GL01355

FIRST CUT ROUGH DRAFT

NATIONAL DIRECT HEAT APPLICATIONS INFRASTRUCTURE REQUIREMENTS TO 1987

PREPARED FOR
DEPARTMENT OF ENERGY
RESOURCE APPLICATIONS
GEOTHERMAL RESOURCE OFFICE

BY
EG&G IDAHO, INC.
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SALT LAKE CITY, UTAH

JUNE 13, 1979

PRELIMINARY DRAFT

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DIRECT HEAT APPLICATIONS INFRASTRUCTURE REQUIREMENTS TO 1987

A. GENERAL

The early commercialization of geothermal energy in the United States requires the development of an infrastructure. Federal goals of 0.1 to 0.2 quads of energy used for direct heat applications in 1985 can only be met with the development of an infrastructure of developers, financiers, designers, builders and operators. The purpose of this activity is to define, in a general sense, the capital expenditures required, and the manpower needed, to develop geothermal resources and construct or retrofit installations using geothermal energy.

B. APPROACH

The general approach to this effort is listed below:

1. Determine the quantity of first drill holes that will be needed.

2. Review and identify current geothermal direct application systems and prospects to determine the cost and power usage of these systems.

3. Review and identify new systems that are proposed, planned and in construction. Estimate the quantity and sizes of projects expected to be on line from now through fiscal year 1987.

4. Develop cost estimates and manpower needs for resource development, design, construction, piping, hardware and operational start-up. Average costs will be assigned to each project type to obtain total capital investment needs. Four major costing categories will be considered; (a) field development (geology, geophysics, drilling and testing), (b) project development (land, environmental, management, legal, financial), (c) design and construction, and (d) operations and maintenance.

5. Layout project time scales.

6. Chart various cost and manpower needs as a function of time.

7. First cut efforts will be generic. Later efforts should be worked into a state by state level.

8. Consider three generic systems. These are District Heating, Industrial Parks, and Single Industry.

9. Private and federally assisted projects will be shown separately, but both will be included in the totals.

C. ASSUMPTIONS

Certain assumptions have been made and are identified as follows:

1. The well drilling success ratio and the number of projects required is shown in Table I. This table includes only the first holes drilled, and does not include the additional drilling that will be required to provide adequate capacity for a given project.

TABLE I

FEDERALLY ASSISTED DRILLING SITE PROJECTS SUCCESS RATIOS

ITEM	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	TOTAL
Projects Initiated (%)	0	15	25	30	20	10	0	0	100%
Projects Initiated (No.)	0	99	165	198	132	66	0	0	660 ea.
Ave. Success Ratio	0	60	54	41	31	25	0	0	--
Number of Successes	0	59	89	81	41	16	0	0	286 ea.
Number of Failures	0	40	76	117	91	50	0	0	374 ea.
% Govt Share* Success/Failure	0	10/100	10/100	5/95	5/92	5/90	5/90	0	---

*Assumed ratio of the government's cost sharing with industry for successful/unsuccessful resource definition costs.

2. The number, size and type of facilities are shown in Table II.

TABLE II

ESTIMATED PROJECT SIZE AND TYPE DISTRIBUTION

SIZE	DISTRICT HEATING	INDUSTRIAL PARKS	SINGLE INDUSTRY	TOTAL UNITS
GOVERNMENT ASSISTED				
100 MWt	1	5	0	6
50 MWt	4	13	6	23
25 MWt	18	18	35	71
10 MWt	39	15	60	114
5 or less MWt	22	0	50	72
				286
PRIVATE				
100 MWt	0	1	1	2
50 MWt	2	4	1	7
25 MWt	2	4	7	13
10 MWt	7	5	21	33
5 or less MWt	46	0	69	115
				170

3. The average resource development and facility construction times are shown in Table III.

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TABLE III

AVERAGE PROJECT DEVELOPMENT TIME

ACTIVITY	TIME (YEARS)
Resource Development	1 to 2
District Heating	3[a]
Industrial Parks	3[a]
Single Industry > 25 MWt	3[a]
Single Industry 5 to 25 MWt	2[a]

[a] After the first well is proven.

4. The estimated manpower and cost requirements for the development of the geothermal first holes only covering the geoscience portion of reservoir confirmation, and the industry infrastructure needed through fiscal year 1985, are shown in Tables IV and V. The number of total drill holes required by industry is being developed and will be shown later.

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TABLE IV

RESERVOIR CONFIRMATION - GEOSCIENCE PORTION[1]
FIRST HOLE PROGRAM
($ Thousands)

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Surface Exploration	0	0	4830	9020	12,360	9160	4840
Gradient Hole Drilling	0	0	4940	9210	12,680	9350	4940
Production & Injection Well Drilling & Testing	0	0	18,970	34,680	44,630	32,450	17,200
Sub-totals	0	0	28,740	52,910	69,670	50,960	26,980
Industry Participation[2]	0	0	32,000	58,000	76,000	55,000	29,000
TOTALS			$60,740	110,910	145,670	105,960	55,980

[1] Resource identification, special projects and management costs are not included. These costs are being developed, and the total resource costs will be reflected later. These costs are only for the first holes drilled, and are based on Table I.

[2] These are approximate amounts that industry will spend in conjunction with the first hole program. Refinement of these amounts will be made in the future.

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TABLE V

INDUSTRY INFRASTRUCTURE MANPOWER & EQUIPMENT
FIRST HOLE PROGRAM

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Geologists	0	10	50	100	130	100	60
Geochemists		5	25	50	65	50	30
Geophysicists		5	25	50	65	50	30
Legal, Land, Environmental People	0	15	50	100	130	100	40
Drill Rigs & Crews							
Deep Production	0	0	12	46	60	43	23
Shallow Production			20	77	100	72	38
Deep Gradient			12	46	60	43	23
Shallow Gradient			10	39	50	36	19
Management		12	27	45	50	38	22
TOTALS		47	231	508	660	532	285

5. The average values shown in Table VI are in addition to resource development costs and are used to develop the infrastructure required for the projected facility installations shown in Table VII. The Regional Hydrothermal Market Penetration Analysis assumes a 25% retrofit rate, and projected costs are made on this basis. Costs and manpower projections are made for both the geothermal systems required for a plant ($300, 500 and $700 per kW), and for the geothermal system plus the plant ($2,000 per kW).

TABLE VI

AVERAGE PROJECT COSTS PER KW

PROJECT	COST $/kW
Single Industry	300
Single Industry - Total Facility	2000
Industrial Parks	500
District Heating	700

6. The current DOE funding level for FY 1980 and 1981 precludes (unless changes are caused to occur) extensive governmental assistance until FY 1982 and beyond. Project development will be estimated accordingly.

