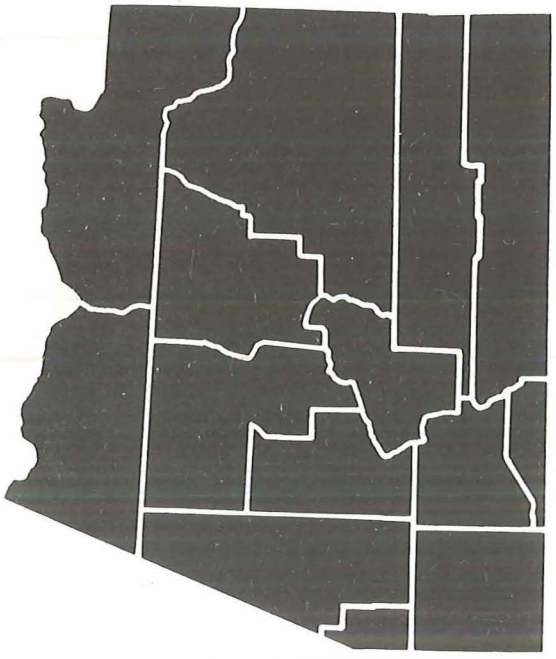

Hydrothermal Commercialization Baseline

for State of Arizona

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ACKNOWLEDGEMENTS

A number of people from EG&G Idaho and the Earth Science Laboratory of the University of Utah Research Institute contributed to this document. Input was also provided by Western Energy Planners Ltd., Stafco Inc., and G. A. Freund (consultant). The contributing state-team people for Arizona are Dr. Frank Mancini P.E., of the Arizona Solar Energy Research Commission, Don White of the Chemical Engineering Department at the University of Arizona, and W. Richard Hahman, Sr., CPG, Claudia Stone, Nile Jones, Bill Weibel, and James C. Witcher of the Arizona Bureau of Geology and Mineral Technology.

1. INTRODUCTION

Little drilling has been done for hydrothermal resources in Arizona. Until recently, Arizona has had little hydrothermal exploration and development activity. However numerous anomalously warm ($T > 30°C$) springs and wells are located in the southern half of the state, some of them near large population centers.

This handbook provides a synopsis of various aspects of the geothermal program in Arizona. The section on Basic State Data lists government personnel (both legislative and executive branches) most directly involved with geothermal development. Some basic demographic data are also included. The various hydrothermal resources and the pertinent geology are summarized in Section 3. Activities (ranging from leases to operational systems) which lead to commercialization are described in Section 4. Plans for various developments are summarized in Section 5, while government assistance to Arizona projects is listed in Section 6. The section on energy use patterns summarizes existing energy use and projects in which of Arizona's counties and industries geothermal energy is likely to have the most impact. The section on leasing and permitting policies deals with legal and institutional considerations and includes a time table of institutional procedures for a typical resource to show the interrelationships between various organizations involved in development and regulation of the resource.

2. BASIC STATE DATA (ARIZONA)

A. Government Contacts

Governor - Bruce Babbitt (D).

Legislature

Senate Natural Resources Committee: Boyd Tenney (D), Chairman.

Senate President ProTem: Leo Corbet (D).

House Natural Resources Committee: Bill Lewis (D), Chairman.

Speaker of the House: Frank Kelly (D).

State Geothermal Team

Operations Research: Dr. Frank Mancini, P.E., Arizona Solar Energy Research Commission; W. Richard Hahman Sr., CPG, Bureau of Geology and Mineral Technology, University of Arizona; Don H. White, Department of Chemical Engineering University of Arizona.

Resource Assessment: W. Richard Hahman Sr., Claudia Stone, Nile Jones, William L. Weibel, James C. Witcher, Arizona Bureau of Geology and Mineral Technology.

State Agencies

Oil and Gas Conservation Commission: W. C. "Bill" Allen, Acting Executive Secretary.

State Land Department: John M. Little, Acting State Land Commissioner.

Arizona Solar Energy Research Commission: James F. Warnock Jr., Executive Director; Dr. Frank Mancini, P.E., Associate Director.

Water Commission: Wesley Steiner, Executive Director.

B. Statistical Data

Demographic

Population (1976 estimate): 2,266,789

Area: 113,909 sq. mi.

Population Density: 19.9 people/sq. mi.

Geothermal Resources

Confirmed Reservoirs > 150°C: None

Prospects > 150°C: Five

Confirmed Reservoirs - 20°C < T < 150°C: None

Prospects - 20°C < T < 150°C: $\sim$ 20

Identified Warm Springs & Wells > 40°C: $\sim$ 40

Geothermal Leases

Federal: 18,341 acres

State: 1,844 acres

Private: None

Test Wells: < 10

Operational Hydrothermal Systems

Spas: Three

Space Heating: None

Others: None

Major Active Developments

Direct Use: None

Electric: None

Government Assisted Activities

PON: None

PRDA: None

Loan Guaranties: None

Energy

Supply (1975): 670 x 10^{12} Btu; 9% Exported; 73% Imported.

Use (1975): 600 x 10^{12} Btu.

Potential Conversion to Geothermal (1975): 52 x 10^{12} Btu.

3. HYDROTHERMAL RESOURCES

A. Geologic Setting[1]

Two geologic provinces are recognized in Arizona: the Basin and Range province and the Colorado Plateau province (see Figure 3.1). Southern, western, and extreme northwestern Arizona are located in the Basin and Range province. It consists of northward- or northwestward-trending mountain blocks separated by flat, alluvial-filled intermontane basins that have a valley floor elevation of 300 to 800 meters. The mountains generally have been uplifted by range-front faulting relative to the basins. Valley areas are typically underlain by several thousand meters of consolidated to relatively unconsolidated sediments from erosion of the mountain blocks. Rocks exposed in the mountains include intrusive, extrusive metamorphic, and sedimentary types that are typically folded and faulted, and range in age from Precambrian to Recent.

Northern Arizona is in the Colorado Plateau province. The flat-lying sedimentary rocks of this area form plateaus having typical elevations of 1,700 meters above mean sea level. Lack of geologic complexity indicates that the plateau has been relatively stable in the recent geologic past, although the plateau margins have been active.

Although no areas of fumarolic or geyser activity are known to exist, several areas of basaltic and rhyolitic volcanism are less than 3 million years old. Four of these areas occur in the Basin and Range province: (1) in the San Bernardino valley at the extreme southeast, (2) in an area about 50 kilometers southeast of Safford, (3) in an area 30 kilometers west of Gila Bend, and (4) in the Pinacate lava field 100 kilometers southeast of Yuma. Three areas of young basaltic volcanism occur in the Colorado Plateau: (1) near Springerville in the east-central part of the state, (2) near Flagstaff, and (3) in the extreme northwest.

