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THE POTENTIAL FOR UTILIZING GEOTHERMAL ENERGY FOR SPACE HEATING IN RE-CONSTRUCTED SUGAR CITY, IDAHO

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January 1977

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

[illegible]

IDAHO OPERATIONS OFFICE UNDER CONTRACT EY-76-C-07-1570

TREE-1016

DISTRIBUTED UNDER CATEGORY:
UC-66
Geothermal Energy
TID-4500, R65

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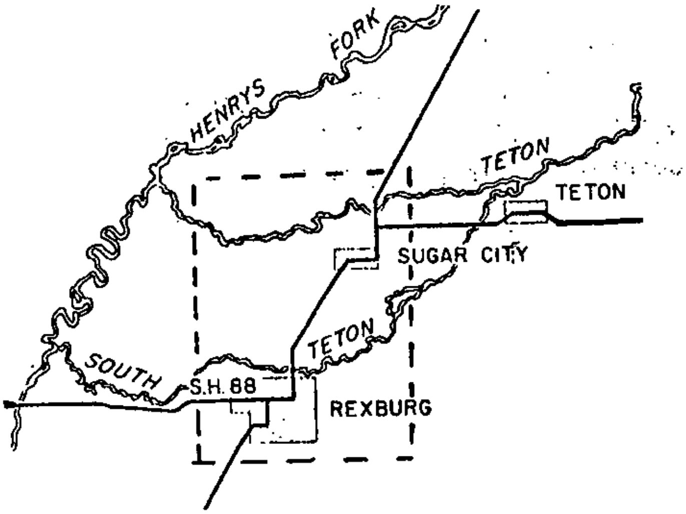

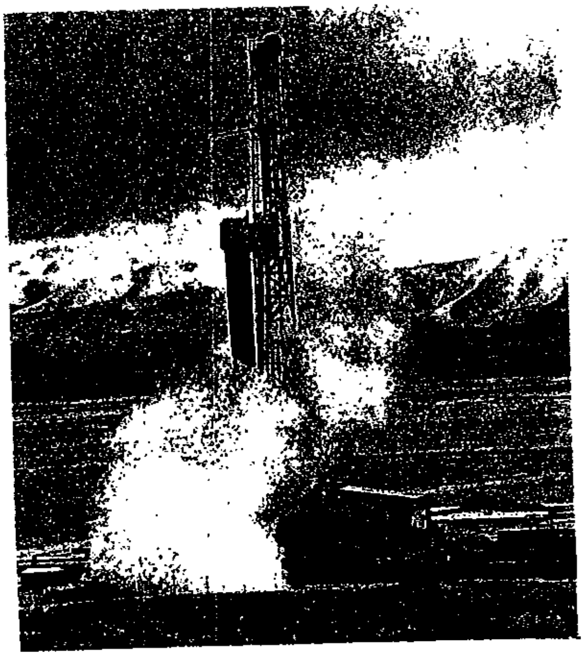

Date Published - January 1977

Prepared for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF GEOTHERMAL ENERGY AND IDAHO OPERATIONS OFFICE
Under Contract No. EY-76-C-07-1570

TREE-1016 - THE POTENTIAL FOR UTILIZING GEOTHERMAL ENERGY FOR SPACE HEATING IN RE-CONSTRUCTED SUGAR CITY, IDAHO

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ABSTRACT

This report is a preliminary overview of the potential application of the geothermal energy space-heating uses for Sugar City, Idaho. The work was conducted as part of the Idaho National Engineering Laboratory's responsibility to assess and stimulate such direct heat uses of geothermal energy for the commercial and non-federal government entities.

The opinions and recommendations presented are based on a cursory study promoted by the urgency for the rebuilding and recovery efforts of Sugar City, a town recently devastated by the Teton Dam collapse.

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SUMMARY

Sugar City's recovery from flooding caused by the Teton Dam failure involves the scheduled rebuilding of over half the homes and non-residential buildings, repair of over one half the sewer system, and complete replacement of the water system. This report analyzes the feasibility of planning the reconstruction to include a central heating system to supply all the space heating, and possibly some of the industrial heat, for Sugar City. The use of geothermal energy to fuel such a system is discussed in detail, with information supplied, principally for comparison, on the use of other fuels.

If a geothermal reservoir producing water of 120°F or higher can be tapped in the immediate vicinity of Sugar City, geothermal water could be fed directly from wells to the central heating plant. From there, hot water would be distributed throughout the city by an underground system. A geothermal reservoir exists in the general vicinity of Sugar City as evidenced by hot springs within about a 20-mile radius. But the limited data available indicate that it is unlikely that geothermal water much above 120°F can be found within a distance of three miles from Sugar City, unless wells are drilled to a depth of 2000 to 3000 ft, or deeper.

However, if a geothermal reservoir producing water of only 90°F can be found close by, this temperature of water can be upgraded to the desired 150°F to 180°F by the use of heat pumps. Geothermal water boosted by heat pumps and distributed by a city-wide underground piping system represents a viable and economical means of supplying the city's space heat. The use of heat pumps extracting heat from water is a technique economically practical even on cool water (50°F) wells. It is being used for heating several large office buildings in Salt Lake City and will be used for the library at Idaho State University.

Even if geothermal water is not available or does not appear economical upon further investigation, a central heating system using locally available abundant fuels (such as coal, or wood waste from Targhee National Forest) deserves further consideration at this time. The economics of such a system will depend heavily upon the loan terms that can be negotiated for the capital costs and on a favorable long-term contract for the fuel supply.

The conclusions and recommendations give a hopeful, but by no means a certain outlook for economical use of geothermal energy in Sugar City. It does appear that one of several alternatives will work, however, saving oil or gas and providing economically attractive space heating methods. Additional geological and hydrological data gathering* is recommended as a very first step prior to undertaking the expensive test drilling operation. It is also recommended that homes and non-residential buildings be designed to use the most versatile heating system--forced air.

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* This next step to the total effort was recently approved for joint funding from the Economic Development Administration and the Energy Research and Development Administration.

A reasonable exploratory drilling operation might cost $150,000 without definite promise of developing suitable geothermal wells. Federal aid or other methods of financing such exploration should be pursued at an early stage. Capital costs of the total geothermal heating system could exceed one million dollars. The basic distribution system would serve the projected needs of the city to the year 2000. Only additional supply wells and additional branch mains would need to be installed for new subdivisions. However, if a geothermal heating system could be developed for the town, it would eliminate what today are equivalent natural gas costs of $270,000 per year. These costs for the projected city size in the year 2000 would be $4-1/2 million, if one assumes natural gas costs will escalate 7% a year in constant 1976 dollars.

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I. INTRODUCTION

Sugar City, Idaho, is a small town of approximately 800 population on the upper, eastern portion of the Snake River Plain of Southeast Idaho, about 50 miles from Yellowstone Park. Sugar City was demolished by the failure of the Teton Dam on June 5, 1976. The citizens plan to completely rebuild the town, and work is now well underway. The high altitude (5000 ft) and harsh climate (-30°F to 90°F extremes, 9100 degree F-days* of heating annually) require heating for nearly 10 months of the year. Thus, in the rebuilding process, it is appropriate that the city consider and encourage the use of very economical and energy conservative space heating systems, not only as a benefit to Sugar City residents, but as a model to the state and the nation.

This report, prepared by the Idaho National Engineering Laboratory (INEL), addresses the energy supply alternatives for space heating in the reconstructed Sugar City, with special emphasis on the use of geothermal energy that appears to be indigenous to the immediate area.**

The INEL, headquartered in Idaho Falls 30 miles southwest of Sugar City, is a principal laboratory of the Energy Research and Development Administration. Research and development programs at the INEL include geothermal energy utilization and improved energy conservation techniques. In addition, the ERDA laboratories have been directed to provide information, encouragement, and other assistance to aid the private sector in using effective and appropriate energy practices.

1. THE TETON DAM DISASTER

The Teton Dam is a Bureau of Reclamation Project constructed to provide flood control and irrigation water to a portion of Eastern Idaho. It is built in a narrow canyon on the Teton River, a tributary to the Snake River. Construction of the 307 ft high earth-filled structure was begun in 1972. By spring of 1976, the dam was essentially complete except for final work on the turbine tunnels. On Saturday, June 5, the dam began to develop major leaks, and at approximately 11:45 AM, the dam sustained a massive breach, spilling almost the entire contents of the reservoir into the canyon below the dam and consequently out onto the Teton River and Snake River flood plains. The rupture was so massive and rapid that almost the entire contents of the reservoir was emptied in a short period of time. At the time of the breach, the reservoir was at about 90% of its capacity of 270,000 acre ft of water storage. The flood plain starts at the mouth of the river canyon about 6 miles below the dam. Near here the Teton River splits into two natural channels. One channel (the South Fork) meanders to the southwest toward Rexburg and then westward to

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* If one adds the average temperature difference between the inside and the outside of a house for each of the heating days in the year, the total Sugar City is 9100; Boise, Idaho is 5800; and San Francisco is 3400.