7. Assume that the private sector and other federally assisted programs will develop 0.05 quads while the first hole program is stimulating the development of 0.15 quads, between now and 1987.

D. WORK TO DATE

The following work has been performed to date:

1. The quantity of first drill holes has been estimated and a probable success ratio has been prepared.

2. Costs and power usage information has been compiled for most of the PON projects, and approximations of energy use have been made for systems identified in ten of the State Hydrothermal Commercialization Baseline Books. Estimated values for other known systems, in place or planned, have been included.

TABLE VII

PROJECTED FACILITY INSTALLATION BY NUMBER AND MWt SIZE

SIZE	MWt	No.	FY 80 a-b-c	FY 81 a-b-c	FY 82 a-b-c	FY 83 a-b-c	FY 84 a-b-c	FY 85 a-b-c	FY 86 a-b-c	FY 87 a-b-c
FIRST HOLE STIMULATED										
100 MWt	600	6						0-1-0	0-2-0	1-2-0
50 MWt	1150	23					0-0-1	1-2-1	1-5-2	2-6-2
25 MWt	1775	71					2-2-4	3-3-8	5-5-10	8-8-13
10 MWt	1140	114		2-1-3	3-2-5	10-4-10	10-4-15	7-2-15	4-1-7	3-1-5
<5 MWt	360	72	2-0-3	2-0-6	4-0-10	4-0-9	4-0-7	2-0-6	2-0-5	2-0-4
Subtotal - Units		286	5	14	24	37	49	51	49	57
Subtotal - Cumulative		286	5	19	43	80	129	180	229	286
Subtotal - MWt	5025		25	100	170	305	595	930	1255	1645
Subtotal - Cumulative	5025		25	125	295	600	1195	2125	3380	5025

a - District Heating; b - Industrial Parks; c - Single Industries; d - Currently Planned; e - Projected.

TABLE VII (contd)

SIZE	MWt	No.	FY 80 a-b-c	FY 81 a-b-c	FY 82 a-b-c	FY 83 a-b-c	FY 84 a-b-c	FY 85 a-b-c	FY 86 a-b-c	FY 87 a-b-c
OTHER		d-e								
100 MWt	200	0-2							0-1-0	0-1-0
50 MWt	350	1-6				1-0-0	0-0-0	0-1-0	0-1-1	1-2-0
25 MWt	325	1-12			0-1-0	0-0-0	0-0-1	1-1-2	1-1-2	0-1-2
10 MWt	330	3-30		0-0-1	2-0-1	1-1-2	1-1-4	1-1-4	1-1-4	1-1-5
<5 MWt	575	10-105	1-0-2	2-0-4	5-0-10	7-0-9	7-0-9	8-0-10	8-0-12	8-0-13
Subtotal - Units		170	3	7	19	21	23	29	33	35
Subtotal - Cumulative Units		170	3	10	29	50	73	102	135	170
Subtotal - MWt	1780		15	40	130	170	165	300	460	500
Subtotal - Cumulative MWt	1780		15	55	185	355	520	820	1280	1780

a - District Heating; b - Industrial Parks; c - Single Industries; d - Currently Planned; e - Projected.

TABLE VII (contd)

	MWt	No.	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
TOTAL - Units		456	8	21	43	58	72	80	82	92
TOTAL - Cumulative Units		456	8	29	72	130	202	282	364	456
TOTAL - MWt	6805		40	140	300	475	760	1230	1715	2145
TOTAL - Cumulative MWt	6805		40	180	480	955	1715	2945	4660	6805

a - District Heating; b - Industrial Parks; c - Single Industries; d - Currently Planned; e - Projected.

3. Types and quantities of new systems, private and government assisted, in generic form, have been identified, and scheduled through FY 1987. These are shown in Table VII. The projected direct applications power on-line for the first hole program and other development efforts through fiscal year 1987 are shown in Figure 1. The resource development costs for the first hole program are identified as to the source of payment; i.e., federal or private. However, the federal portion of the costs for facility development is not identified.

4. Average costs have been assumed for three generic systems, and labor and material costs have been apportioned. These values have been converted to equivalent manpower needs, and the number of people needed, by major categories, are identified through FY 1987. (PON information was primarily used as the data base to develop project breakdowns into design, construction, etc.) Table VIII shows the manpower requirements for the geothermal systems only whereas Table IX includes the geothermal systems and the plant. Figure 2 graphically displays this.

   The development of the manpower required, and the years in which they are required, assumes in general that design being done in a current year is for a project that will be operational three years later. The labor and material costs are split evenly over the years of design and construction. "Other" manpower costs are assumed to be mostly plant testing and operating and are considered to occur in the year the plant goes on line. Table X summarizes the yearly expenditures required for geothermal systems and indicates the year in which the expenditures will occur after start of design. Table XI includes the geothermaal systems costs and other plant costs. Figure 3 is a graph of these expenditures.