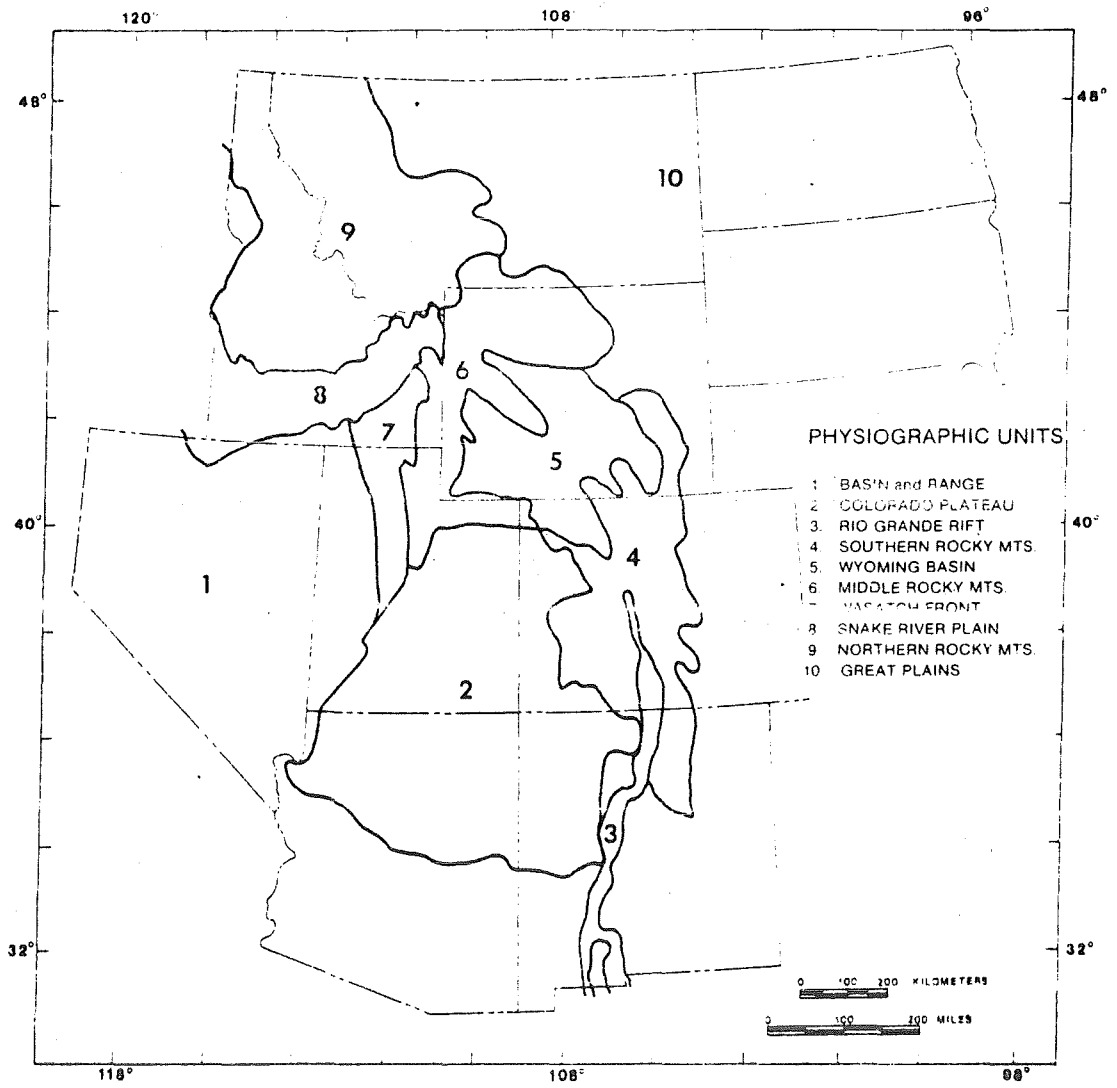

Fig. 3.1 Physiographic Provinces[1]

B. High Temperature Resources (> 150°C)[1,2,3] (see Figure 3.2)

Confirmed Reservoirs: None
Prospects: Chandler (Power Ranch Wells), San Bernardino Valley, Clifton-Morenci, Springerville-St. Johns, Hyder Valley.

C. Low- and Moderate-Temperature Resources (< 150°C)[1,2,3] (see Figure 3.2)

Confirmed Reservoirs: None.

Prospects: Near Phoenix, Tucson, and Safford; Castle Hot Springs, Florence, San Bernardino Valley, Clifton-Morenci, Springerville-St. Johns, Kingman, Wilcox, Yuma, Hyder Valley.

D. Comments

High-Temperature Resources: Little drilling has been done expressly for hydrothermal resources in Arizona, and only four deep holes have resulted since 1973 (see Table 4.6).

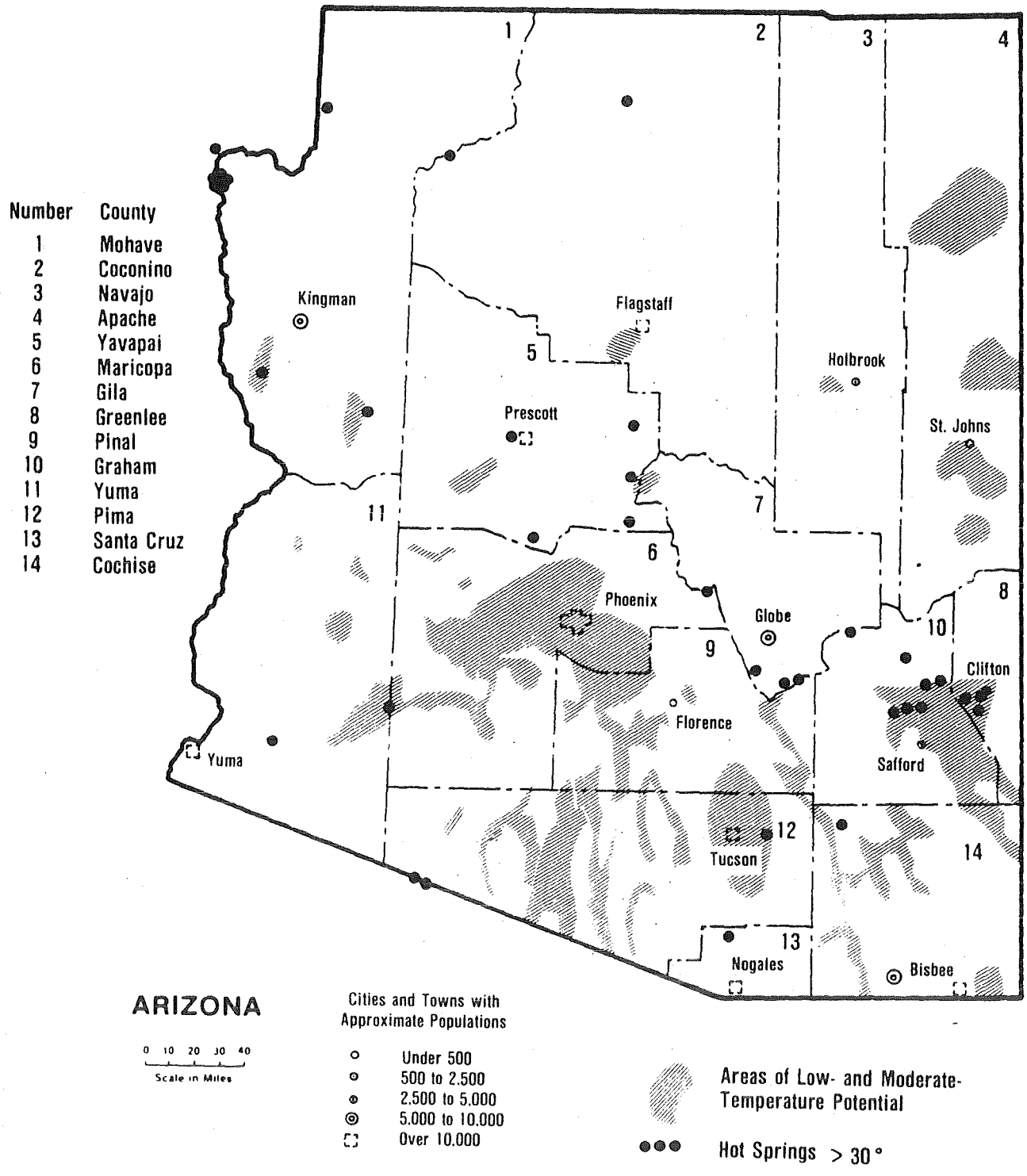

Fig. 3.2 Arizona counties and geothermal springs and resource areas[4]

In numerous wells water at unusually high temperatures (generally less than 100°C) has been encountered. Most of these wells have been drilled in the basin areas. To date no systematic hydrothermal prospecting has been done in any area of recent volcanism. A number of locations are known to have anomalously high geothermal gradients and/or heat flow. Geochemical thermometers indicate anomalously high subsurface temperatures throughout the state. Until recently it had been thought that Arizona has little hydrothermal potential, but recent data compilation and exploration work indicate otherwise. It now appears that one or more reservoirs hot enough for electrical power generation will probably be discovered, especially if generation from 150°C water becomes economical.

Low- and Moderate-Temperature Resources: Numerous anomalously warm springs and wells ($T > 40°C$) are located in Arizona (see Table 3.1). They occur mainly in the Basin and Range province. Data on water-well temperatures are currently being compiled, and additional warm wells are being measured for the first time. In the Basin and Range portion of Arizona, deep circulation in the many range-front and basin faults can be expected. Water with temperatures from 30 to 90°C at depths from 0 to 500 meters should be discovered in many portions of the Basin and Range; hotter water could be found at greater depths. The alluvial valley fill material could form large and productive aquifers for these deeper resources. In the Colorado Plateau portions of Arizona, potential for discovery is greatest in areas of recent volcanism.

E. Hydrothermal Springs and Wells

A listing of hydrothermal springs and wells with measured temperatures in excess of 40°C is given in Table 3.1 for Arizona[5].

