0	0	446	446	84389	9798
20	0	0	0	0	0	0	472	472	99633	10328

THE RATE OF RETURN ON THE INVESTMENT(%)= 44.4
YRS UNTIL UNDISC. FUEL SAVINGS = INVESTMENT 4.
UNDISCOUNTED CUMULATIVE GEOTH. SAVINGS = \$ 610915.
PRESENT WORTH OF YEARLY TOTAL COSTS WITH GEOTHERMAL = \$ 17369.
PRESENT WORTH OF YEARLY TOTAL COSTS W/O GEOTHERMAL = \$ 132224.
PRESENT WORTH OF CUMULATIVE GEOTHERMAL SAVINGS = \$ 114855.

VIII. Conclusions

The economics of geothermal heating for the six units studied appear to be extremely favorable. Space heating is the highest priority, and can easily be provided via forced air or radiant slab even if the supply temperature is as low as 110F. Estimated incremental costs are \$11,310 for space heating and an additional \$4530 if domestic water heating is added, for a total of \$15,630.

Space heating from geothermal should be accomplished using hot water coils added to the electric furnaces currently specified. For future buildings at the site, however, radiant slab space heating should be considered in the preliminary design stage.

The viability of domestic water heating for the project is dependent on the geothermal supply temperature and the required rate of return on the investment. It was not possible in the time allocated for this study to project the rate of return on the domestic water system investment for varying supply water temperature. If a test report on the well verifies that the supply temperature is low, additional cost analyses should be completed to assess whether geothermal domestic water heating should be provided.

The very favorable economics of geothermal heating for the six units considered here suggests application to other buildings in the project as well. Consideration should be given to installing lines below slabs for future connection to main supply and discharge lines to either the existing or future well(s). Cost of installing the lines alone should not exceed \$100 per unit. Building designs should be checked to determine whether adequate space exists for geothermal heating components.

Additional work is also required to identify the lowest cost discharge technique which is environmentally acceptable. If the supply temperature is low, discharge temperature may also be quite low. The storm drain system could then be used for discharge, at a substantial savings compared to the estimates used in this study.

APPENDICES

Data Form 7 : Geothermal Hot Water System - Direct Use

1. Well Data

- a) Depth of well: 350'
- b) Diameter of well: 8"
- c) Temperature of water at well head: 160° F
- d) Flow rate (gpm): 300-400
- e) Transmission Pipe: 2" diameter (inches) 350' length
distance from well to end use see Figs 1 & 2
- f) Pump horsepower: artesian well

2. Energy Delivery/Heat Exchange System

- a) Describe unit in detail; provide flow diagram:
see Figs. 3 & 4
- b) Heat requirement of system (heat flow in Btu/hr) peak
- c) Temperature drop (ΔT °F): 10° (DWH) 600,000 Btu/hr.
- d) Operating head (feet): 10' 50° (space heating)

CORRECTION ✓

Data Form 2: Economic Analysis Data

1. Capital Cost

Equipment: wellhead connection, piping, components
Materials: inside buildings
Labor:
Other:

Total: \$15,630

2. Capital Savings (Itemize savings resulting from not installing alternative to above system. For any project note these savings may not occur for all projects).

conventional systems will remain
as backup.

3. Annual Operating and Maintenance Cost (Itemize)

Assumed at 1%/yr.

4. Annual Cost of Parts Replacement (Itemize)

none

5. Life Energy System (Years)

assumed 20 yrs.

6. Fuel Being displaced and cost per unit

Electricity	_____	\$.024 /kwh
Natural Gas	_____	\$. /therm
Propane	_____	\$. /gallon
Distillate	_____	\$. /gallon
Other	_____	\$. /

HOURLY AND ANNUAL
BUILDING HEAT LOSS RATE

Form 2

MODOC LASSEN
owner
2 BDRM NE UNIT
project
system type
documentation author
date

checked by
date

HOURLY HEAT LOSS

DESIGN TEMPERATURE DIFFERENCE

For All Conditions Other Than the Following $70^{\circ}\text{F} - \frac{\text{ }^{\circ}\text{F}}{T_{ow} \text{ from Form 1}} = \Delta T_{w1}$ 1 $\text{ }^{\circ}\text{F}$
For Insulated Floor Over Vented Unheated Space Line 1 $\div 2 = \Delta T_{w2}$ 2 $\text{ }^{\circ}\text{F}$
For Uninsulated Floor Over Vented Unheated Space Line 2 $- 5^{\circ}\text{F} = \Delta T_{w3}$ 3 $\text{ }^{\circ}\text{F}$