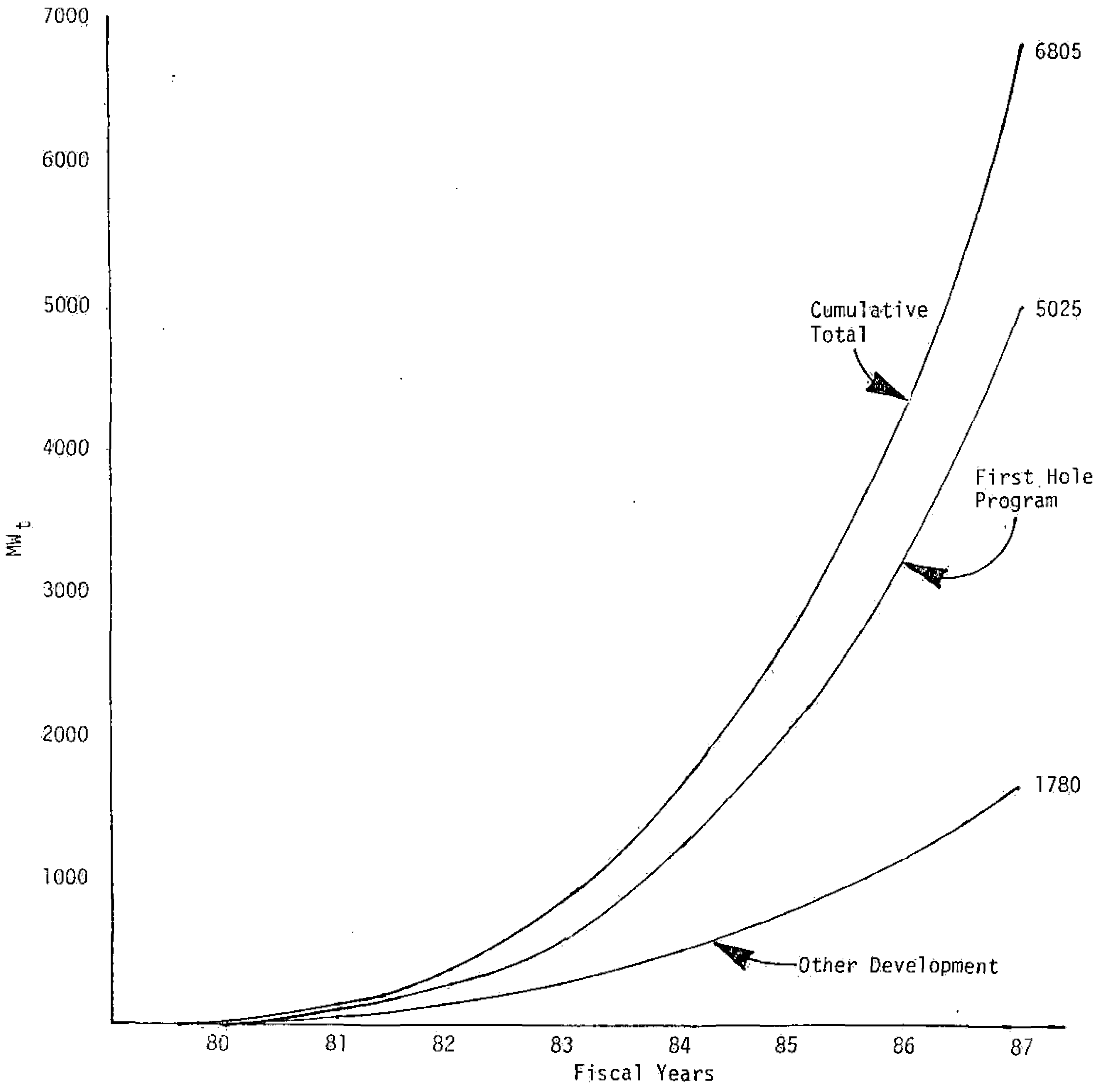


Fig. 1. Projected direct applications power on line

TABLE VIII

PROJECTED MANPOWER REQUIREMENTS THROUGH FY 1987 FOR FACILITY DEVELOPMENT[1]
GEOTHERMAL SYSTEMS ONLY
(Man Years)

Fiscal Year	Design	Labor	Admin.	Other	TOTALS
1980	530	610	160	20	1,320
1981	770	1,010	270	70	2,120
1982	1,240	1,590	430	150	3,410
1983	1,760	2,360	630	260	5,010
1984	2,190	3,250	860	390	6,690
1985	2,680	3,950	1,100	620	8,350
1986	3,150	4,460	1,330	860	9,800
1987	3,630	4,830	1,560	1,100	11,120

[1] These projections include geothermal systems, but do not include plant costs.

TABLE IX

PROJECTED MANPOWER REQUIREMENTS THROUGH FY 1987 FOR FACILITY DEVELOPMENT[1]
PLANT AND GEOTHERMAL SYSTEMS
(Man Years)

Fiscal Year	Design	Labor	Admin.	Other	TOTALS
1980	3,390	3,890	1,040	130	8,450
1981	4,900	6,390	1,700	450	13,440
1982	7,890	10,110	2,690	970	21,660
1983	11,140	14,950	3,990	1,690	31,770
1984	13,920	20,590	5,490	2,450	42,450
1985	17,000	25,060	6,980	3,940	52,980
1986	20,000	28,300	8,420	5,470	62,190
1987	23,000	30,600	9,900	6,960	70,460

[1] These projections include a 25% retrofit factor, and a total cost including the geothermal system and the plant cost.