TABLE 3.1

HYDROTHERMAL SPRINGS AND WELLS - ARIZONA
(Source: USGS File GEOTHERM)

(W) Well
(S) Surface

COUNTY, NAME AND TYPE	LOCATION	TEMP °C	FLOW L/min	TOTAL DISSOLVED SOLIDS, ppm
COCHISE				
(S)	T13S, R21E	51.5	800	
San Simon (W)	T13S, R30E	134.0		
Well Domestic (W)	T13S, R30E	41.7		
Well for Agricultural Use (W)	T13S, R24E	47.7		
Well for Agricultural Use (W)	T12S, R23E	54.4		
Well Irrigation (W)	T13S, R24E	40.5		
GRAHAM				
(S)	T5S, R24E	48.0	1000	
(S)	T7S, R25E	42.0		
Well (W)	T7S, R27E	46.1		
Well Irrigation (W)	T8S, R26E	42.2		
Artesian Hot Well (W)	T8S, R26E	44.0		1248
Collins Health Spa (W)	T8S, R26E	41.5		1992
Hot Pumped Well (W)	T10S, R28E	41.1		960
Indian Hot Spring (S)	T5S, R24E	46.5		3004
Indian Hot Spring (S)	T5S, R24E	47.0		2672
Lebanon Mineral Bath (W)	T8S, R26E	41.5		2256
Lucats Health Spa (W)	T8S, R26E	42.0		1152
Mr. Graham Mineral Bath (W)	T6S, R25E	43.5		8292
Hot Pumped Well (W)	T7S, R27E	43.5		1076

TABLE 3.1 (contd)

COUNTY, NAME AND TYPE	LOCATION	TEMP °C	FLOW L/min	TOTAL DISSOLVED SOLIDS, ppm
GREENLEE				
Gillard Hot Springs (S)	T5S, R29E	82.0		1244
Hanna Hot Springs (S)	T1N, R31E	55.5		677
Hot Spring N. of Clifton (S)	T4S, R30E	44.0		
Hot Spring N. of Clifton (S)	T4S, R30E	61.0		7205
Spring (S)	T4S, R30E	48.0		1454
Spring (S)	T4S, R28E	42.0		676
MARICOPA				
Buckhorn Mineral Bath (W)	T1N, R6E	48.5		740
Hot Pumped Well (W)	T1N, R2W	44.0		1040
Power Ranch Well (W)	T2S, R6E	120.0		
Power Ranch Well (W)	T2S, R6E	185.0		
MOHAVE				
Hoover Dam Hot Spring (S)	T22S, R65E*	42.2		1040
PIMA				
Tucson South (W)	T16S, R5E			
Well Domestic Use (W)	T16S, R14E	40.6		
Well on Papago Indian Res. (W)	T19S, R1E	43.7		
Well on Papago Indian Res. (W)	T19S, R1E	47.0		327
Well on Papago Indian Res. (W)	T19S, R1E	46.0	7571	417

* Nevada Coordinates.

TABLE 3.1 (contd)

COUNTY, NAME AND TYPE	LOCATION	TEMP °C	FLOW L/min	TOTAL DISSOLVED SOLIDS, ppm
PINAL				
Hot Pumped Well (W)	T5S, R7E	41.1		552
Hot Pumped Well (W)	T5S, R7E	55.6		1172
Hot Pumped Well (W)	T5S, R8E	56.8		744
Hot Pumped Well (W)	T4S, R7E	49.5		572
Hot Pumped Well (W)	T6S, R7E	61.0		924
La Planta (W)	T7S, R8E	113		
Picacho (W)	T8S, R8E	116		
Well Domestic (W)	T6S, R6E	46.1		
Well Irrigation (W)	T6S, R7E	61.7		
Well Irrigation (W)	T5S, R7E	46.1		
Pumped Well (W)	T2N, R7W	49.4		612
Pumped Well (W)	T2N, R9W	40.0		544
YAVAPAI				
Surface (S)	T8N, R1W	46.0		1200
YUMA				
Radium Springs Well (W)	T8S, R18W	50.0		2240
Pumped Hot Well (W)	T5S, R10W	45.8		696
San Louis (W)	T11S, R24W	138.0		

F. References

[1] Regional Hydrothermal Commercialization Plan, Department of Energy-Division of Geothermal Energy and Idaho Operations Office, EG&G, Idaho Inc. and the University of Utah Research Institute Earth Science Laboratory.

[2] Dr. P. M. Wright, Utah University Research Institute Earth Science Laboratory, Personal Communication, April 1979.

[3] L. J. P. Muffler, Ed., Assessment of Geothermal Resources of the United States - 1978, Geological Survey Circular 790, 1979.

[4] W. R. Hahman, Sr., C. Stone, J. C. Witcher, Preliminary Map, Geothermal Energy Resources of Arizona, Geothermal Map No. 1, February 1978.

[5] U.S.G.S. File GEOTHERM as of March 1979.

4. COMMERCIALIZATION ACTIVITIES

A. Highlights

Due to a state leasing moratorium during 1975-1979, very little land leasing and test drilling has been done thus far in Arizona.

The state geothermal team has identified more than forty springs yielding anomalously warm water.

B. Leases

Very little geothermal leasing has been done in Arizona, either on federal or state lands. Tables 4.1 - 4.5 and Figure 4.1 summarize the current status of leasing activity in the state. Table 4.1 provides latest totals of Federal and State acreages leased to private organizations for geothermal development.

For federal lands in Arizona, Figure 4.1 is a synopsis of various leasing summaries produced by Automatic Data Processing (ADP) of USGS' Conservation Division. It traces the three types of federal leases (noncompetitive, competitive, and Indian Land) from inception to production. For noncompetitive leases it summarizes: (1) applications, (2) withdrawals, (3) rejections, (4) pending actions, (5) total leases, (6) terminations, (7) active leases, (8) production status and, (9) unitization. For competitive leases the figure summarizes the lease offerings and the same items (5) - (9) as for the noncompetitive leases. For Indian land leases, it shows the same items (5) - (9). Table 4.2 is a county-by-county listing of the holders of active noncompetitive Federal leases, the size and location of holdings.

Table 4.3 summarizes by KGRA the bidding history of Federal competitive geothermal lease sales in Arizona. It lists the KGRA, the county, number of sale dates, number of tracts and acreage offered, number of offerings culminating in leases, acreage leased, and average cost per acre in successful bids.

Table 4.4 is a county-by-county listing of the holders of active competitive Federal leases, the size and location of their holdings, the effective date and cost per acre of the lease.

Table 4.5 lists the holders of active state leases in Arizona and the size of their holdings.

TABLE 4.1

TOTAL ACREAGES OF GEOTHERMAL LEASES - ARIZONA
(As of May 1979)

Federal Leases:	
Total Acreages of Competitive Leases in KGRA's:	NONE
Total Acreages of Non-competitive Leases: (Eleven leases)	18,341
State Leases:	
Total Acreages of State Leases: (Three leases)	1,844
TOTAL OF ALL ACREAGES LEASED	20,186