** This report was first prepared for the Sugar City Council and Madison County Commissioners in August, 1976. This version contains minor wording revisions.

its confluence with the Henry's Fork of the Snake River about 20 miles from the dam site. (Figure 1) The other channel (North Fork) continues almost due west across the flood plain to the Henry's Fork about 17 miles west of the dam site. The ancient flood plain is a highly fertile area and the towns and communities for the most part have grown up around farming and agricultural activities.

As the flood waters from the dam left the mouth of the canyon and spread across the plain, great devastation to homes, farms, and towns occurred. A flood water crest of 3 to 12 ft in depth covered a 10 mile wide path as it swept toward the Snake River. Extensive flood damage was sustained by all communities located in the flood path along the Teton and Snake Rivers until it was terminated by catchment in the 1.7 million acre-ft American Falls Reservoir on the Snake River about 100 miles from the Teton Dam.

Damage was sustained in portions of Fremont, Madison, Jefferson, Bonneville, and Bingham Counties.

Sugar City, a small town located in Madison County between the forks of the Teton River at approximately the center of the flood plain was the first town directly in the path of the flood crest.

The flood crest was moving with such velocity and force that over half of the homes and business buildings in the town were either swept from their foundations or suffered extensive structural damage. Many of the buildings in the town have been condemned and are scheduled for demolition. All buildings were flooded with mud and water, and will require extensive repairs or replacement of heating equipment.

Considerable damage and contamination was sustained by the city services. The entire water supply, an estimated third of the sewage collection system, and all of the sewage treatment facilities must be replaced.

Since Sugar City is essentially to be newly built, it is appropriate now to explore systems for home and business space heating that will be both efficient and in the long range cost effective. For, if a centralized system is to be installed, it should be considered in the early planning stages of the town reconstruction. This total system approach should include encouragement to citizens to use the best possible energy conservation techniques now available in their home and business building planning and construction.

2. STATISTICS FOR SUGAR CITY ENERGY REQUIREMENTS

Sugar City is located approximately three miles from a much larger town, Rexburg, which was also extensively damaged by the flood (Figure 2). However, the utility systems of Rexburg largely survived intact, while the Sugar City water and sewer system did not. Therefore, Sugar City is more logically considered for a major change in its space heating mode. The proximity to Rexburg, however, makes consideration of geothermal wells,

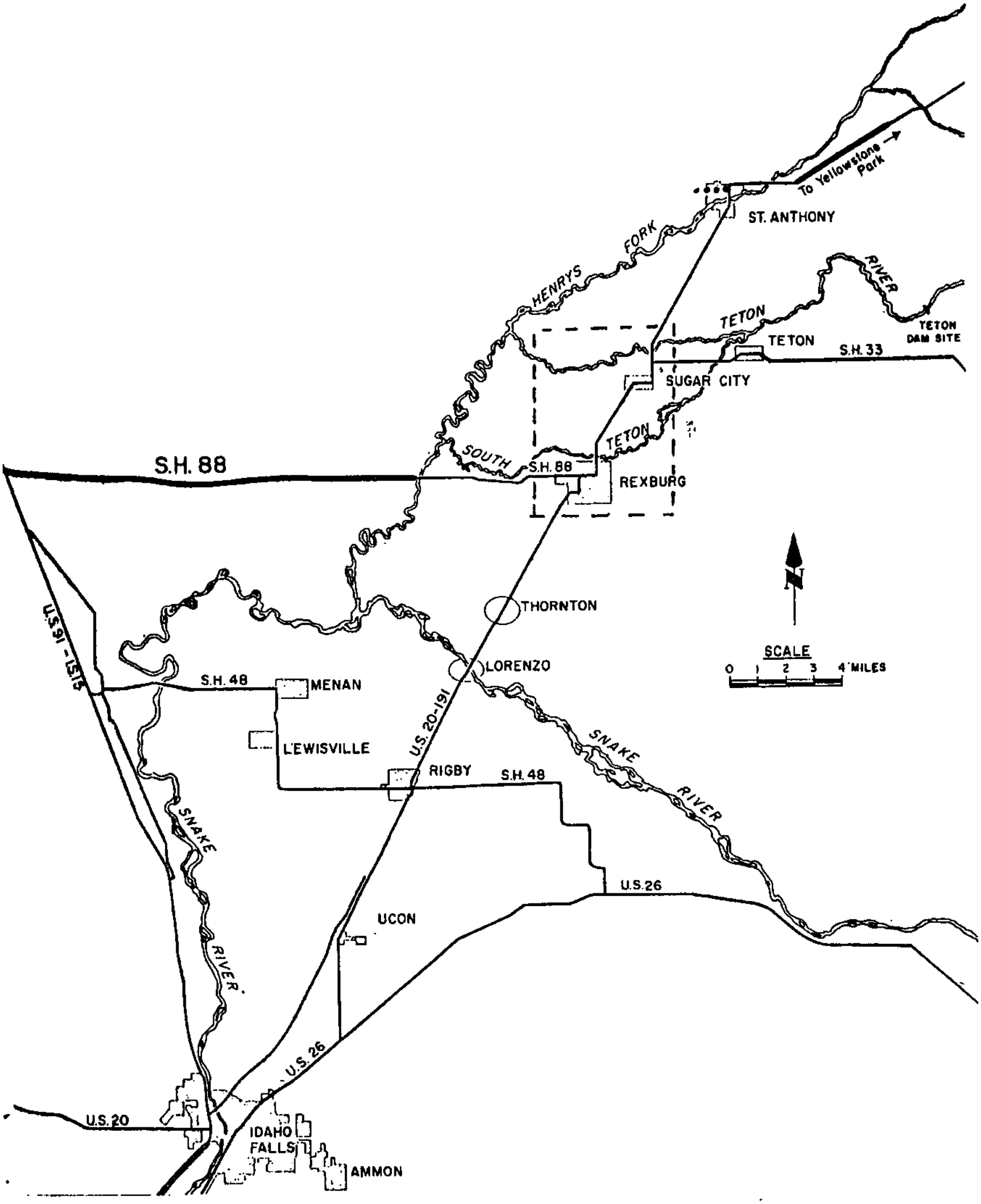

Fig. 1 Map showing Teton Dam site, Sugar City and surrounding communities

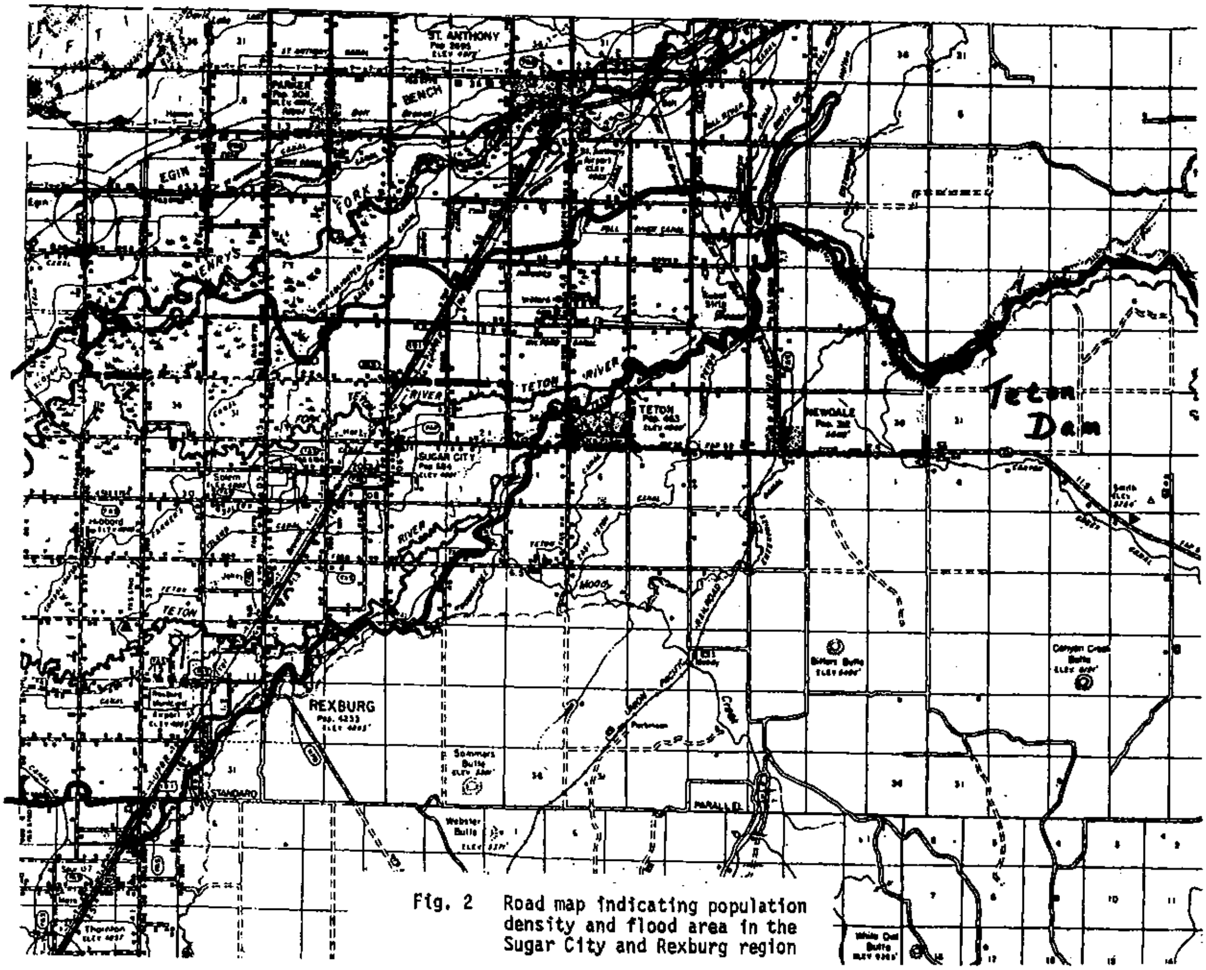

Fig. 2 Road map indicating population density and flood area in the Sugar City and Rexburg region

for instance, as also useful to this city of 8000 permanent population, plus 5000 seasonal college population.