CONDUCTIVE HEAT LOSS

Description of Assembly	Area, ft ² or Length, ft	U from Form 1, or F _s from Table 4-1	Framing Factor from Table 3-6	ΔT_w from above		
Glazing	140	.62	1		=	86.5 Btu/hr $^{\circ}\text{F}$
Wall	806	.05	1.16		=	46.9
Door	20	.34	1		=	6.8
Ceiling/Roof	938	.032	1.18		=	35.4
Floor PERIMETER 15' R-5	91	.35			=	31.2
Other					=	
					=	
					=	
Subtotal	4					208 Btu/hr $^{\circ}\text{F}$

INFILTRATION (Enter 0 on Line 5 if there is positive ventilation)

$\frac{938}{\text{Gross Floor Area}} \text{ ft}^2 \times \frac{8}{\text{Weighted Average Ceiling Height}} \text{ ft} \times \frac{(.9)(0.018)}{\text{From Table 3-7}} \times \frac{\Delta T_w \text{ from Line 1}}{\text{ }^{\circ}\text{F}} = 5$ 122 BTU/Hr $^{\circ}\text{F}$

VENTILATION (Enter 0 on Line 6 if there is no positive ventilation)

$\frac{\text{Ventilation Rate from Calculations}}{\text{ft}^3/\text{min}} \times \frac{\Delta T_w \text{ from Line 1}}{\text{ }^{\circ}\text{F}} \times 1.08 = \dots \dots \dots 6$
Subtotal 7 330 Btu/hr $^{\circ}\text{F}$

DUCT HEAT LOSS (Enter 0 on Line 8 if there are no ducts)

$0.15 \times \text{Line 7} = 8$ 50 BTU/hr $^{\circ}\text{F}$

TOTAL (Line 7+8) q_h 9 380 Btu/hr $^{\circ}\text{F}$

ANNUAL HEAT LOSS

$\frac{\text{HDD from Appendix C}}{\text{ }^{\circ}\text{F} \cdot \text{day/yr}} \times \frac{\text{Hourly Heat Loss from Line 9}}{\text{Btu/hr}} \times \frac{\text{C from Table 3-8}}{\text{ }^{\circ}\text{F}} \times 24 \text{ hr/day} = Q_h$ 10 Btu/yr
 $\Delta T_w \text{ from Line 1}$

MODOC LASSEN

10/20

2 BDRM NE UNIT

FLR AREA = 938

R-30 CEILINGS

R-19 WALLS $\frac{5}{8}$ " EXT PLY

8' CEILINGS

4" CONC SLAB

DBL GLAZING

$$\text{PERIMETER} = 40 + 24 + 50 + 24 = 138$$

$$\text{GROSS WALL AREA} = 138' \times 8' = 1104 \text{ SQFT}$$

$$\text{COMMON WALL} = 17' \times 8' = 136 \text{ SQFT}$$

$$\text{WINDOWS} \quad (3) \quad 5'4" = 60$$

$$4'12" = 4$$

$$6'6" = 40$$

$$4'3" = 12$$

$$6'4" = 24$$

$$\underline{140 \text{ SQFT}}$$

$$\text{WINDOW AREA} = 140 \text{ SQFT}$$

$$\text{SOLID CORE WD DR} = 3'6" = 20 \text{ SQFT}$$

ASSUME .9 AIR CHANGES/HOUR

MODOC LASSEN 10/20

COMMUNITY CENTER CLINIC

FLLR AREA = 1840

$$\text{PERIMETER} = 40 + 50 + 40 + 8 + 50 = 188$$

$$\text{INSUL PERIMETER} = 121'$$

$$\text{GROSS WALL AREA} = 188 \times 8 = 1504 \text{ SQFT}$$

$$\text{COMMON WALL} = 24' \times 8' = 192 \text{ SQFT}$$

$$\text{WINDOWS (4)} \quad 4'6'' = 10.4$$

$$2'6'' = 14.6$$

$$5'4'' = 20$$

$$2'6'' = 16.3$$

$$(2) \quad 6'2'' = 24$$

$$(2) \quad 4'2'' = 16$$

$$2'3'' = 7.5$$

$$202.4 \text{ SQFT}$$

DOORS

(3)

3'6"

W/GLASS

10.7 SQFT GLASS

$$\frac{(10.7 \times .62) + (9.3 \times .34)}{20}$$

UVAL = .49

(2)

3'6"

SC

100 SQFT

ASSUME

1.2 AIR CHANGES/HR