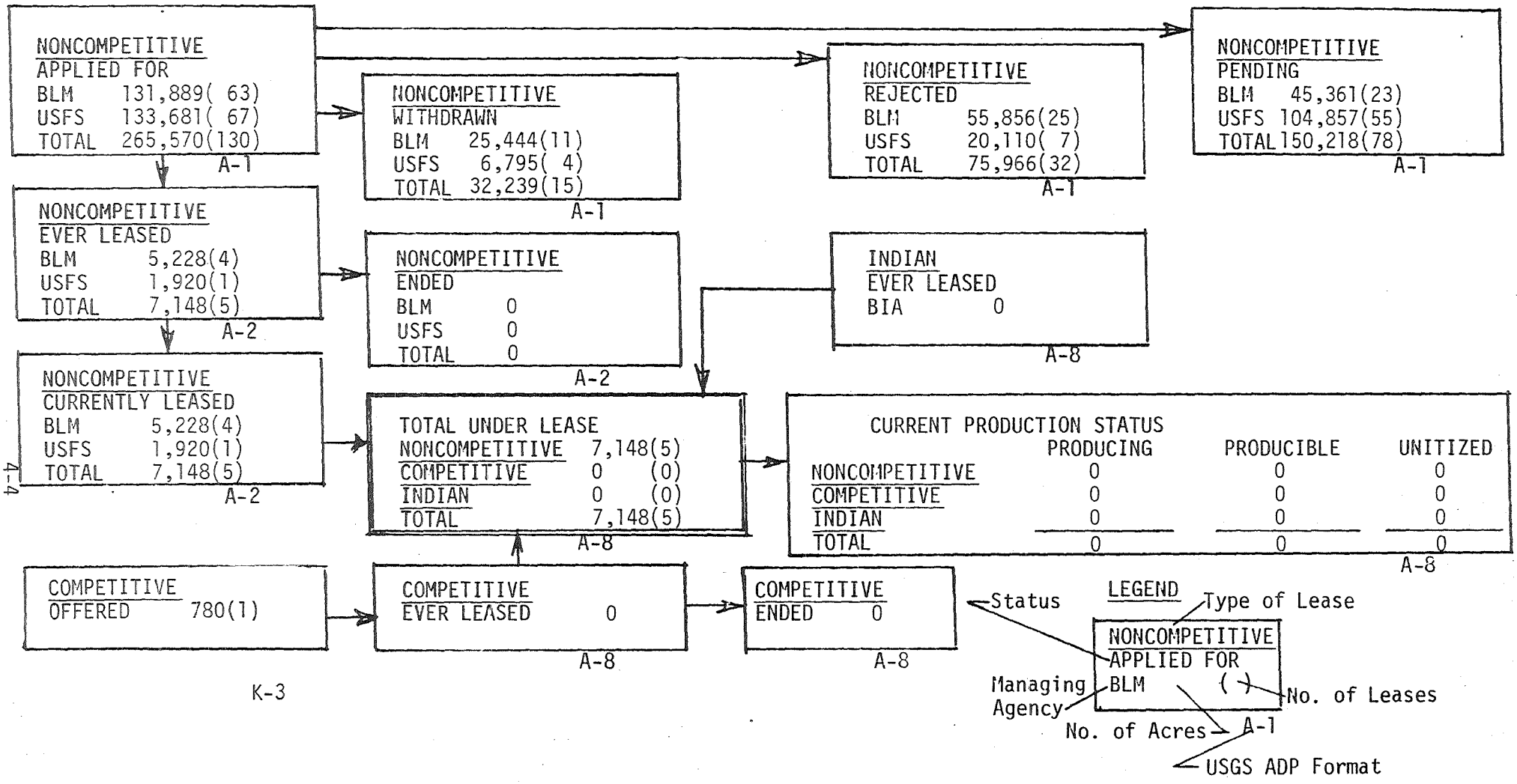

Figure 4.1. Summary of Federal Leasing Activity - Arizona

(Source - USGS ADP File)[1]
(as of March 1979)

TABLE 4.2

FEDERAL ACTIVE NON-COMPETITIVE GEOTHERMAL LEASES - ARIZONA

(Source USGS ADP File - Format A-7)

(as of 5/1/79)[2]

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION	DATE ISSUED
GREENLEE			
Phillips Petroleum	6,507.77(4)	T4 & 5S, R29 & 30E	
MARICOPA			
M. Albrecht	1,746.32(1)	T4N, R5W	4/1/79
G. Smith et al	640.00(1)	T5N, R6W	
G. Smith et al	9,447.32(5)	T4 & 5N, R5 & 6W	4/1/79

TABLE 4.3

SUMMARY OF BIDDING HISTORY FOR COMPETITIVE GEOTHERMAL LEASE SALES ON FEDERAL LANDS - ARIZONA
(Source: USGS ADP File - Format K-4)

COUNTY	KGRA	OFFERED SALES	(INC. REOFFERS) TRACTS	ACREAGE	LEASES ISSUED NUMBER	ACREAGE	AVG. $/ ACRE
Greenlee	Clifton	1	1	780	0	0	N. A.
TOTAL		1	1	780	0	0	---

TABLE 4.4

FEDERAL ACTIVE COMPETITIVE GEOTHERMAL LEASES - ARIZONA
(Source: USGS ADP File - Format K-1)
(as of 12/22/78)

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	KGRA/LOCATION	DATE ISSUED & (COST/ACRE)
NONE AT THIS TIME			

TABLE 4.5

STATE LEASES - ARIZONA[2]

(as of 5/1/79)

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	KGRA/LOCATION	DATE ISSUED & (COST/ACRE)
MARICOPA			
Dixel Resources	641.92(1)	T5S, R10W	4/79 ($3.00)
G. Smith et al	1,202.44(2)	T4 & 5N, R6W	4/79 ($1.50)

C. Test Wells

Test wells in Arizona are listed in Table 4.6.

TABLE 4.6

TEST WELLS - ARIZONA

COUNTY & LOCATION	COMMENTS
MARICOPA	
Sec. 1, T2S, R6E (Power Ranch)	Geothermal Kinetics Systems, January to April 1975.
Sec. 1, T2S, R6E (Power Ranch)	Geothermal Kinetics Systems, May to August 1973.
PINAL	
Sec. 8, T7S, R8E	AMAX drilled one hole in 1974.
Sec. 16, T5S, R24E	Nix Drilling Co. drilled one hole between April 1974 and late 1977.

D. Other Exploratory Activity

Other exploratory activity in Arizona for geothermal resources is given in Table 4.7.

TABLE 4.7

OTHER EXPLORATORY ACTIVITY - ARIZONA

COUNTY & LOCATION	COMMENTS
GRAHAM	
Safford Area	Arizona Bureau of Geology and Mineral Technology-Resistivity survey in progress, 5/1/79
GREENLEE	
Clifton Area	USGS mapping.
MOHAVE	
Kingman District	USGS filed, BLM approved three 400 ft heat flow holes February 1978; two more approved March 1978.
	Cyprus Georesearch, status unknown.
MOHAVE & YAVAPAI	
Kingman; SW of Bagdad	Cyprus Georesearch performing electrical resistivity, seismic refactions, 10 ft heat-flow holes. Status unknown.
VARIOUS	
Basin & Range	USGS is drilling 49(?) 400 ft deep heat-flow holes.
Statewide	N. M. Bureau of Mines and Mineral Resources - thermal gradient and heat flow programs.
	Arizona Bureau of Geology and Mineral Technology - thermal gradient determinations, geologic field work, and geochemical sampling (both water and mercury soil samples).
	Los Alamos Scientific Laboratory - magneto-tellurics (wide-spaced) and geologic fieldwork.

TABLE 4.7 (contd)

COUNTY & LOCATION	COMMENTS
San Bernardino Valley, Clifton, Springerville - St. Johns	Univ. of Texas at El Paso, New Mexico State Univ., Univ. of Arizona completed field work summer 1978. Electrical resistivity, active and passive seismics.
Transition Zone and B&R	USGS shallow heat-flow holes in progress.

E. Operational Systems

Table 4.8 provides a summary of operational systems using geothermal energy in Arizona.

F. References

[1] USGS Conservation Division, Office of Geothermal Supervisor, Automatic Data Processing File.

[2] W. Richard Hahman, Sr., and W. L. Weibel, Arizona Bureau of Geology and Mineral Technology, Personal Communication, May 1979.

[3] A. K. Doss, Arizona State Land Department, Personal Communication, March 1979.

TABLE 4.8

OPERATIONAL SYSTEMS - ARIZONA[2,3]

COUNTY	LOCATION	COMMENTS
COCHISE		
Resort	Hooker Hot Springs	Formerly a health spa; presently owned by private non-commercial entity.
GRAHAM		
Resorts	Safford	Several hot baths
PINAL		
Resorts	Buckhorn Hot Springs	Several hot baths
YAVAPAI		
Resorts	Castle Hot Springs	Formerly a hotel resort; under development by Arizona State University for conference center.

5. DEVELOPMENT PLANS

A. Description

The State of Arizona through the Arizona Solar Energy Research Commission has participated since June 1977 in the DOE operations research geothermal planning project[1-3]. One major objective of this DOE/State geothermal planning process has been to generate specific plans for prospective development and commercialization of geothermal energy from now through the year 2020.

The present planning process for Arizona and other states in the Rocky Mountain/Basin and Range Region consists of three categories of plans for prospective and actual geothermal developments. The three are called Area Development Plans (ADP), Site Specific Development Plans (SSDP), and Time Phased Project Plans (TPPP).

Area Development Plans are plans for prospective development of geothermal resources and utilization of the geothermal energy in a multi-county sub-state area. The plan encompasses several geothermal resource sites and all potential residential, commercial, industrial and agricultural uses of geothermal energy. The resource sites for an ADP include confirmed (proven) reservoirs and reservoir prospects (potential and inferred resources). In most cases no private sector action has been taken toward development or commercialization. The time table for an ADP is a best guess of when increments of geothermal energy will come on line from the several geothermal prospects and applications in the plan area.