The city limits of Sugar City is a rectangle 1/2 mile by 1 mile. About 1/2 of this area is laid out in blocks, 460 ft square. Much of the remainder is planned for development. Figure 3 shows the layout of the town with the projected additions on the east side. Prior to the flood there were 218 homes within the city limits with approximately 20 homes within 1 block of the city limits. Plans for four additions within the city limits were underway which would have added nominally 100 more residences. It is estimated that existing plus near-term development would have resulted in about 300 living units in the city.

The average home size is estimated to be about 1300 square ft. It is estimated that about 20% are split level or multi-level, 5% are single level with a basement, and 75% are single level with no basement. About 40% of the homes are brick or brick veneer siding and the remainder have wood siding.

There are a few (approximately eight) commercial buildings in town but most of these are vacant or have been converted to apartments. These are either single or two story buildings averaging about 5000 square ft each. Most are of brick or stone construction. Plans for rebuilding the commercial area are not firm at this time. Church and public buildings total almost 100,000 ft^2. The sizes of these buildings are estimated as follows:

Post Office	2500 ft^2	
City Building and Fire Station	5000 ft^2	
LDS Church Building (chapel, class rooms, and gymnasium)	17000 ft^2	$\sim$4000 ft^2 single story $\sim$9000 ft^2 2 story, single floor $\sim$4000 ft^2 2 story, 2 floors
Central Elementary School	22000 ft^2	$\sim$20000 ft^2 single story $\sim$ 2000 ft^2 2 story, single floor
Sugar Salem High School	37000 ft^2	$\sim$28000 ft^2 single story $\sim$ 9000 ft^2 2 story, single floor
LDS Church Seminary	$\sim$3000 ft^2	
High School Administration Building	$\sim$3000 ft^2	
High School Shop Building (planned)	$\sim$3000 ft^2	
Auditorium (old movie theatre used by High School)	$\sim$5000 ft^2	

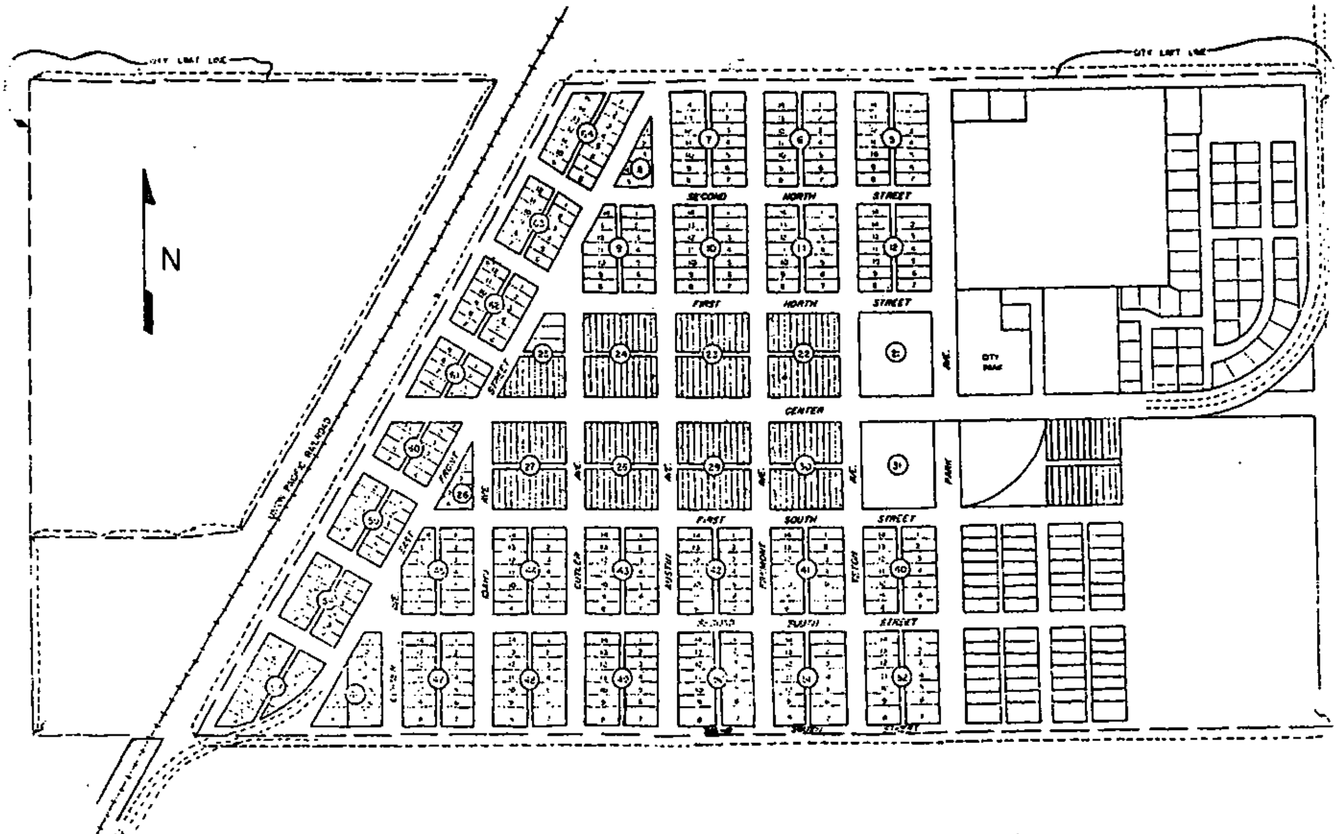

Fig. 3 Plot plan for Sugar City including undeveloped additions on the east side

Industrial operations within the city limits or immediately adjacent to the city consist of five potato "fresh pack" plants, one sugar beet loading operation, a grain elevator, a lumber yard, a small dairy operation (20 to 30 head), and a potato processing plant. It is estimated that the heated areas of these businesses are about 100,000 ft^2. Located within two miles is a cheese factory and a large (12,000 head) cattle feedlot operation. In sizing city heating requirements, those plants adjacent to the city limits should be considered and included in the requirements if the plant owners express interest.

Space heating needs of Sugar City, as presently planned and described can be calculated if the construction and thermal insulation details are known. For the purposes of this report, average values for homes and buildings will be used for heat loss during the winter assuming that all new construction will be well insulated (to what is often referred to in this area as "electric heat standards"), and that older buildings have been or will be upgraded with better insulation. The following, therefore, have been assumed:

1. The average distribution of homes will be seven per city block. This distribution allows for 224 homes and apartments in the presently plotted city.
2. Homes will be rebuilt with floor areas averaging 1400 ft^2 per house.
3. Houses will be well insulated and in general, be of good quality construction, with heat loss values of nominally 550 btu/hr-^{o}F.
4. Non-residential buildings would average 28,000 ft^2 of floor area per city block, and cover ten blocks. Heat loss values for these buildings are assumed to be 0.63 Btu/hr-^{o}F per foot of floor space.

On the basis of weather data compiled over the last five years (Figure 4), a winter outdoor design minimum temperature of -25^{o}F was selected.* This represents, then, a residential heating demand figure of 11 x 10^6 Btu/hr and a commercial heating demand figure of 16 x 10^6 Btu/hr for a total city demand of 27 x 10^6 Btu/hr. Applying the average yearly temperature distribution data, the yearly heat load for the city becomes 65 x 10^9 Btu/hr.

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* Figure 4 represents average temperatures for the last five years and even though used for preliminary design and scoping purposes it does not reflect the extreme lowest winter temperatures. For example, the coldest temperature for the five year data was -39^{o}F.