PRELIMINARY DRAFT

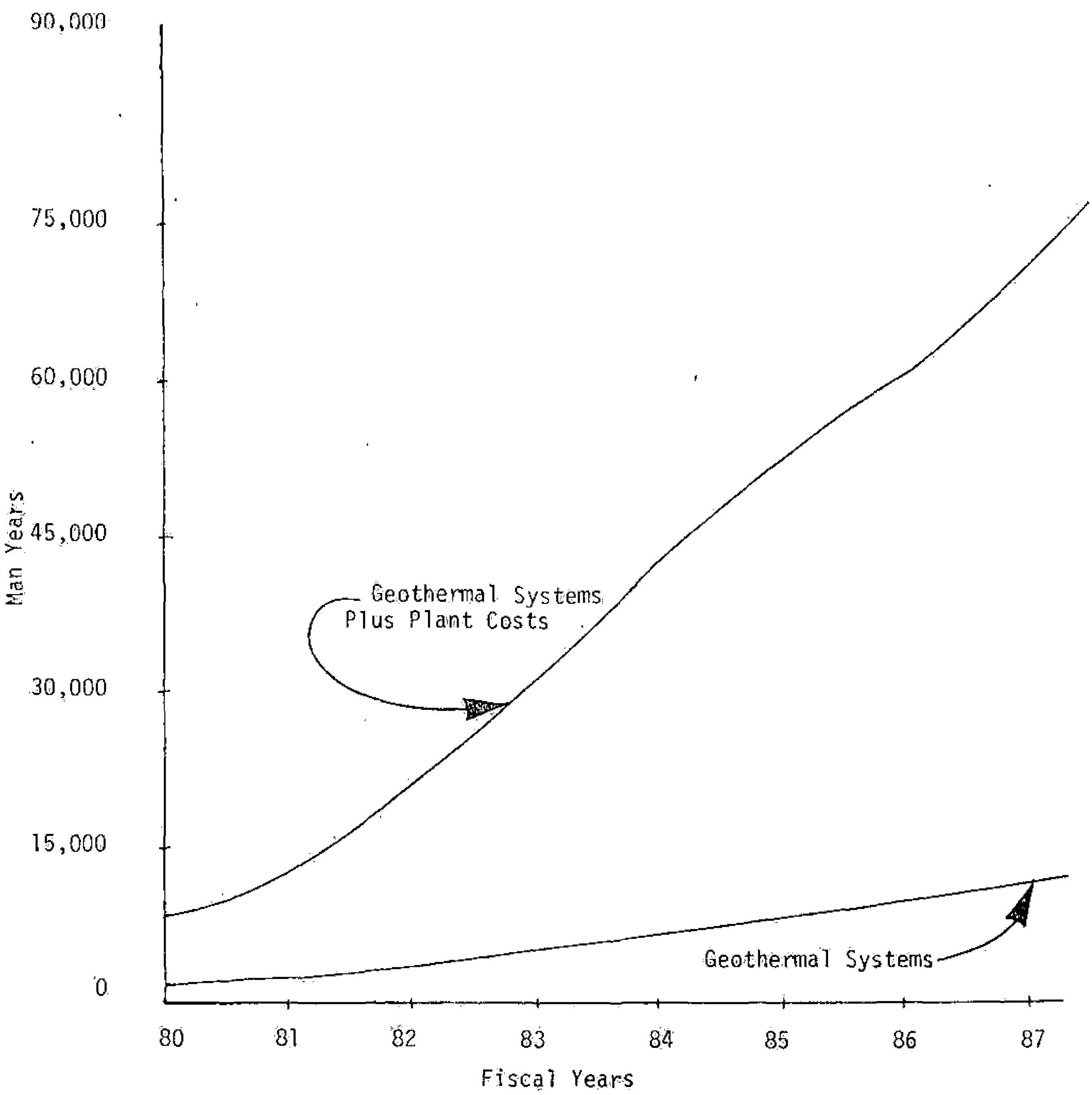


Fig. 2 Projected manpower requirement through FY 1987 for facility development.

PRELIMINARY DRAFT

TABLE X

PROJECTED EXPENDITURE REQUIREMENT THROUGH FY 1987 FOR FACILITY DEVELOPMENT [1]
GEOTHERMAL SYSTEMS ONLY
($ Million)

Fiscal Year	Design	Labor	Matl	Admin.	Other	TOTALS
1980	26	25	25	8	1	85
1981	40	40	40	13	3	136
1982	62	64	64	21	8	219
1983	88	94	94	32	13	321
1984	110	130	130	43	19	432
1985	118	165	165	57	31	536
1986	142	200	200	69	44	655
1987	165	237	237	82	55	776
					TOTAL	3,160

[1] These projections include geothermal systems, but do not include plant costs.

PRELIMINARY DRAFT

TABLE XI

PROJECTED EXPENDITURE REQUIREMENT THROUGH FY 1987 FOR FACILITY DEVELOPMENT[1]
PLANT AND GEOTHERMAL SYSTEMS
($ Million)

Fiscal Year	Design	Labor	Matl	Admin.	Other	TOTALS
1980	169	156	156	51	6	538
1981	256	256	256	85	22	864
1982	394	404	404	135	49	1,386
1983	557	598	598	200	85	2,038
1984	696	824	824	275	122	2,741
1985	750	1,047	1,047	359	197	3,400
1986	900	1,268	1,268	441	279	4,156
1987	1,050	1,500	1,500	525	348	4,923
					TOTAL	20,046

[1] These projections include a 25% retrofit factor, and a total cost including the geothermal system and the plant cost.

PRELIMINARY DRAFT

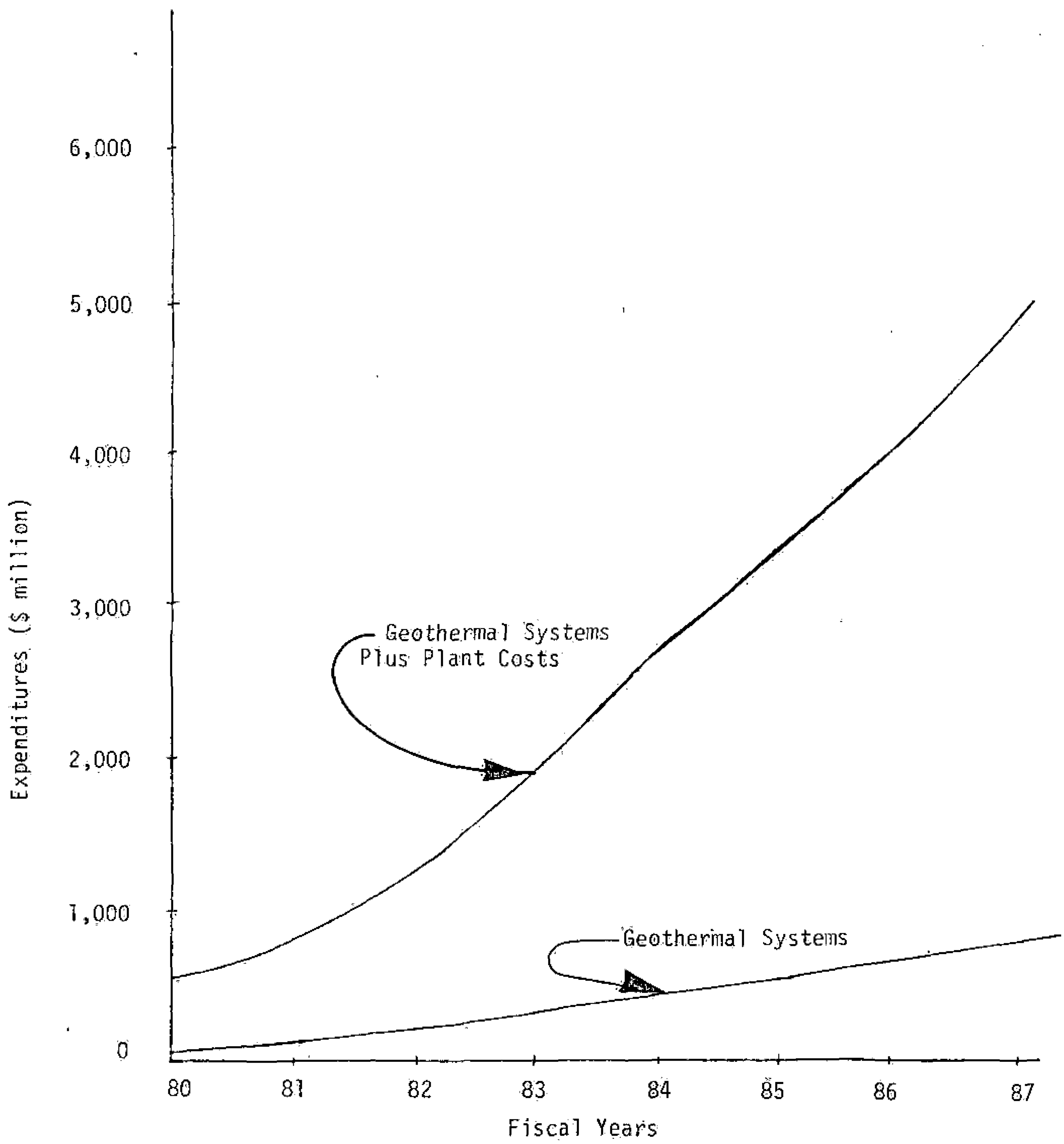


Fig. 3 Projected expenditure requirement through FY 1987 for facility development.