Site Specific Development Plans are plans for development of specific geothermal single or integrated applications of the geothermal energy. The plans are restricted to confirmed (proven) reservoirs and potential reservoirs. Applications may be for any electric and/or direct thermal use of geothermal

energy which is compatible with the quality of the confirmed (proven) or potential resource. In most cases, either some level of development or commercialization activity is already underway or is deserving of consideration by the community of geothermal energy developers and users. The time schedule of events in a SSDP represents a possible sequence of technological and institutional achievements under an atmosphere generally favorable for geothermal development of the specific site and application.

Time Phased Project Plans are plans for geothermal developments that are now at a commercialization level of activity or are in advanced stages of planning by the public and private sectors. The plans are confined to site-specific confirmed reservoirs or high potential geothermal prospects and to specific energy consumptive applications, either electric or direct thermal. The TPPP portrays or reproduces as closely as possible the actual planning and construction array of events and the associated time schedule of the commercial developer and user of the geothermal energy. The TPPP reveals actions by both the private and government sectors that must be accomplished on time in order to achieve successful geothermal energy production and utilization of a specific site for a committed application.

Table 5.1 identifies for Arizona the geothermal resource sites and applications for which development plans have been prepared or which are candidates (designated by asterisk) for the preparation of development plans by the State Planning Teams in 1979.

TABLE 5.1

DEVELOPMENT PLANS - ARIZONA

TIME PHASED PROJECT PLANS	SITE SPECIFIC DEVELOPMENT PLANS	AREA DEVEL-OPMENT PLANS
None	Safford (Electric power)	San Bernardino Valley*
	Chandler (Electric power)	Graham County*
	Chandler (Space heating)*	
	Tucson (Space heating)*	
	Phoenix Area (Space or district heating & cooling)*	
	Yuma (Salt production, desalinization)*	
	San Manuel - Globe - Morenci Copper Belt (Copper solution mining)*	
	Morenci (Copper dump leaching)*	
	Hyder (Integrated citrus processing, peak electrical power, desalinization)*	
	Springerville-St. Johns-Alpine (Upgrade of water quality, preheat boiler water for power plant, coal washing, electrical power)*	
	Clifton (Electrical power)*	

* Candidates for preparation of development plans in 1979.

B. References

[1] Regional Operations Research Program for Development of Geothermal Energy in the Southwest United States, New Mexico Energy Institute Report, ALO/3992-1, January 1979.

[2] R. T. Meyer & R. Davidson, Summary Report - Southwest Regional Geothermal Operations Research Program, June 1977 - August 1978, Western Energy Planners Ltd Report GP-01-79, December 1978.

[3] W. R. Hahman Sr., et al (ed), Potential of Geothermal Energy in Arizona, Appendix F to the Report NMEI 10, New Mexico Energy Institute, August 1978.

6. GOVERNMENT ASSISTED ACTIVITIES

A. Geothermal Direct Use PON Program

Background: In September 1977 and April 1978, the Department of Energy (DOE), Division of Geothermal Energy, in conjunction with the San Francisco Operations Office, issued a document which indicated DOE's desire to receive and consider for partial support proposals for direct heat utilization or combined electric/direct heat utilization field experiments demonstrating single or multiple usages of geothermal energy. These documents were issued under the title, "Program Opportunity Notice - Direct Utilization of Geothermal Energy Resources - Field Experiments". The Program Opportunity Notice (PON) is the name of this offering document, but it has become common practice to call any program which results from these notices a PON.

These solicitations are part of DOE's national geothermal energy program plan, which has as its goal the near-term commercialization by the private sector of hydrothermal resources for direct use purposes. Encouragement is being given to the private sector by DOE cost sharing a significant portion of the front-end financial risk in a limited number of field experiments.

DOE's primary interest under these PONs is to encourage field experiments in space/water heating and cooling for residential and commercial buildings, agricultural and aquacultural uses, and industrial processing application.

Current Status: No activity so far in Arizona.

B. Program Research and Development Announcement

Background: This program, commonly referred to as the PRDA program, is to provide funding for engineering and economic studies for direct applications of geothermal energy. The last announcement had a closing date for applications of January 16, 1979. Studies are up to $125,000 each, and cover a study period of six to twelve months.

Current Status: No activity so far in Arizona.

C. Demonstration Projects and Experiments

No projects so far in Arizona.

D. Geothermal Loan Guaranty Program (GLGP)

Background: Congress authorized $300,000,000 for loan guaranties. Each loan can be up to 75% of the total development cost. Nationally, DOE has received eleven applications to date, totalling $150,000,000 in loan guaranties. Of those eleven, three have been approved (two electric and one direct application); two turned down; one withdrawn; one is obtaining more information, and four are in the review process.

Current Status: In Arizona, there has been no activity on this program.

E. National Conference of State Legislatures (NCSL)

Background: After a preliminary study on geothermal energy in 1976, the National Conference of State Legislatures (NCSL) launched the Geothermal Policy Project in January 1978. The objective of the project is to stimulate and assist the review

of state policies that affect the development of geothermal resources. Successful completion of the project is to facilitate state statutory and regulatory environments that are consistent with efficient development of geothermal resources.

Current Status: The project selected six states in which to concentrate its efforts in 1978. Arizona is not one of these states so there has been no activity in the state on this project.

F. State Coupled Program

Background: The objectives of the State Coupled Program are: (1) to assist the U. S. Geological Survey in its ongoing geothermal resource assessment effort, and (2) to stimulate confirmation of low- and intermediate-temperature reservoirs at sites with an apparent but unquantified potential for direct heat application development. Major energy companies have generally shown little interest in lower grade resources because of a national and industrial focus on electrical power generation.

The State Coupled Program consists of cooperative effort among: (1) DOE, (2) an agency or institution in each state, (3) the U.S. Geological Survey, (4) the National Atmospheric and Oceanic Administration (NOAA), and (5) the Earth Science Laboratory of the University of Utah Research Institute. DOE provides overall program management and direction. The State Agency manages and performs the project within the state. The U.S. Geological Survey interfaces with the program through the local Water Resources Division Offices, through the U.S. Geological Survey Geothermal Program Office, and by providing the use of computer file GEOTHERM. NOAA will publish the state map. The Earth Science Laboratory provides management assistance to DOE. For Arizona, the Los Alamos Scientific Laboratory provides management assistance to DOE.

In order to accomplish this work contracts are written between DOE and each participating state. A separate contract for overall management assistance and program coordination is negotiated between DOE and the University of Utah/University of Utah Research Institute.

Each state project consists of: (1) Phase I, geothermal data compilation, with emphasis on low- and intermediate-temperature systems, culminating in publication of state maps and reports on the location and possible viability of geothermal resources, and (2) Phase II, investigation of specific geothermal sites, with drilling to demonstrate reservoir characteristics.

Current Status: The Arizona state geothermal team is conducting the DOE funded State Coupled Program. It submitted 91 records from thermal springs and wells to the USGS for inclusion in GEOTHERM. With supplemental location information to be submitted for some sites, these records will be complete. The Arizona team, in coordination with ESL/UURI and the USGS, was able to identify 20 areas suitable for depiction on the Circular 790 map and inclusion in the Circular 790 tables.

Resource data compilation is continuing as part of Phase I activities. A preliminary map of "Geothermal Energy Resources of Arizona" was distributed by the Bureau of Geology and Mineral Technology in March 1978. Updating of this map is continuing as new information becomes available. Publication of new maps for public and scientific uses, on a revised USGS base map, is slated for late 1979 or early 1980. Phase I data compiled under the program so far includes:

(1) thermal gradients from water wells in southern Arizona
(2) geochemical thermometry on most springs and many wells
(3) microearthquake data from selected areas
(4) existing and new heat flow data
(5) lineaments
(6) gravity, and
(7) thermal gradients in wells at Springerville and on the Papago reservation.

Phase I assessment work has pointed out an apparent correlation between thermal areas in this part of the Basin and Range physiographic province and deep (>400 m) sedimentary basins. This correlation is being studied in more detail and may form part of the exploration strategy, especially for low- and moderate-temperature resources.

Twenty-two sites have been identified where Phase II assessment work might be appropriate. Work is planned on reservoir definition tasks for the Castle Hot Springs site on the Papago reservation. Other important sites are Springerville-St. John, Clifton, and San Bernardino. Also the Arizona team will be assisting with geothermal exploration at Williams AFB.

The Arizona team is also doing a geothermal program in the state for the U. S. Bureau of Reclamation. This program is looking for higher temperature resources for desalinization purposes.

G. Industry Coupled Program

Background: The purpose of DOE's Industry Coupled Program is to foster a viable geothermal electrical power generation industry in the United States. Development by industry has been seriously lagging due to a number of problems. Front end costs are high in geothermal development due to leasing costs, regulatory costs, and the high cost of exploration, particularly for drilling. In addition, geothermal electrical power generation is a high-risk venture given the uncertainties of reservoir longevity. As a result of these factors, industry has made only a limited commitment to the development of high-temperature resources.