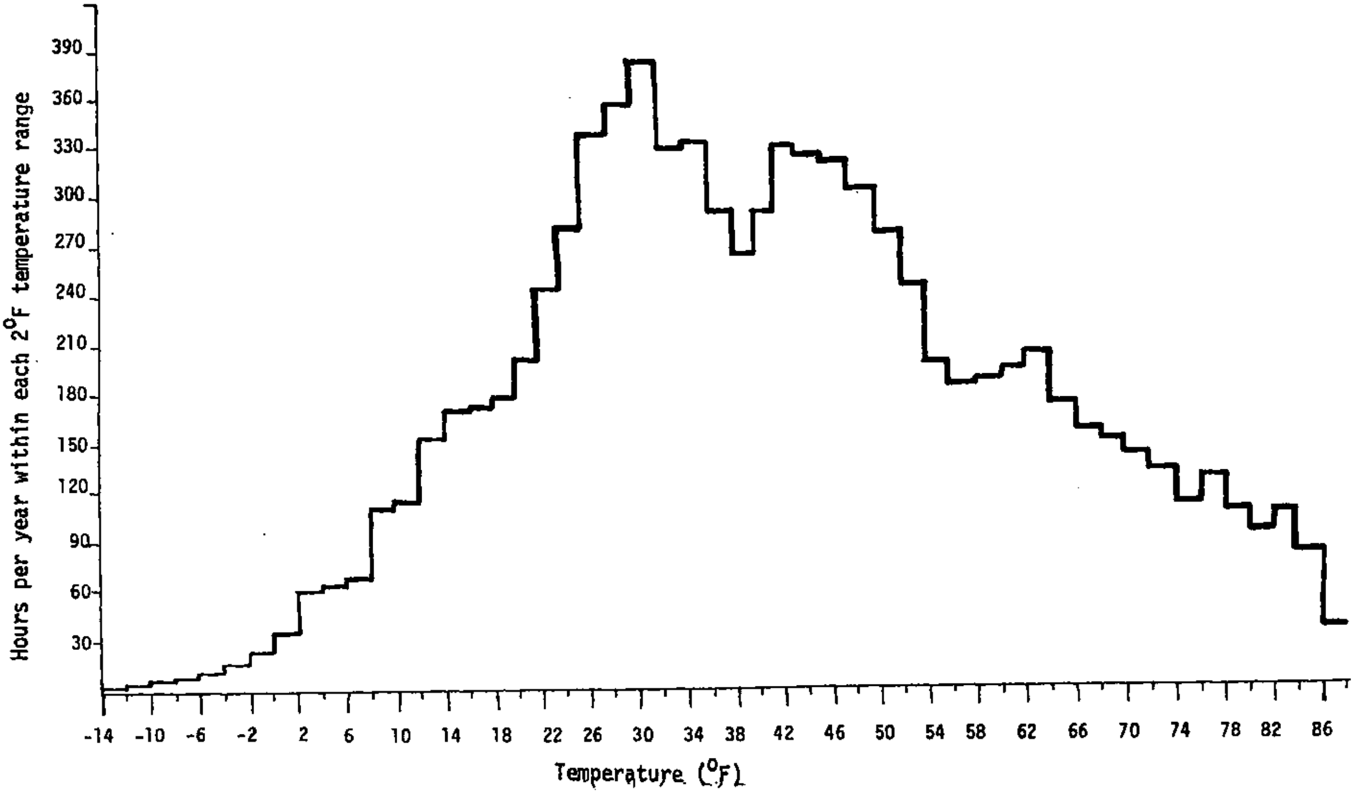

Fig. 4 Average temperature data for Sugar City

3. PROJECTED EXPANSION

Southeast Idaho, a 20,000 square mile area with 160,000 population would appear to be a natural target for future growth within the nation. Though the present residents of the region do not encourage growth, they do recognize that population pressures elsewhere will quite naturally result in the flow of new residents to the area. Expansion of agriculture will continue because of the abundant underground aquifer in the area, and establishment of new industries in the area can be anticipated. Sugar City can be expected to be a part of such expansion, as projected in Table I below.

The Rexburg-Sugar City area is experiencing a 5% annual population growth rate typical of the upper Snake River Valley and the population is expected to double by the year 1990. It will be assumed that the same growth figures will apply to Sugar City. However, if Sugar City becomes a model of efficient and economical energy usage, one could anticipate higher than regional average growth rates.

TABLE I

PROJECTED POPULATION AND SPACE HEATING REQUIREMENTS AND COSTS

	Today 1976	1985	2000
Population	800	1240	2600
Homes	214	320	630
Apartments	~10	50	200
Businesses (equivalent 28,000 ft^2 units, including schools and churches)	11	16	36
City Limit Area (square miles)	0.5	0.75	1.5
Annual Heating Needs (millions of Btu's)	65,000	102,000	216,000
Projected Annual Fuel Cost, if heated by natural gas (assumes 8% annual price increase in gas)	$270,000	$660,000	$4,450,000

II. GEOTHERMAL RESOURCE POTENTIAL

Exploration and development of a local geothermal resource requires an understanding of the inter-relationships between the geology and the hydrology of the Sugar City area. The process of locating, developing, and utilizing a geothermal resource should be accomplished within the existing regulatory and legal constraints.

1. AREA GEOLOGY*

Sugar City is located on the eastern margin of the Snake River Plain in Madison County, Idaho. The Snake River Plain is a huge volcanic rift area that has undergone some limited downwarping and faulting along its boundaries. Along many of these edge faults, hot water springs exit. In the eastern half of the plain, volcanism has been concentrated along a northeast-trending axis, so that this part of the plain is higher in its center than along its edges. Rivers flow near the margins rather than within the plain. The Yellowstone Plateau--the high northeast end of the Snake River Plain structural and volcanic province--is located approximately 46 miles northeast of Sugar City. Both the Snake River Plain and the Yellowstone Plateau have been the site of intense bimodal basalt-and-rhyolite volcanism for the last 10 million years. The youngest eruptions (Craters of the Moon and Cedar Butte) apparently occurred as recently as 1,625 years ago.

The Snake River Range and Big Hole Mountains that lie to the east and southeast of Sugar City are exhibits of a general northwest structural trend. This trend is further emphasized by the valleys, thrust faults and axes of folds that are present in the area. The gentle folding of the mountains in the area was followed by normal faulting and thrusting along this same northwest structural trend. There are also inferred hidden older faults that occur in the area that trend northeast. (Figure 5)

2. AREA WELLS AND SPRINGS**

The domestic and irrigation wells in the area are generally characterized by their shallow depths and high water quality. Many wells have been drilled to depths in excess of 150 ft and some have exhibited above normal temperatures ranging from 65°F to 97°F. The majority of irrigation wells range in depth from 250 to 450 ft. Very few wells have been drilled in excess of 800 ft in the search for adequate production. The maximum production temperature (97°F) was recorded at the Newdale City well which was drilled to a depth of 385 ft. However, a well was drilled less than a quarter mile from the Newdale well to a depth of 850 ft. The well was originally dry. Presently, this well has a small amount of cold water. Figure 5 and Table II give a partial listing of the wells in the area.

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* Partial data and interpretations supplied by the U. S. Geological Survey.