PRELIMINARY DRAFT

E. WORK PLANNED

The following will be performed to develop and refine the work done so far:

1. Develop cost estimates for resource field development, including industry participation.

2. Obtain more cost and manpower information about specific sites.

3. Look at new exploration environments.

4. Continue to refine the program requirements.

5. Continue investigation of the availability of drill rigs, and testing and logging crews. (It appears that geologists and geophysicists are available in adequate numbers within existing consultant and other firms.)

6. Resource development manpower and costs are only for the first hole program. Assess expenditures by industry to develop a resource site.

7. Develop cost estimates for average operating systems (exclusive of well development) of different types in order to obtain more refined costing data and a greater breakdown of manpower type requirements.

8. Determine the quantity of labor services, and materials that are a function of the infrastructure needed to cause early utilization of geothermal energy. Labor, material and other costs for facility development will be developed. These will include, but not be limited to; labor by crafts, basic material needs, financial structure, management needs, environmental factors, and legal and institutional considerations. In addition, unit costs and quantities will be developed for significant features.

9. Develop these data from a site specific location to a state level, thence to a national level, as more information becomes available.

10. Perform additional charting and analysis of the information (now compiled and to be developed).

11. Resource development costs shown include government and industry efforts for the first hole program. Develop other costs incurred by Industry.

Anticipated Results

~~Assuming~~ According to the information developed in Table 1 there will be 286 successful reservoir confirmations from a total of 660 projects initiated, for an overall success rate of 43 percent. If these 286 successes result in installations of the same size distribution as was shown on page —, then the power on line by FY87 (allowing 2 years for equipment installation after reservoir confirmation) will be as follows:

Utilization System Size	number	contribution
100 MWt	6	600 MWt
50	23	1150
25	71	1775
10	114	1140
5	72	360
	286	5025 MWt

This amount of power-on-line is equivalent to 0.15 Quads/yr, and corresponds to the projection of Line 5 to 1987.

~~5025 MWt ÷ 33,400 MWt/Q/yr = 0.15 Quads/yr.~~

A great deal of private capital, in addition to the DOE share must be invested in order to reach this level of utilization. Whereas the federal share of the reservoir confirmation program is $245 million, the private sector share (for successes in which the federal cost share is only 5-10 percent) would be about $262 million. In addition, assuming an average cost of $500 per kWt of installed

Assume	MWe/well	Ratio Prod/Inj	# Prod	# Inj	Total #
100 MWe	10	1:0.75	10	8	18
50	8	1:0.75	6	5	11
25	6	1:0.9	4	4	8
10	5	1:1	2	2	4
5	5	1:1	1	1	2

	# wells each	# sites	Total # wells	Cost/well ($) w/ Testing	Total cost
100 MWe	18	6	108	1,250K	135,000
50	11	23	253	750K	189,750
25	8	71	568	600 K	340,800
10	4	114	456	400 K	182,400
5	2	72	144	250 K	36,000
			1530		883,950