The Industry Coupled Program addresses some of the above problems through: (1) cost sharing with industry for exploration, reservoir assessment and reservoir confirmation, (2) release

to the public of geoscience data which will improve our understanding of the geothermal resource. Improved understanding will decrease reservoir uncertainty and lower exploration and assessment costs.

The Program is a cooperative effort between DOE and an industrial organization engaged in geothermal exploration. Industry responds with proposals to DOE procurement initiatives. Succcessful proposers then negotiate contracts with DOE. The contracts specify: (1) an exploration and/or reservoir confirmation program which industry will manage and perform, (2) a data package which industry agrees to make public, and (3) a certain percentage of total costs (generally in the range of 20% to 50%) which DOE will contribute toward funding the work.

The Earth Science Laboratory of the University of Utah Research Institute provides assistance to DOE on the Industry Coupled Program by: (1) assisting in management of the Program, (2) releasing geoscience data generated by the program to public open file, and (3) interpreting and supplementing the above data for the purpose of developing and publishing reservoir case studies.

Current Status: In Arizona, there has been no activity on this program.

H. Technical Assistance

Background: Technical assistance is provided to potential geothermal users as an on-call service by EG&G Idaho's geothermal program Office and by the Earth Sciences Laboratory of UURI. The strategy of this program is to provide a catalytic agent in fostering geothermal energy use, particularly for direct applications. The amount of assistance given is limited so as to protect the interest of private engineering organizations and others working in the field. Generally, enough information

is provided so that a potential user can make an evaluation of how or where to proceed. The technical assistance activity is extensive: 115 separate requests were handled for the ten-state Rocky Mountain Basin and Range Region during the first half of FY-79.

Current Status: Information has been supplied to interested investors, business men, and government entities. An electronics firm in Phoenix has made an initial program cost estimate to provide cooling for over 167,000 square feet of space.

Assistance is being given to Williams Air Force Base for laying out a program for reservoir assessment and heating/cooling possibilities. Adjacent to the base, two existing wells drilled to an approximate depth of 9 - 10,000 feet show temperatures in excess of 300°F. Assistance activities are centered upon the development of a program plan in cooperation with the State of Arizona, Bureau of Geology and Mineral Technology, University of Utah Research Institute, and the engineering staff at Williams AFB. The base purchases approximately 1-1/2 million dollars per year of electricity and natural gas to provide their requirements mostly for space conditioning and lighting.

I. State Assisted Programs

None

J. References

None

7. ENERGY USE PATTERNS

A. Energy Use Summary - Arizona[1,2]

One of the most significant factors in Arizona's pattern of energy consumption and supply is the large portion of the net energy Arizona must import (Figure 7.1). Transportation is the largest energy-consuming sector in Arizona; the industrial sector is the second largest followed by the residential and commercial sectors. Natural gas, almost all of which is imported, is the major source of energy used in the residential, commercial, and industrial sectors of Arizona's economy. Figure 7.2 is a map that approximates the amount of energy used by communities throughout the state.

The primary metals industries consume about 50% of the industrial energy needs; however, industries making food and kindred products, lumber and wood products, chemicals and allied products, and stone, clay and glass products account for about 25% of the industrial energy consumption. Growing industries should require an additional 88.2 trillion BTUs by 1985. Arizona's energy use is shown in Figure 7.1.

Due to the wide range of climates in Arizona, air conditioning is as necessary as space heating. The larger population centers are located in the warmer sections of the state, and air conditioning uses more energy than space heating. Space-conditioning requirements amount to approximately 50% of the residential and commercial sectors' energy needs.

The state's population is expected to increase from 2.2 million in 1975 to 3.4 million in 1985, indicating a large increase in all sectors of energy demand. The increase in residential and commercial energy demands from 1975 to 1985 is projected to be 320 trillion BTUs. Figure 7.3 shows the energy-demand projection for the state. As the figure indicates, Arizona's energy-demand should more than double by the end of this century.

Arizona 1975

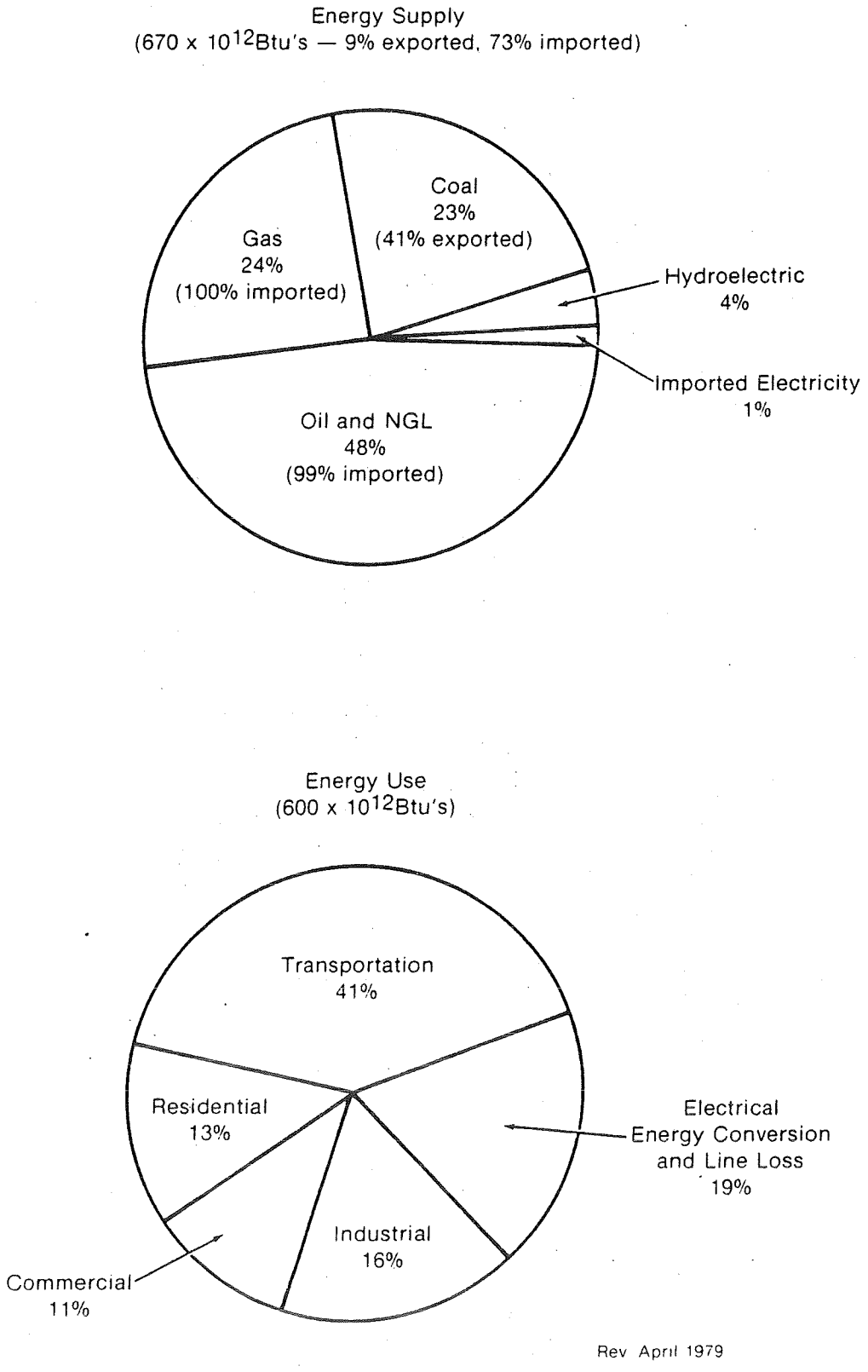

Fig. 7.1 Arizona energy supply and use[1]