** Partial data supplied by the Idaho Department of Water Resources.

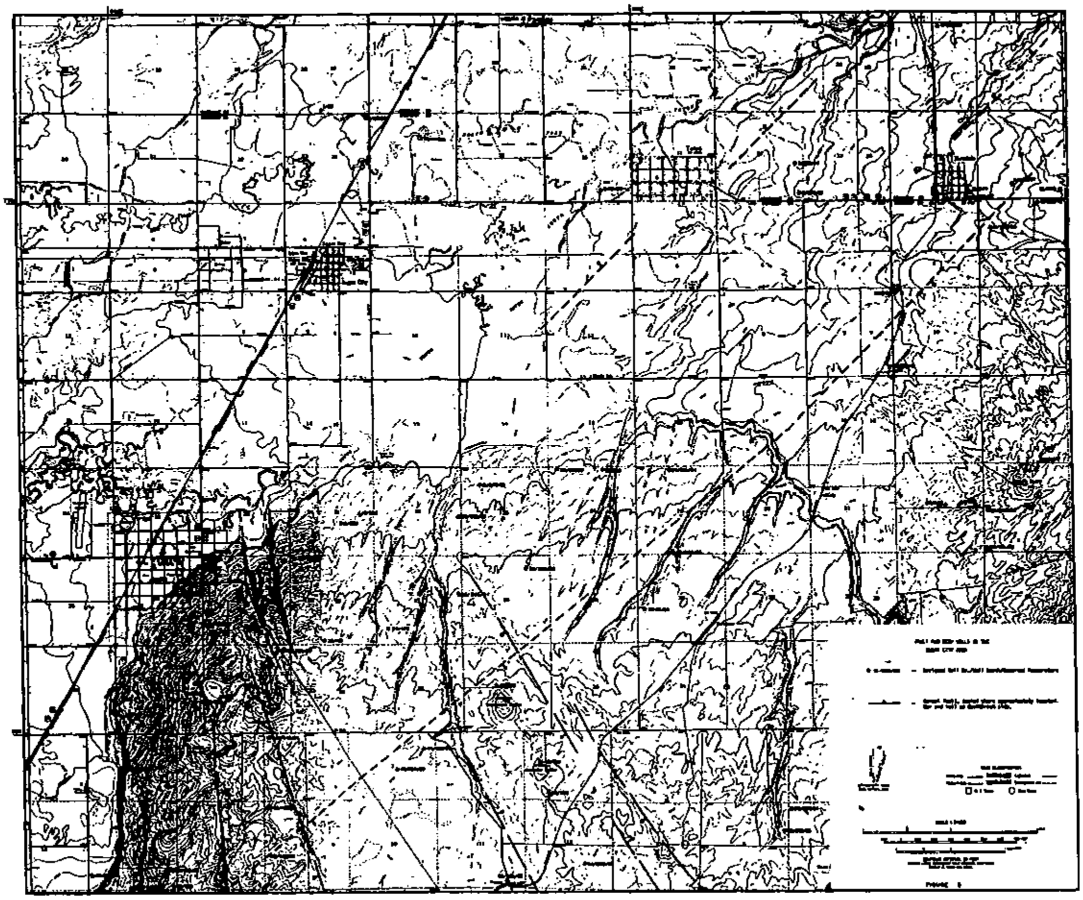


Fig. 5 Fault and deep wells in the Sugar City area

TABLE II

DEEP WELLS IN THE SUGAR CITY AREA

Well No.	Owner	Location			Well Depth (ft)	Static Water Level (ft)	Reported Temperature (°F)
1	Myrtle Egbert	T7N	R40E	23dd	160	90	54
2	Brad Ostermiller	T7N	R40E	23dd	136	75	54
3	Meyers Brothers	T7N	R40E	28cd	153	70	
4	Miles Allen	T2N	R41E	27ab	245	181	60
5	Roland Schaat	T7N	R40E	33aa	187	129	53
6	Bill Hollist	T7N	R40E	36dc	145	70	54
7	D. P. Hathaway	T7N	R41	32da	220	136	54
8	Buck Hathaway	T7N	R41E	32dd	206	134	52
9	City of Newdale	T7N	R41E	34dd	385	233	97
10	City of Newdale	T7N	R41E	34dd	244		
11	Melvin Schwendiman	T7N	R41E	35cd	400	285	87
12	Wallace Little	T7N	R41E	35dd	400	320	
13	Sugar City	T6N	R40E	4da	195	23	54
14	Clair Robinson	T6N	R41E	2bc	350	271	96
15	Val Schwendiman	T6N	R41E	2ab	300	300	78
16	Craig Wood	T6N	R41E	10bb	265	218	
17	Don Staker	T6N	R41E	9dd	283	210	51
18	John H. Smith	T6N	R40E	21db	650	248	
19	John H. Smith	T6N	R40E	21da	204	120	
20	Kim Summers	T6N	R40E	22da	250	200	53
21	Parkinson Brothers	T6N	R40E	23bb	249	155	52
22	Ralph Huskinson	T6N	R40E	24bb	317	294	50
23	Summers Brothers	T6N	R40E	24ab	350		
24	Huskinson Brothers	T6N	R41E	19ba	312	198	54
25	Huskinson Farms	T6N	R41E	19cd	222	165	53
26	Staker I. Walters	T6N	R41E	22ac	435	335	
27	Staker I. Walters	T6N	R41E	22ac	775	402	
28	Laird Robinson	T6N	R41E	23cb	545	440	56
29	Wallace Robinson	T6N	R41E	23cc	751	480	53
30	Wallace Robinson	T6N	R41E	14dd	915	571	

TABLE II

(Continued)

Well No.	Owner	Location			Well Depth (ft)	Static Water Level (ft)	Reported Temperature (°F)
31	City of Rexburg	T6N	R41E	29ccb	305	203	56
32	Bryon Harris	T6N	R40E	28bbb	320	285	53
33	Dick Smith	T6N	R40E	28cc	450	355	
34	Frank Sommers	T6N	R40E	27cc	475	314	
35	Kelly Summers	T6N	R40E	27ad	342	180	54
36	Sommers Brothers	T6N	R40E	26ab	300	270	53
37	David Beesly	T6N	R41E	30cb	471	308	54
38	Bowen and Thomasen	T6N	R40E	31da	360	328	
39	City of Rexburg	T6N	R40E	31dad	388	324	
40	Owen Slaugh	T6N	R40E	32aa	338	299	50
41	Sommers	T6N	R40E	35bd	1300	400	
42	Myron Lewis	T5N	R40E	4bbb	442	396	54
43	Gary Ball	T5N	R40E	3ac	430		59
44	Gary Ball	T5N	R40E	3aa	430		59
45	Jensen	T5N	R40E	1bc	750		
46	Jensen	T5N	R40E	1ca	700		
47	Mark Ricks	T5N	R40E	7cc	125	86	
48	Mark Ricks	T5N	R40E	7dd	220	100	
49	Mark Ricks	T5N	R40E	7dd	320	260	
50	Brent Arnold	T5N	R40E	7dda	106	17	53
51	Webster Brothers	T5N	R40E	9cb	460	401	53
52	Clint Hoopes	T5N	R40E	9bb	420	350	52
53	Jensen Brothers	T5N	R40E	11dd	562	350	53
54	Jensen Brothers	T5N	R40E	12db	1000		68
55	George Brown	T5N	R41E	8ad	863	528	53
56	Steve Wood	T5N	R41E	10ba	600	366	54
57	City of Rexburg	T6N	R40E	20cc	160		
58	City of Rexburg	T6N	R40E	30bd	172		
59	City of Rexburg	T6N	R40E	29bb	155		

There are three hot springs in the upper Snake River Valley that may be used as indications of the geothermal system that exists in this area. From Sugar City, Ashton Warm Springs is located 23 miles northeast, Green Canyon Hot Springs is located 21 miles east-southeast, and Heise Hot Springs is located 18 miles southeast. The surface discharge temperatures and the predicted reservoir temperatures for these springs are tabulated in Table III. This data should be reviewed with caution and only interpreted as indicators of possible geothermal reservoirs in the area of interest.

3. GEOLOGIC RESOURCE EVALUATION

If there is a shallow geothermal resource at or near Sugar City, it is probably controlled by the faulting that occurs in the area. All of the area warm springs are intimately associated with the "young" Northwest structural trend and are located around the faults. It appears that the older northeast trending faults also influence the occurrence of hot water where they intersect the major northwest-trending faults. The hot water apparently circulates from depth up and along some major younger faults and is either absorbed by the huge fresh water aquifer or breaks out at the surface in the form of warm springs.

The warm wells around Newdale appear to be associated with the Green Canyon and Heise Hot Springs water as it moves along the northwest-trending faults and spreads along the older northeast-trending fault where they intersect west of Newdale. The relative movement of the water along the northwest-trending faults is undetermined at this time. If the two warm springs are indeed indicative of the geothermal reservoir that exists in the area, then the reservoir temperature that can be expected at depth could range from 150°F to 300°F.

The two major questions that remain to be answered are where and how deep to drill to obtain the required temperature.

It is felt that a geothermal well in the Sugar City area must be drilled within the area of a major fault system at depth for maximum benefit of a hot resource. The thick overburden in this area would indicate that 3000 to 5000 ft of drilling would be required to tap geothermal waters in the range necessary for space heating. The massive overburden in the area acts as an insulator, retaining heat. However, the area immediately surrounding Sugar City (within 4 miles) does not suggest any major faulting and thus does not look favorable for a productive geothermal well from shallow depth (about 1000 ft), using the faults for conductive paths from the deeper reservoir. This technique has worked elsewhere (Boise, for instance), where the faults were tapped somewhat below the region where the geothermal water could mix with the near surface aquifer. Such potentially useful faults do exist within a few miles to the south and east of Rexburg, but the distance is a minimum of six miles from Sugar City.

TABLE III

SUGAR CITY AREA

WARM WELLS *

	Distance from Sugar City	Surface Temperature	Predicted Reservoir Temperatures	
			Geothermometer Silica **	Geothermometer Na-K-Ca **
Green Canyon Hot Springs	18 miles	111°F	158°F	41°F
Ashton Warm Springs	22	106°F	293°F	194°F
Big Springs	56	54°F	203°F	149°F
Lily Pad Lake Springs	43	63°F (min.)	95°F	68°F
Newdale Well	7	97°F	176°F	401°F
Heise Hot Springs	21	120°F	176°F	401°F

* Table compiled from Idaho Department of Water Resources Bulletin No. 30

** Silica and Na-K-Ca geothermometer indications of temperatures are less reliable at the lower temperatures. None of the predicted temperatures were made using the enthalpy/chemical dilution correlation model, which would give higher results than shown here.