DIRECT HEAT RESERVOIR CONFIRMATION - blue

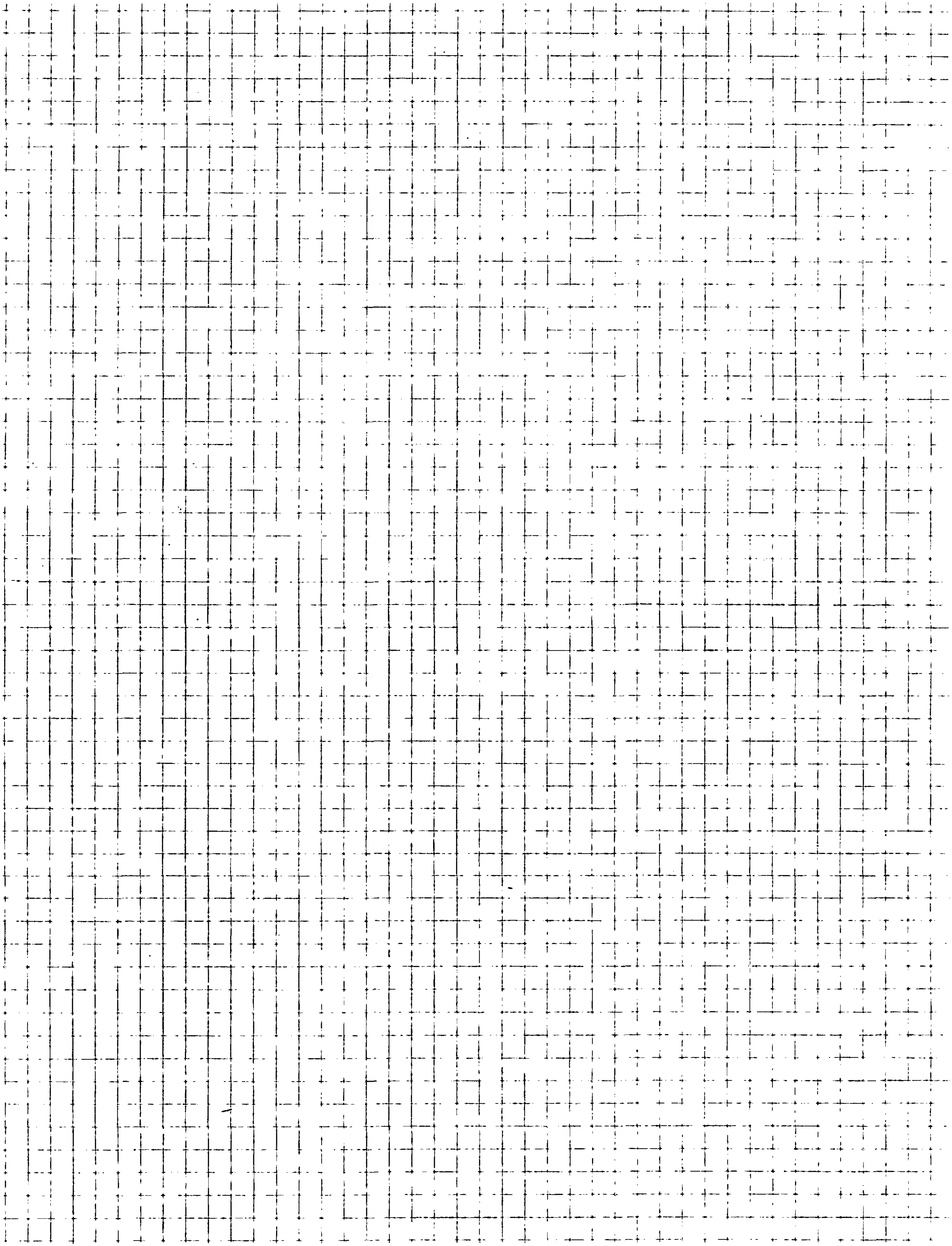
PRIVATE INVESTMENT - red

blue -	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	TOTAL
CONFIRMATION MANPOWER	32	127	245	310	238	142	30	0	1124
DRILL RIGS/CREWS	0	54	208	220	194	103	30	0	859
CONFIRMATION COSTS ($M)	0	31	65	75	51	26	7	0	255
DEVELOPMENT HOLES	0								
DEVELOPMENT MANPOWER	0	30	65	110	130	90	35	20	480
DRILL RIGS/CREWS	0	0	11	21	26	17	7	2	84
DEVELOPMENT COSTS ($M)	0	1	41	75	86	58	24	13	298

Wrong (bracketing the development rows)

UTILIZATION SYSTEM MANPOWER

UTILIZATION SYSTEM COSTS ($M)



FOR BEN LEWIS
EG&G, IDAHO

FROM MIKE WRIGHT
UURI

RESERVOIR CONFIRMATION - GEOSCIENCE PORTION

COSTS $K

	FY-79	FY-80	FY-81	FY-82	FY-83	FY-84	FY-85
Surface Exploration	0	0	4830	9020	12360	9160	4840
Gradient Hole Drilling	0	0	4940	9210	12680	9350	4940
Production & Injection well Drilling & Testing	0	0	18970	34680	44630	32450	17200

INDUSTRY INFRASTRUCTURE
MAN POWER & EQUIPMENT

(other than management)

Geologists,	0	10	50	100	130	100	60
Geochemists		5	25	50	65	50	30
Geophysicists		5	25	50	65	50	30
Legal, Land, Environmental People	0	15	50	100	130	100	40
Drill Rigs & Crews							
Deep Production	0	0	12	46	60	43	23
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The general approach to this effort is listed below:

1. Determine the quantity of first drill holes that will be needed.

2. Review and identify current geothermal direct application systems and prospects to determine the cost and power usage of these systems.

3. Review and identify new systems that are proposed, planned and in construction. Estimate the quantity and sizes of projects expected to be on line from now through fiscal year 1987.

4. Develop cost estimates and manpower needs for resource development, design, construction, piping, hardware and operational start-up. Average costs will be assigned to each project type to obtain total capital investment needs.

5. Layout project time scales.

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8. Consider three generic systems. These are District Heating, Industrial Parks, and Single Industry.

9. Private and federal projects will be shown separately, but both will be included in the totals.

C. ASSUMPTIONS

Certain assumptions have been made and are identified as follows:

1. The well drilling success ratio and the number of projects required is shown in Table I.

TABLE I

DRILLING SITE PROJECTS SUCCESS RATIOS

ITEM	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	TOTAL
Projects Initiated (%)	0	15	25	30	20	10	0	0	100%
Projects Initiated (No.)	0	99	165	198	132	66	0	0	660 ea.
Ave. Success Ratio	0	60	54	41	31	25	0	0	--
Number of Successes	0	59	89	81	41	16	0	0	286 ea.
Number of Failures	0	40	76	117	91	50	0	0	374 ea.
% Govt Share Success/Failure	0	10/100	10/100	5/95	5/92	5/90	5/90	0	---

2. The number, size and type of facilities are shown in Table II.

TABLE II

ESTIMATED PROJECT SIZE AND TYPE DISTRIBUTION

SIZE	DISTRICT HEATING	INDUSTRIAL PARKS	SINGLE INDUSTRY	TOTAL UNITS
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100 MWt	1	5	0	6
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5 or less MWt	22	0	50	72
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PRIVATE				
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3. The average resource development and facility construction times are shown in Table III.

TABLE III

AVERAGE PROJECT DEVELOPMENT TIME

ACTIVITY	TIME (YEARS)
Resource Development	1 to 2
District Heating	3[a]
Industrial Parks	3[a]
Single Industry > 25 MWt	3[a]
Single Industry 5 to 25 MWt	2[a]

[a] After the first well is proven.

4. The estimated manpower and cost requirements for the development of the geothermal first holes covering the geoscience portion of reservoir confirmation and the industry infrastructure needed through fiscal year 1985 are shown in Tables IV and V.

TABLE IV

RESERVOIR CONFIRMATION - GEOSCIENCE PORTION[1]

	(COSTS - $ K)						
	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Surface Exploration	0	0	4830	9020	12,360	9160	4840
Gradient Hole Drilling	0	0	4940	9210	12,680	9350	4940
Production & Injection Well Drilling & Testing	0	0	18,970	34,680	44,630	32,450	17,200
TOTALS	0	0	28,740	52,910	69,670	50,960	26,980

[1] Resource identification, special projects and management costs are not included. These costs are being developed, and the total resource costs will be reflected in a future revision.

<u>TABLE V</u>

INDUSTRY INFRASTRUCTURE MANPOWER & EQUIPMENT

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
(other than Management)							
Geologists	0	10	50	100	130	100	60
Geochemists		5	25	50	65	50	30
Geophysicists		5	25	50	65	50	30
Legal, Land, Environmental People	0	15	50	100	130	100	40
Drill Rigs & Crews							
Deep Production	0	0	12	46	60	43	23
Shallow Production			20	77	100	72	38
Deep Gradient			12	46	60	43	23
Shallow Gradient			10	39	50	36	19
(Management)							
Evaluation & Monitoring		12	27	45	50	38	22
TOTALS		47	231	508	660	532	285

4. Average values are assumed for each project (excluding well development) and are shown in Table VI. The costs shown are for the geothermal systems, except as noted. Retrofit systems are included.

TABLE VI

AVERAGE PROJECT COSTS PER KW

PROJECT	COST $/kW
Single Industry	300
Single Industry - Total Facility	2000
Industrial Parks	500
District Heating	700

5. The current DOE funding level for FY 1980 and 1981 precludes (unless changes are caused to occur) extensive governmental assistance until FY 1982 and beyond. Project development will be estimated accordingly.