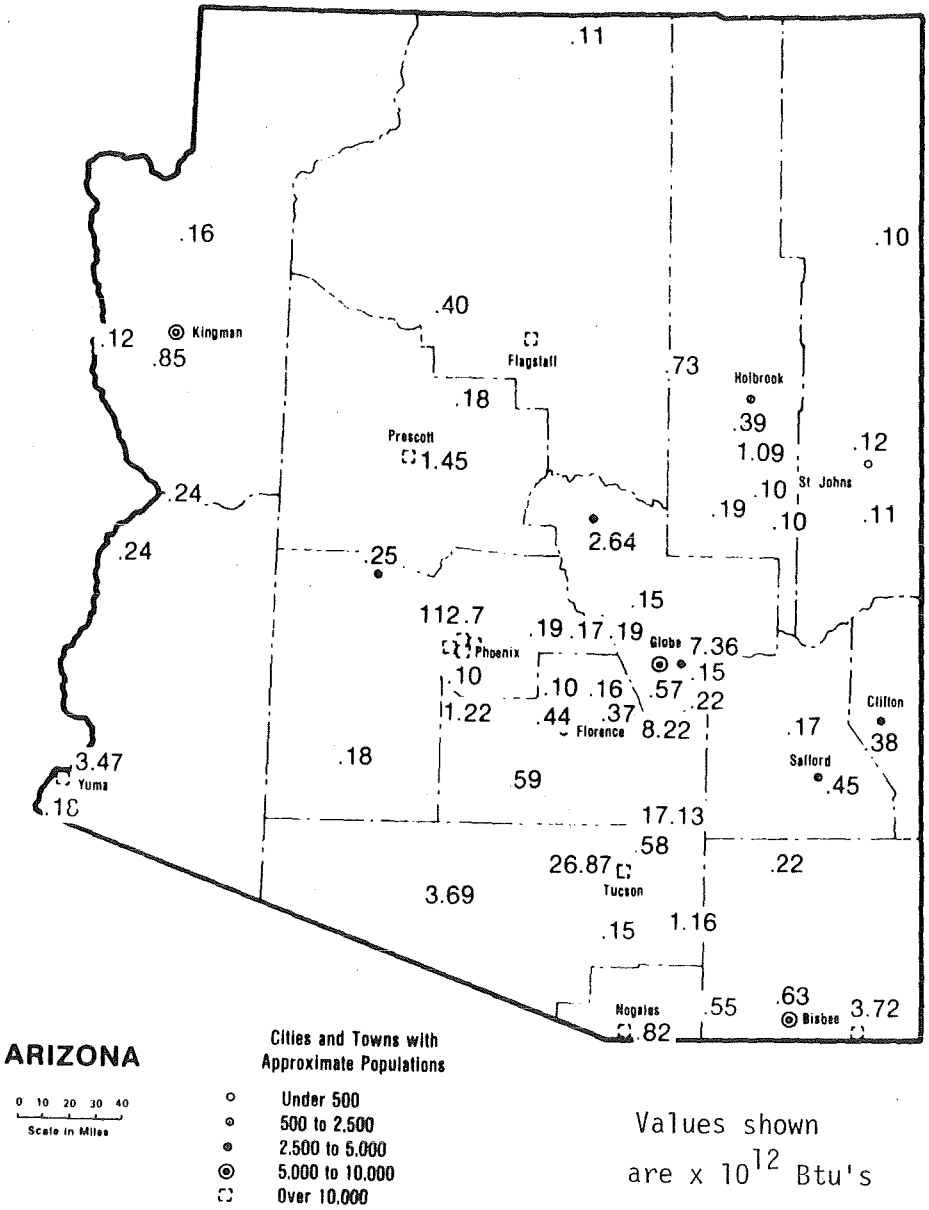

Fig. 7.2 Arizona energy usage map[1]

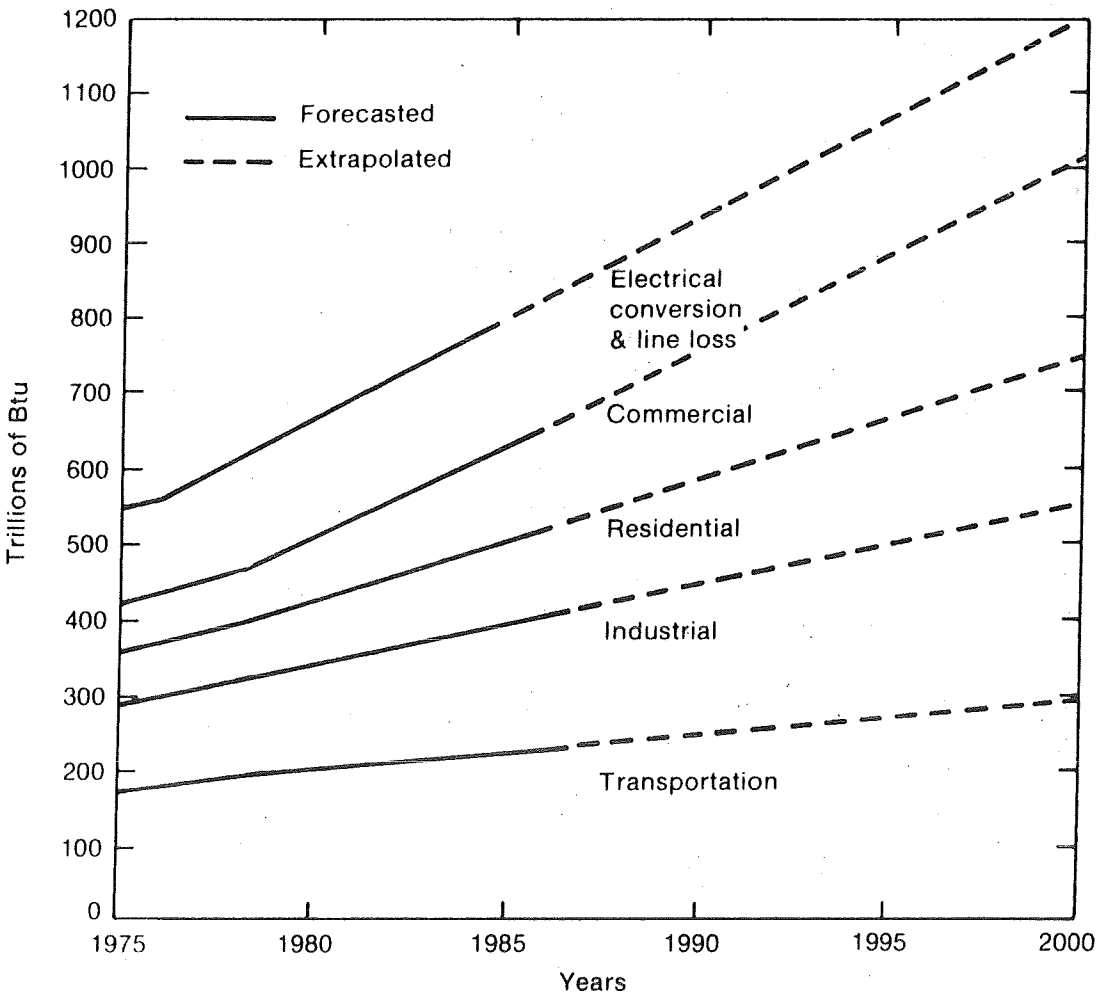

Fig. 7.3 Arizona total energy use projection[1]

Counties overlying hydrothermal resources (Figure 3.2) have been assessed to determine how many manufacturers could use the available hydrothermal energy in their industrial processes. Average resource temperatures are estimated for these counties. A list of potential hydrothermal use industries is compiled from the manufacturer's directory for the state. The number of employees per manufacturer is taken to be the midpoint of the employee range listed for the manufacturer. Each Standard Industrial Classification (SIC) category is aggregated within the county. A BTU use value for each manufacturer was determined by employing energy intensity coefficients (BTU/employee). Industrial, as well as residential/commercial, data for each such county is given in Table 7.1. These data show the potential for conversion to hydrothermal energy based on 1975 usage in these counties.

Table 7.2 lists the industry, the SIC number, and the percent of the process heat used in various temperature ranges from 40°C to 275°C. By use of this temperature breakdown, industries are considered as candidates for hydrothermal energy applications, even if their total energy requirements cannot be met by hydrothermal energy.

B. References

[1] Regional Hydrothermal Commercialization Plan, Department of Energy Division of Geothermal Energy and Idaho Operations Office, EG&G Idaho, Inc., and University of Utah Research Institute Earth Science Laboratory, July 14, 1978.

[2] Draft Regional Hydrothermal Market Penetration Analysis, Appendix B, EG&G Idaho, Inc., and Utah University Research Institute Earth Science Laboratory, October 31, 1978.