4. REGULATORY AND LEGAL CONSIDERATIONS

Geothermal rights are handled differently than ordinary water rights or mineral rights. The Idaho State Legislature has declared geothermal "Sui Generis," i.e., an entity of its own. On private land the initial rights belong to the land owner. On state land, the state reserves all rights to the geothermal source. On former federal land, the state reserves all geothermal and mineral rights that were not retained by the federal government. On all present federal land, the federal government owns the geothermal rights and leases these rights. Competitive leasing occurs on certain designated areas while first come leasing occurs on all others.

Care must be exercised to prevent infringement on existing water rights. Although a geothermal well almost always draws from a different and deeper aquifer than irrigation or culinary water wells, there is the possibility that conflicts may arise. For instance, if unusual drawdown is exparienced in a neighboring well, it could be supposed to be caused by the geothermal well operation. The supposition may or may not be based on sound engineering and scientific reasons or data.

III. SCHEMES FOR UTILIZING GEOTHERMAL ENERGY

1. DIRECT USE

From a technological or engineering position, the transferring of heat from the geothermal water directly into the building is the simplest method of heating the buildings. Certain resource prerequisites are necessary before a direct application can be proposed. Those minimal requirements are:

1. Well site or resource location should be reasonably close to the immediate Sugar City area, preferably within 3 miles.
2. Resource temperature should be at least 120°F.
3. Conventional materials of construction can be used for piping and distribution.
4. An environmentally acceptable disposal method must be available within close proximity to the immediate Sugar City area; i.e., preferably within 5 miles.

If the geothermal water can be used directly, the utilization design concept proposed is based on the following:

1. Geothermal water is produced by a well or wells, piped underground, or in insulated pipes above ground at road side to Sugar City for distribution in underground mains to each building.
2. If the geothermal water meets drinking water standards, it could be used directly for domestic hot water supplies for washing and cooking.
3. Each building would remove heat from the geothermal water, dropping the temperature to a nominal 105°F from 140°F (depending upon the temperature at the source). The method employed for transferring heat into the building would be either by convectors, similar to the conventional wall units or by heat exchangers in a central forced air circulating unit and/or its ductwork. The forced air system is much preferred for its comfort, convenience, versatility (easily adaptable to other than geothermal) and efficiency, being able to remove more heat from the geothermal water than the convector system.
4. The discharge fluid from the building will be piped to a suitable disposal area.

The amount of water required to supply these heating needs depends on the geothermal supply temperature. A further consideration is the supply utilization factor; i.e., the fraction of the year that the full capabilities of the system are needed. In other geothermal applications (Reykjavik, Iceland, and the INEL study for Boise), the geothermal system is not designed to supply all of the heat for the coldest days. Instead, the geothermal system is sized to supply all the heat on the average winter day, and for colder temperatures, oil heaters are used to boost the temperature sufficiently. The economic trade off is between the larger capital investment for a total geothermal heating system, versus the smaller investment for a hybrid system (geothermal plus oil-burning) to handle moderately cold temperatures, plus the added fuel costs of supplying the extra heat on the coldest days. These economic considerations are discussed in Section IV.

The water flow required for a geothermal system thus depends on a number of aspects. Table IV summarizes the system flow requirements for several geothermal source temperatures. The values given in the table represent both residential and commercial space heating needs in 1976 and also as projected for 1985. The values also assume that all of the heat is supplied by the geothermal system even on the coldest days.

The range in required flow rates is considerable for the requirements on an all-geothermal system. However, if fossil fuel peaking is used with a hybrid system to supply the extra heat needed on the coldest days, the needed flow rate is substantially reduced, as indicated by the data in Table V. The data in Table V is derived from the temperature data in Figure 4.

From the data in Tables IV and V, it would appear appropriate to design for a maximum flow rate of 2000 gallons per minute for the first iteration on the costs shown in Section IV. In general, this flow would be more than enough, even without supplementary peak heating, in 1976, and adequate for the 1985 projections, if a small amount of supplementary heat is supplied on very cold days.

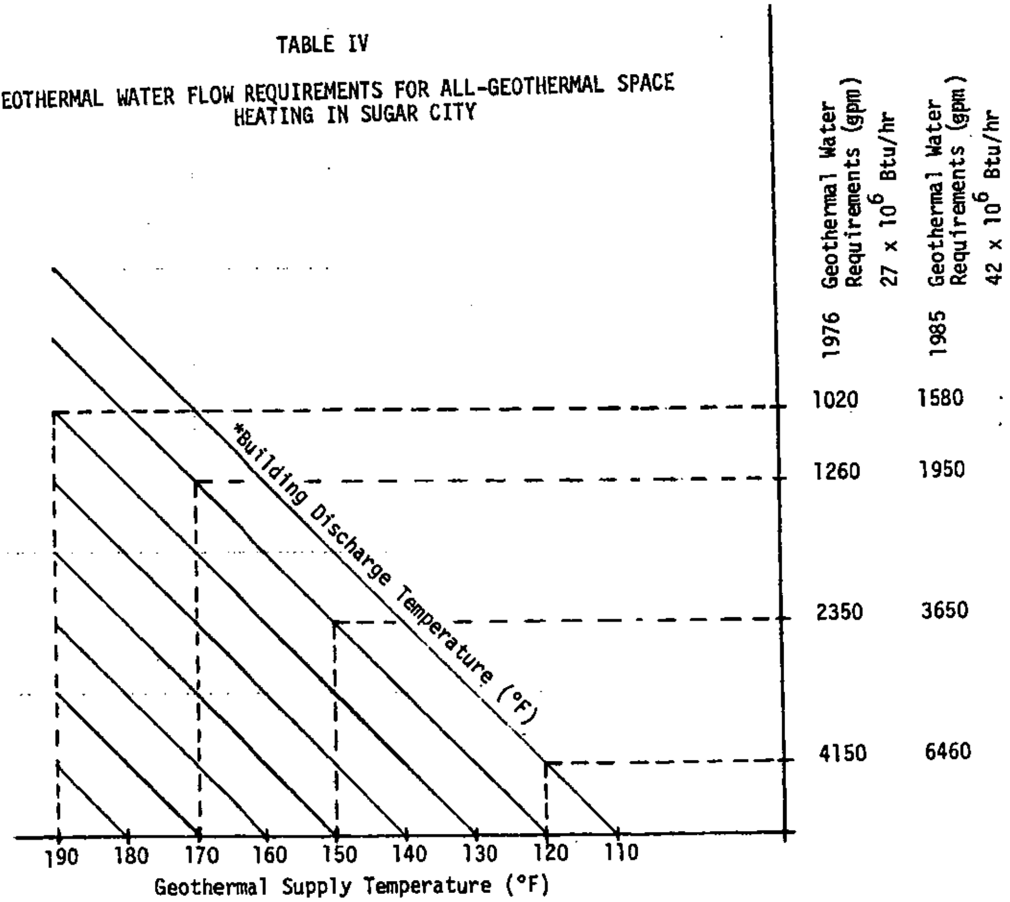
From the 2000 gpm supply, the distribution is typically 5 gpm to each home and 90 gpm to each commercial block. Residential connections would be 1 inch in diameter and commercial connections 2-1/2 inches in diameter. For this system, 10 inch diameter mains through the commercial area with 4 in. diameter branch mains to the residential areas will allow for the projected expansion of the city to the year 2000. The system layout is illustrated in Figure 6.

Such a system would operate with a pressure of approximately 80 psi at the central pumping station discharge. Individual users would not have to install circulation pumps for their heating systems. Large commercial users would have the option to install circulation pumps for more precise temperature control. Pump requirements for the city would total approximately 120 horsepower. Total installed horsepower including some backup would be in the range of 180 horsepower.

In one variation of the direct use concept, geothermal water is only piped to a heat exchange loop at the central pumping facility. Treated water is then circulated through the distribution system as a secondary

TABLE IV

GEOTHERMAL WATER FLOW REQUIREMENTS FOR ALL-GEOTHERMAL SPACE HEATING IN SUGAR CITY



* A 7°F temperature reduction due to heat losses in the piping from the wells to the buildings is arbitrarily assumed. This is a high loss (therefore conservative) based on calculations and experience in other geothermal systems.