6. Assume that the private sector will develop 0.05 quads while DOE is developing 0.15 quads, between now and 1987.

D. WORK TO DATE

The following work has been performed to date:

1. The quantity of first drill holes has been estimated and a probable success ratio has been prepared.

2. Costs and power usage information has been compiled for most of the PON projects, and approximations of energy use have been made for systems identified in ten of the State Hydrothermal Commercialization Baseline Books. Estimated values for other known systems, in place or planned, have been included.

3. Types and quantities of new systems, private and government assisted, in generic form, have been identified, and scheduled through FY 1987. These are shown in Table VII.

TABLE VII

PROJECTED FACILITY INSTALLATION BY NUMBER AND MWt SIZE

SIZE	MWt	No.	FY 80 a-b-c	FY 81 a-b-c	FY 82 a-b-c	FY 83 a-b-c	FY 84 a-b-c	FY 85 a-b-c	FY 86 a-b-c	FY 87 a-b-c
GOVERNMENT ASSISTED										
100 MWt	600	6						0-1-0	0-2-0	1-2-0
50 MWt	1150	23					0-0-1	1-2-1	1-5-2	2-6-2
25 MWt	1775	71					2-2-4	3-3-8	5-5-10	8-8-13
10 MWt	1140	114		2-1-3	3-2-5	10-4-10	10-4-15	7-2-15	4-1-7	3-1-5
<5 MWt	360	72	2-0-3	2-0-6	4-0-10	4-0-9	4-0-7	2-0-6	2-0-5	2-0-4
Subtotal - Units		286	5	14	24	37	49	51	49	57
Subtotal - Cumulative		286	5	19	43	80	129	180	229	286
Subtotal - MWt	5025		25	100	170	305	595	930	1255	1645
Subtotal - Cumulative	5025		25	125	295	600	1195	2125	3380	5025

TABLE VII (contd)

SIZE	MWt	No.	FY 80 a-b-c	FY 81 a-b-c	FY 82 a-b-c	FY 83 a-b-c	FY 84 a-b-c	FY 85 a-b-c	FY 86 a-b-c	FY 87 a-b-c
PRIVATE		d-e								
100 MWt	200	0-2							0-1-0	0-1-0
50 MWt	350	1-6				1-0-0	0-0-0	0-1-0	0-1-1	1-2-0
25 MWt	325	1-12			0-1-0	0-0-0	0-0-1	1-1-2	1-1-2	0-1-2
10 MWt	330	3-30		0-0-1	2-0-1	1-1-2	1-1-4	1-1-4	1-1-4	1-1-5
<5 MWt	575	10-105	1-0-2	2-0-4	5-0-10	7-0-9	7-0-9	8-0-10	8-0-12	8-0-13
Subtotal - Units		170	3	7	19	21	23	29	33	35
Subtotal - Cumulative Units		170	3	10	29	50	73	102	135	170
Subtotal - MWt	1780		15	40	130	170	165	300	460	500
Subtotal - Cumulative MWt	1780		15	55	185	355	520	820	1280	1780

TABLE VII (contd)

	MWt	No.	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
TOTAL - Units		456	8	21	43	58	72	80	82	92
TOTAL - Cumulative Units		456	8	29	72	130	202	282	364	456
TOTAL - MWt	6805		40	140	300	475	760	1230	1715	2145
TOTAL - Cumulative MWt	6805		40	180	480	955	1715	2945	4660	6805

a - District Heating; b - Industrial Parks; c - Single Industries; d - Currently Planned; e - Projected.

4. Average costs have been assumed for three generic systems, and labor and material costs have been apportioned. These values have been converted to equivalent manpower needs, and the number of people needed, by major categories, are identified through FY 1987. PON information was primarily used as the data base to develop project breakdowns into design, construction, etc.

E. WORK PLANNED

The following should be performed to develop and refine the work done so far:

1. Develop cost estimates for average operating systems (exclusive of well development) of different types in order to obtain more refined costing data and a greater breakdown of manpower type requirements.

2. Determine the quantity of labor services, and materials that are a function of the infrastructure needed to cause early utilization of geothermal energy. Labor and material costs have been broken down for resource development; however, labor, material and other costs for facility development are needed. These would include, but not be limited to; labor by crafts, basic material needs, financial structure, management needs, environmental factors, and legal and institutional considerations. In addition, unit costs and quantities could be developed for significant features.

3. Develop these data from a site specific location to a state level, thence to a national level, as more information becomes available.

4. Additionally, charting and analysis of the information (now compiled and to be developed) should be performed.

5. Resource development costs shown include both government and industry efforts. Data is being compiled to reflect separation of these costs and will be made available later. Costs shown in this draft do not include all costs; these are being developed.

6/8/79

TO: MIKE
FROM: DEBBIE
RE: AVAILABILITY OF ROTARY DRILLING EQUIPMENT

ACCORDING TO MY FATHER, RIG AVAILABILITY SHOULDN'T BE A PROBLEM ASSUMING THE FOLLOWING:

AVERAGE FOOTAGE / DAY / RIG ≈ 300'

AVERAGE WORKING YEAR ≈ 200 days / year

AVERAGE FOOTAGE / YEAR / RIG ≈ 60,000' / yr

(A REALLY AGRESSIVE DRILLER W/ GOOD EQUIPMENT CAN MAKE AS MUCH AS 100,000' / yr / RIG)

1st YEAR'S FOOTAGE REQUIREMENTS ASSUMING 100 PROJECTS:

TEMP. GRADIENT HOLES	=	275,000'
PRODUCTION HOLES	=	175,000'
		450,000

MIKE WEIGHT

DIRECT HEAT APPLICATION REQUIREMENTS TO 1985

Planning Session

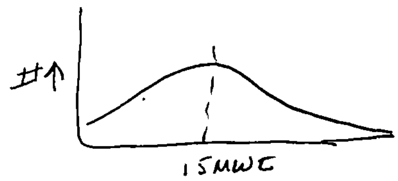
Present: Bob Schultz, Joe Hanny, Ben Lunis, Dave Wilkins, Fred Cerven

DISCUSSION:

A. General Approach

1. Review and identify the current systems operating nationally; determine size, costs.
2. Review and identify new systems in the planning stage, in construction and proposed.
3. Determine how many "first" drill holes are needed (UURI).
4. Layout a time scale of the projects.
5. Layout systems to determine numerous cost and manpower needs (as a function of time), i.e.,
   - ° piping heat exchanger and drilling costs
   - ° $ of support hardware
   - ° how much loan, equity capital is needed.
6. Determine manpower needs for resource development, design, construction, piping, hardware and operations. (UURI to provide resource development needs.)
7. First cut efforts will be generic, worked into a state level later, even though existing state data will be used. Use Lloyd Donovan's rough MWt values for existing systems. The three generic systems are:
   a. District Heating
   b. Industrial Parks
   c. Single Industry
8. Separate federal projects from private.