TABLE 7.1

1975 ARIZONA ENERGY USE BY COUNTY

County	Assumed Maximum Reservoir Temperature (°C)	INDUSTRIAL		RESIDENTIAL/COMMERCIAL	
		Standard Industrial Code (SIC)	Energy Use ($Btu/yr \times 10^{12}$)	Total Energy Used ($Btu/yr \times 10^{12}$)	Energy Used For Space Conditioning And Water Heating ($Btu/yr \times 10^{12}$)
APACHE	90°	3273	0.002	0.1	0.05
COCHISE	76°	2011	0.003		
		3273	0.002		
		Subtotal	0.005	.19	0.10
CONCONINO	90°	2026	0.010		
		2034	0.105		
		3273	0.025		
		Subtotal	0.135	1.97	0.98
GRAHAM	86°	No match		0.38	0.19
MARICOPA	177°	2011	0.525		
		2016	0.105		
		2021	0.135		
		2026	0.305		
		2034	0.340		
		2048	1.075		
		2074	0.280		
		2075	0.070		
		2077	0.015		
		2086	0.540		
		2421	0.605		
		2435	0.155		
		2511	0.035		
		2819	0.090		
		2821	0.560		
		2834	0.195		
		2841	0.210		
		2842	0.020		
		3271	2.000		
		3273	1.305		
		Subtotal	8.565	59.80	29.90

TABLE 7.1 (CONT'D)

1975 ARIZONA ENERGY USE BY COUNTY

County	Assumed Maximum Reservoir Temperature (°C)	INDUSTRIAL		RESIDENTIAL/COMMERCIAL	
		Standard Industrial Code (SIC)	Energy Use ($Btu/yr \times 10^{12}$)	Total Energy Used ($Btu/yr \times 10^{12}$)	Energy Used For Space Conditioning And Water Heating ($Btu/yr \times 10^{12}$)
PINAL	78°	No match		0.33	0.16
PIMA	64°	2011	0.015		
		2013	0.015		
		2022	0.135		
		2086	0.185		
		2511	0.100		
		3271	0.470		
		3273	0.367		
		Subtotal	1.287	20.30	10.15
STATE TOTAL			9.994		41.53

TABLE 7.2

INDUSTRIAL PROCESS HEAT REQUIREMENTS - ARIZONA

INDUSTRY	SIC Number	40°C-60°C	60°C-80°C	80°C-100°C	100°C-120°C	120°C-140°C	140°C-160°C	160°C-180°C	180°C - 200°C	200°C	275°C
Meat packing	2011	NA	99%	100%							
Prepared meats	2013	NA	46.2%	61.5%	100%						
Poultry dressing	2016	100%									
Creamery butter	2021										
Natural Cheese	2022	23%	100%								
Fluid milk	2026	NA	NA	100%							
Dehydrated fruits and vegetables	2034	NA	100%								
Potato dehydration	2034										
granules		NA	19.9%		53%					100%	
flakes		NA	19.9%		53%				100%		
Prepared feeds	2048										
pellet conditioning		NA	NA	100%							
Alfalfa drying		NA	NA	NA	NA	NA	NA	NA	NA	100%	
Cotton seed mills	2074										
Soybean oil mills	2075	NA	24.7%	26.5%	73.4%			100%			
Animal and marine fats	2077	NA	NA	NA	NA	NA	NA	NA	100%		
Soft Drinks	2086	60.9%	100%								
Sawmills and planing mills	2421	NA	NA	NA	NA	NA	100%				

TABLE 7.2 (contd)

INDUSTRY	SIC Number	40°C-60°C	60°C-80°C	80°C-100°C	100°C-120°C	120°C-140°C	140°C-160°C	160°C-180°C	180°C – 200°C	200°C	275°C
Plywood drying	2435	NA	NA	NA	NA	100%					
Wooden furniture	2511	60%	100%								
Alumina	2819	NA	NA	NA	NA	76.2%					100%
Plastic materials	2821	NA	NA	51.0%	100%						
Pharmaceutical	2834	NA	0.3%			100%					
Soaps	2841	NA	NA	0.6%						100%	
Detergents	2841	NA	NA	52.2%				99.9%		100%	
Specialty cleaning products	2842										
Concrete block	3271										
low pressure		NA	100%								
autoclaving		NA	NA	NA	NA	NA	NA	NA	100%		
Ready mix	3273	100%									

8. LEASING AND PERMITTING POLICIES

A. General

Three agencies in Arizona state government include geothermal development as part of their responsibility.

The Oil and Gas Conservation Commission regulates the development of oil, natural gas, and geothermal resources within the state and serves as technical consultant to resource developers throughout the state. As provided by law, "The Commission shall so supervise the drilling, operation, maintenance and abandonment of geothermal resource wells as to encourage the greatest ultimate economic recovery of geothermal resources, to prevent damage to and waste from underground geothermal reservoirs, to prevent damage to or contamination of any waters of the state or any formation productive or potentially productive of fossil fuels or helium gas, and to prevent the discharge of any fluids or gases or disposition of substances harmful to the environment by reasons of drilling, operation, maintenance, or abandonment of geothermal resource wells." (A.R.S. 27-652).

The Oil and Gas Conservation Commission consists of six members of which five are appointed by the Governor with Senate consent. The State Land Commissioner serves as an ex-officio member. The terms for appointed members are five years.

The Arizona Solar Energy Research Commission (ASERC) collects, analyzes, and provides information and data relating to solar energy technology and other non-polluting renewable energy sources. ASERC cooperates with all federal agencies involved in solar and advanced energy (including geothermal) technologies development.

The Arizona Solar Energy Research Commission has seventeen members. At the present time the Commission is comprised of

the Chairman of the Arizona Power Authority, six representatives from Arizona's three state universities, eight representatives of the business and industrial sectors, and as ex-officio members, the President of the Arizona Senate and the Speaker of the House of Representatives. New legislation provides three-year terms.

The State Land Department is responsible for the planning, development and protection of all forests and natural resources located on state lands. In its administration of the 9.6 million acres of state trust lands (13% of land in Arizona) the Department, among other duties, is authorized to:

(1) Create long range plans for the exchange, lease, or the sale of state lands (A.R.S. 37-102);
(2) Exercise the power of eminent domain (A.R.S. 37-461);
(3) Officially represent the state in any matter between state and federal government concerning public lands (A.R.S. 37-102);
(4) Engage in many activities administratively relating to the control and supervision of the lands and waters of the state (A.R.S. 37-102, 37-132).

New legislation (Chapter 87, House Bill 2257, 33rd Legislature), adopted February 1977, provides for the exemption of geothermal resources from the ground-water laws of Arizona and for means of selling state geothermal leases by competitive bidding. Regulations pursuant to this law have been developed by the Department, were certified by the State Attorney General on March 6, 1979, and were released to the Office of the Secretary of the State on March 12, 1979: Geothermal Resource Rules R12-5-858 through 866. The head of the State Land Department, the State Land Commissioner, is appointed by the Governor.

None of the state regulations pertains to the leasing of private land for geothermal development. However, the Oil and Gas Conservation Commission supervises all "drilling, operation, maintenance and abandonment of geothermal resource wells". A proposed geothermal drilling operation must apply to the Oil and Gas Conservation Commission for a drilling permit. This requirement applies to State, Federal, Indian or private land. It is possible that both the Oil and Gas Commission and the State Land Department could be involved in the cooperative development of a geothermal resource pool.

Geothermal leases on State land can be initiated by either of two methods:

(1) the Land Department can designate likely resource areas that it wishes to lease, or

(2) an individual or company may apply for a lease on a given tract of State land.

Department review of the proposal then takes place. If it is satisfactory, a notice of availability for lease is then published for ten weeks in statewide newspapers and other publications.

When the time for receipt of competitive bids ends, the bids are opened, and the lease is awarded to the "highest and best bonus bid by a qualified applicant". (The State Land Commissioner reserves the right to reject any or all bids). The bonus bid is the excess bid above the standard rental of $1.00 per acre for the first year. Thereafter the annual rental is $1.00 per acre.

The awarded lease is then executed by all parties and the first year's rental paid. Finally the lease is issued to the lessee.

B. Time Table of Institutional Procedures

A generic time table, showing minimum times for various institutional procedures related to any geothermal project in Arizona, is given in Table 8.1.

C. References

[1] W. R. Hahman Sr., et al, ed., Potential of Geothermal Energy in Arizona, Annual Report for the Period June 12, 1977 - June 11, 1978. Appendix F to the Report NMEI 10, New Mexico Energy Institute, August 1978.

TABLE 8.1

TIME TABLE OF INSTITUTIONAL PROCEDURES FOR A GEOTHERMAL PROJECT - ARIZONA

To be prepared by State Team in FY-79.

9. BIBLIOGRAPHY SELECTED REFERENCES

This list of selected references is not yet a complete bibliography on geothermal energy in Utah. This objective will be sought in future updates of this baseline document.

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