TABLE V

REDUCTION FACTORS USING FOSSIL PEAKING IN A GEOTHERMAL SYSTEM FOR SUGAR CITY

(-25°F maximum design requirement for comfort)

Lower Limit Outdoor Design Basis Temperature for Geothermal System (°F)	Fraction Now Needed as Flow (heat) Compared to -25°F Design Temperature	Fraction of Annual Total Heating Needs That Must be Supplied by Supplementary Boiler	Fraction of Heating Season That Supplementary Boiler Would Need to Operate at Complete or Partial Load
8	63%	0.8%	9%
12	59%	1.6%	15%
20	50%	4.8%	30%

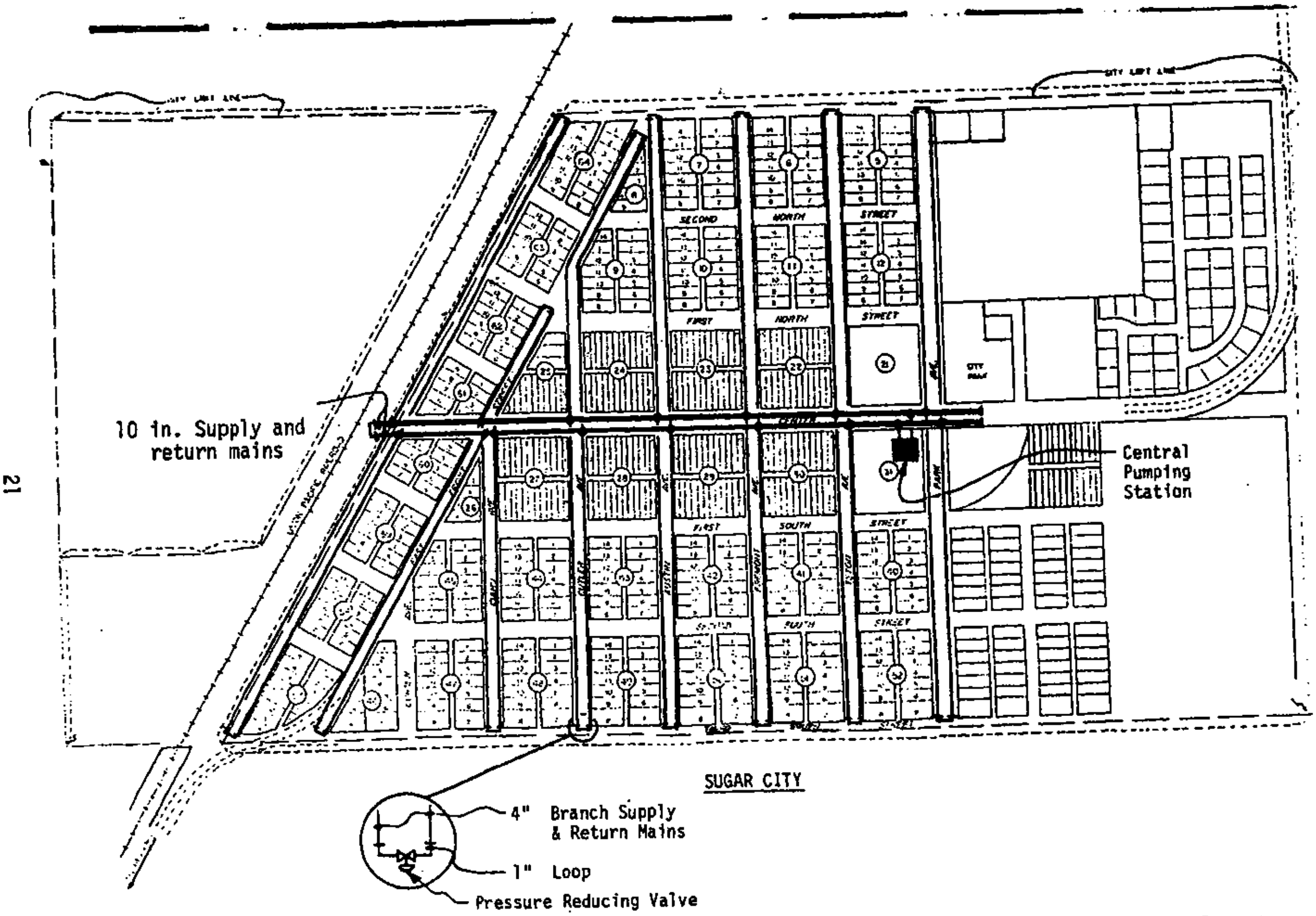


Fig. 6 Hot water distribution layout

loop. Such a scheme would be desirable if the geothermal water chemistry is such that significant corrosion or fouling of pipe and heating components would result.

2. HEAT PUMP BOOST

If a geothermal resource cannot be located of sufficient temperature to allow direct use by pumping throughout a distribution system or through an intermediate heat exchanger, the resource can be upgraded through the use of heat pumps. In the heat pump concept, a secondary fluid in a compression-expansion cycle is used to extract heat from a low temperature source and to reject that heat to a higher temperature media.

2.1 Central Heat Pump Concept

Heat pumps could be installed in the central pumping facility as shown in Figure 6. These heat pumps would extract heat from a marginal geothermal supply and in turn, use their heat energy to raise the temperature of water in a closed secondary loop. Heat pumps operating from 90°F water would probably have a coefficient of performance of about four. This performance coefficient means that for every Btu of energy put into the heat pump in the form of electrical energy, four Btu's of heat energy can be transferred from the geothermal water to the closed loop central hot water supply system.

2.2 Individual User Heat Pump Concept

Instead of concentrating the heat pump installations at one central facility, the marginal geothermal water could be pumped through the distribution system and smaller individual heat pumps installed within homes and commercial buildings. With a geothermal water temperature of 90°F, standard units in this smaller size would operate with a coefficient of performance in the 3.0 to 3.5 range, depending on how much heat was removed from each gallon of the geothermal water. Demand flow rates to individual users would depend on the actual inlet and outlet geothermal temperatures, but would typically be 60 to 80% of the values for the all-geothermal system. Fossil peaking would be used at the central distribution station on extremely cold days.

An attractive extra feature of these "off-the-shelf" smaller heat pumps, is that of built-in air conditioning for the summer months. With an automatic switchover valve arrangement, heat is rejected to the water from the space being served.

3. COOL WATER HEAT PUMP

Individual user installed heat pumps can operate with a still lower temperature water source, such as from the present domestic wells. Heat pumps operating with 55°F inlet water show a coefficient of performance in the 2.5 to 3.0 range. Demand flow rates with this cooler water would be approximately 7 gpm to 11 gpm for a home and about 105 gpm for a commercial block. The exact values would depend on the characteristics of the heat pump.

4. DISPOSAL OF WASTE WATER

In any geothermal application, the disposal of spent or cooled geothermal water must be addressed. For the direct geothermal water system, an average year heating season would require disposal of approximately 800 acre feet of water for the present Sugar City population. With a central heat pump installation, depending on different exchanger efficiencies, the water disposal quantity per heating season could approach 1200 acre feet. These quantities represent a holding pond approximately 40 to 60 acres in surface area. The water from an entire heating season might be stored and used during the growing season for crop irrigation. Disregarding evaporation and seepage losses, the amount of water involved would irrigate from 250 to 400 acres of crop land.

Regulations governing the disposal of used geothermal water must also be considered. Mineral content may be the governing factor on the disposal method. Depending on environmental regulatory considerations, disposal methods may range from release to surface streams to reinjection into the same aquifer from which the water was obtained. Presently, the State of Idaho has established both thermal and chemical discharge regulations for water into surface streams. Almost without exception, space heating discharge water will need to be cooled in spray ponds prior to reaching a water way to meet these regulations. Chemical content difficulties will depend on the particular situation.

For the economic evaluation in Section IV, re-injection to the geothermal aquifer was assumed the appropriate method for disposal. This method is more expensive than surface disposal.

IV. ECONOMICS

The following section analyzes the costs of the various methods of providing space heating in the Sugar City area, using today's costs and projected costs for the future. The following basic assumptions are included:

1. Escalation - for the purposes of this report, inflation or essential dollar devaluation has been assumed as zero, since the rate has been so variable over the recent past.
2. Oil Prices - a 5% per year price increase because of increased costs of exploration and production, and the developing scarcity of this resource.
3. Natural Gas Prices - an 8% per year price increase, same reasons as oil.
4. Synthetic Gas and Oil - Same prices as the natural products.
5. Coal and Wood - delivered in the Sugar City area at 1/2 of the equivalent energy price of oil.
6. Materials of Construction and Geothermal Drilling - present day prices are assured. Though material prices have some dependence on gas and oil prices, construction in the near future at present-day prices is assumed.

1. CURRENT FACT COSTS AND FUTURE PROJECTIONS

Natural gas is the principal space heating fuel presently used in the newer homes and businesses in Sugar City and Rexburg. Some fuel oil and some resistance heating is employed. Table VI lists typical costs of space heating fuels today in the Sugar City area.

Table VI shows the obvious fuel cost advantage of geothermal, if the geothermal water supply (the wells) are considered as a capital, not a fuel cost. The only geothermal energy costs would be the electric pumping costs and operation of the compressor motor in the case of heat pump boost. It should be cautioned, however, that many commercially proposed geothermal projects would have the water supplied by a "resource company" to the user's heating system. In such a case, the user pays a fee based on the quantity of geothermal water he uses. Separate accounting of this type would significantly alter the costs as shown, since profit necessary to operate on risk capital would be included.

The relatively attractive present costs of oil and gas (compared to electricity) are likely to become far less attractive in the future. For instance, if natural gas prices continue to rise at 8% per year, then in 1985, the average homeowner in the Sugar City area would be spending 1/10 of his annual income just to keep warm.

TABLE VI

HEATING SEASON ENERGY COSTS

(Does not include costs of capitalization)

	Home	Commercial Block	Total City
Natural Gas (26¢/therm)	$390	$12,500	$211,000
Fuel Oil (40¢/gal)	460	14,700	248,000
Electric Resistance(2.2¢/kW-hr)	775	25,000	420,000
Coal-fired Boiler, central community heating ($40/ton delivered from Wyoming)	290	9,300	157,000
Geothermal * Direct Use Pumping Costs	70	1,000	25,000
Low Temperature Geothermal ($\sim 90^{\circ}$F) Central Heat Pump COP = 4 and pumping costs	280	9,000	152,000
Individual Heat Pumps COP = 3.5 and pumping costs	310	9,900	168,000
Cool Water Heat Pump COP = 3.0 and pumping costs	380	12,200	206,000

* Does not include royalty payments to the geothermal rights owner, but does include both production well and reinjection well pumps as well as distribution pumping.

** COP = coefficient of performance = $\frac{\text{Heat output}}{\text{Work input}}$

2. GEOTHERMAL WELLS, PIPING AND PUMPING, PLUS FOSSIL PEAKING

The cost of the geothermal heating system depends on the location and depth of the resource. For the purpose of estimates, two cases will be considered, both with the same distribution system supplying the city's needs. The two possibilities for wells are as discussed in Section II. Deep wells can be drilled by a truck-mounted exploratory oil well drilling rig. Such a rig has the capability of drilling to 4000 ft, and casing the hole to about 2000 ft. Each well will cost about $200,000. The second, less expensive drilling procedure, would use a water well drilling rig to drill to a maximum of 1500 ft in search of hot water being ducted up faults from prior earth movement. Though those wells are far less expensive, the hitting of the faults has a higher risk for failure. The following summarizes the estimated costs of the various components of the geothermal heating system, and the cost estimates of wells of these different types.

Distribution System Construction Costs Within the City Limits

Pipelines	$500,000
Well Pumps	50,000
Distribution Pumps	30,000
	$580,000

Deep Wells

Typically 4000 ft deep delivering 200°F or hotter water at 1500 gpm would require three successful wells, at $200,000 each, plus one failure well at $125,000. This is a conservative estimate, for a deep well at Raft River. It is estimated each well can produce 1000 gpm when pumped.

$725,000

Shallow Fault-Located Wells

Typically 1500 ft deep, delivering 150 to 170°F water at 2000 gpm, would require four successful wells plus two failures, costing $50,000 and $40,000 each, respectively. A conservative estimate would be 500 gpm per well.

$280,000

Cost of Pipelines from Wells to Sugar City and to Place of Discharge

$100,000 per mile installed, either buried or at surface with insulation.

It is apparent from the preceding that the major cost would be deep well drilling. However, the option of finding a hotter resource near to or under Sugar City exists with such drilling. It appears unlikely that successful tapping of faults occur closer than three miles to Sugar City. So, even though the fault drilling will be cheaper, it represents greater risk and probably higher pipeline costs.

An approximate minimum estimate for the geothermal system would be $1,000,000 including some exploration costs not shown. Most of the cost would need to be expended in the initial phases. Only some of the well drilling cost could be deferred until the system expands in later years.

A system cost of $1,000,000 amortized over 25 years at 7% interest represents an annual cost of $86,000. Operating and maintenance costs are estimated as $50,000/year. This cost added to the "fuel" costs shown in Table VI make the geothermal system competitive with current natural gas costs. Obviously, the attractiveness depends on the loan terms that can be negotiated. Furthermore, an estimated $150,000 minimum "front-end" cost must be arranged for, a cost that could be lost without any useful resource being encountered if the first wells are unsuccessful. If they prove successful, however, this "front-end" cost would become part of the total project costs indicated.

The question now becomes one of how Sugar City can undertake such an investment. The $150,000 minimum "front-end" risk cost represents a nominal $150 per resident. Such a risk would normally not be born by a municipality or a nonprofit or regulated utility. Risks of that type might be undertaken by private industry, which would, however, expect 30% or more return on a successful geothermal investment. Such a figure, if added to the other costs for geothermal energy, make it economically unattractive with respect to the other, nominally conventional, types of space heating energy. Only when geothermal energy sources are better understood and the "front-end" risk reduced can one expect industry to make a lower return on successful investments.

3. ASSOCIATED HEATING EQUIPMENT COSTS

The geothermal heat supply system represents only a part of the total system costs. The individual home or building units to distribute the heat within the living space have cost summaries given as follows. The following lists the approximate installed costs for both geothermal and heat pump systems operating on city water, and compares these with gas or oil furnaces.

3.1 Building-Located Heating Systems

1. 50,000 Btu/hr capacity, single homes

a.	4 ton heat pump, with forced air system	$3,700
b.	70,000 Btu/hr gas furnace with forced air system	2,300

c.	70,000 Btu/hr oil furnace with forced air system	$2,500
d.	50,000 Btu/hr geothermal heat exchanger with forced air system	1,900

2. Commercial Building, 1,600,000 Btu/hr net

a.	Heat pump, with forced air	$115,000
b.	Gas fired boiler with forced air	90,000
c.	Geothermal forced air	77,000

An option similar to a central geothermal system, but utilizing conventional fuels should also be considered.

3.2 Central Heating Plant

1. Central heating plant, 50 million Btu/hr net, sufficient to supply total needs through to 1985.

a.	Heat pump - electric motor driven	$1,600,000
b.	Oil Fired Boiler	700,000
c.	Coal fired boiler without stack cleanup*	1,200,000

4. COAL AND WOOD WASTE FUEL FOR TOTAL CENTRAL HEATING AND/OR GEOTHERMAL PEAKING

For a central heat plant, coal, and wood (waste or general bio-mass) represent the most viable conventional fuels to consider. Both are abundant and relatively inexpensive, and available from sources within 150 miles. Both should have long term prices based more on conventional supply and demand economics for non-scarce materials, as opposed to gas and oil which threaten to become scarce in the near future.

Wood waste, in the newly designed burners, combusts cleanly and efficiently. Air pollution is generally tolerable even without stack gas scrubbers. That is not, generally, true of the locally available coals.

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* Stack gas cleanup capital costs (extra) cannot be specified until the exact environmental conditions are known and the quality of coal to be purchased is ascertained.

Wood waste represents an interesting option. Targhee National Forest has a present tremendous stockpile of wood waste, and a steady rate of natural production of about 100,000 tons/year. This is 20 times the heating needs of Sugar City. Such wastes are now being processed into easily burned pellet fuel to economically fire boilers elsewhere in the Northwest.*

The use of wood or coal in a central heating system has several institutional and planning advantages. At half the cost of natural gas, it is economically attractive even when the cost of the distribution system is considered. If a geothermal resource is found, the central heating plant would be retained as a peaking unit, at very attractive cost compared to gas, oil, or heat pump peaking.

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* Further information may be obtained on use of Targhee Forest Wastes by contacting the Targhee National Forest Supervisor, George Olsen, St. Anthony, Idaho.

V. CONCLUSIONS AND RECOMMENDATIONS

Though it appears that geothermal energy is an economically attractive space heating method, there is no certainty that a geothermal resource can be found close enough to Sugar City to be economical. It should be noted, however, that from available data, there appears to be a better chance of finding it near Rexburg. Shallow drilling into faults for a cost of typically $30,000 per well is the most attractive of the two drilling alternatives. The other is deep drilling, directly underneath the Sugar City area, to at least a 3,000 ft depth. Such wells typically cost $200,000 each, and there is no guarantee of finding a resource, particularly on the first attempt.

Therefore, the following recommendations are made for consideration in the immediate future. No commitment is implied at this time that this laboratory necessarily could or would be permitted to act on any of these recommendations. The Washington Office of Division of Geothermal Energy of the Energy Research and Development Administration (ERDA) has recommended, however, that an interagency panel give further consideration to the recommendations from this report.

1. Additional well data from the area near Sugar City on depths and temperatures should be gathered. This may involve downhole temperature logging of some wells. The present data is sketchy. Many records are incomplete on the older wells.

2. Geochemical reservoir temperature analysis be conducted on several dozen of these wells.

3. The owners of rebuilt homes and businesses in Sugar City be encouraged to use a forced air heating system, easily adaptable to a variety of heating sources--geothermal, heat pump, central boilers, electric, oil, or gas.

4. The water and sewer piping in Sugar City be sized to handle ordinary domestic water flows for a heat pump system (nominally seven gallons per minute per home on the coldest of days).

5. Coal and wood as a fuel for a central fired boiler receive further study for its long term economics, even as a supplement to peak a geothermal system on the coldest days.

6. The boosting of the temperature heat extracted from well water by use of heat pumps should be considered as a practical, energy conserving method free of pollution in the local area. This method could be employed on any well water that is not quite warm enough to be used directly for geothermal heating.

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