B. <u>Assumptions</u>



1. Assume system sizes as follows:

5	5%	100 MWt	-	3 units	3
10	10%	50 MWt	-	10 units	10
25	15%	25 MWt	-	~~31~~ units	51
~~40~~	30%	10 MWt	-	~~153~~ units	204
20	40%	5 MWt	-	408 units	204
		5100 MWt		605 units	472

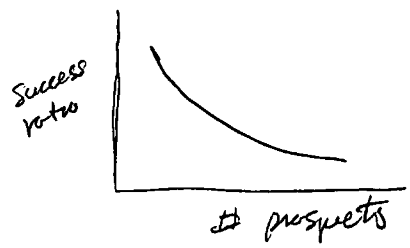
– but only have to pay for unsuccessful ones + 10-20% of others for data

2. Schedule planned projects as follows:

introduce sliding scale for success ratio

System	Time[1]	Percentage
District Heating	3 yrs	25%
Industrial Park	3 yrs	40%
Single Industry > 25 MW	3 yrs	35% (Single Industry, both sizes)
Single Industry 5 to 25 MW	2 years	

to this add time for resource confirmation



[1] from time the well is proven.

C. <u>Action Items</u>

What	Who	Due
1. Review & identify current operating systems nationally from PON's, state baseline books, O.I.T. data	BCL, DEW, FC	
2. Review & identify planned systems	BCL, DEW, FC	

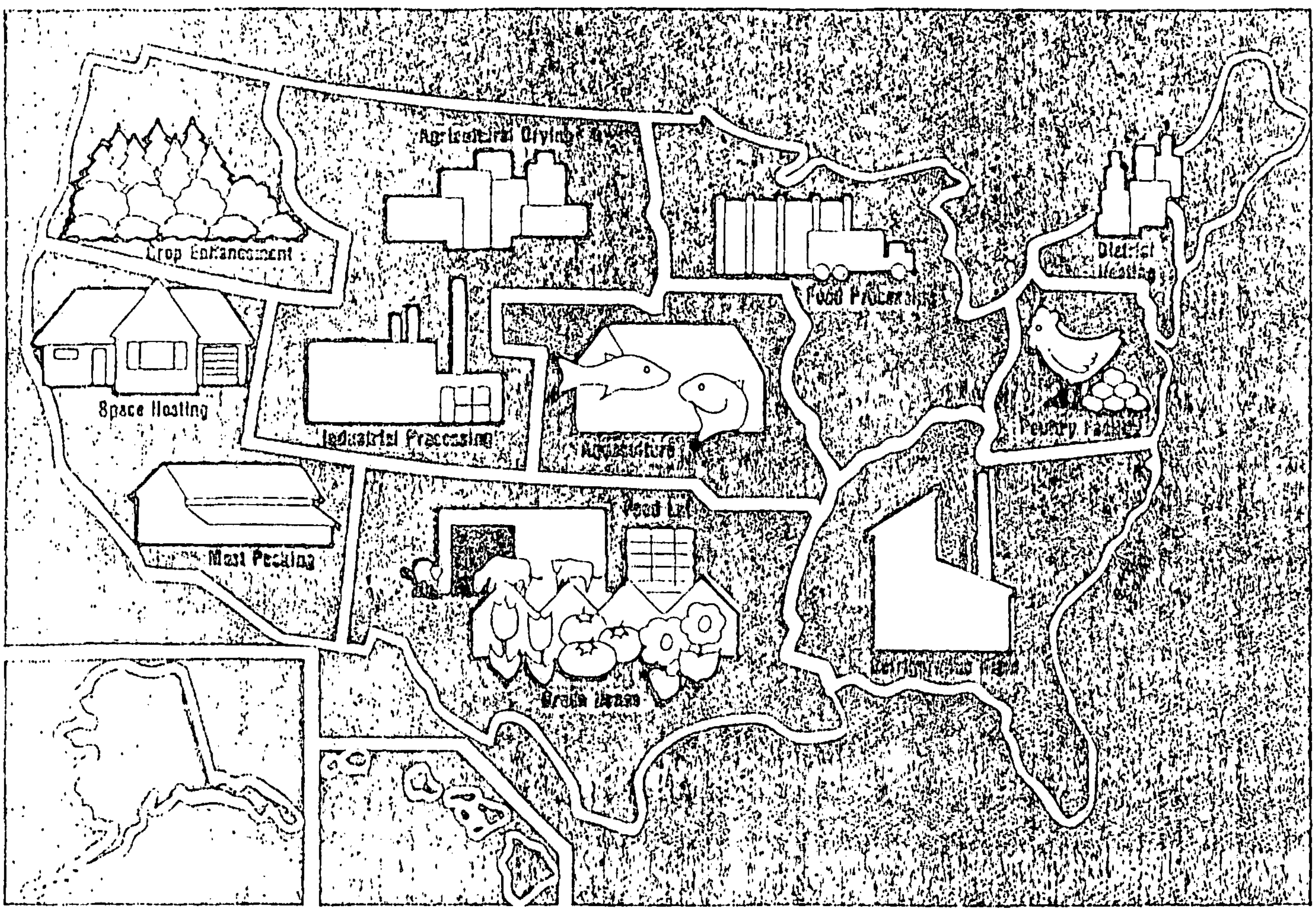
3.	Contact NMEI for cost models	DEW, BCL	
4.	Rough cut report	all	6/13
5.	Set up systems to identify and chart operating, planned systems; develop curves on power. Obtain Dick Schmitt's Direct Application curve of power on line by 1985.	DEW, FC, BCL	
6.	Determine "average" costs for systems	DEW, FC, BCL	
7.	Obtain Lloyd Donovan's curve of well depth vs. cost	BCL	
8.	PON data, state baseline books to DEW, FC	BCL	
9.	Obtain copy of U. of Utah study of manpower involved in U.S. as geothermists	BCL	
10.	Do we use 0.15Q for federal effort, 0.05Q for private work?	RJS - PMW	
11.	Discuss facility MW size assumptions with UURI.	RJS	

WRIGHT

PRELIMINARY DRAFT

3 ed

Energy Technology
Geothermal Direct Applications
Program Plan



Division of Geothermal Energy

ENERGY TECHNOLOGY
GEOTHERMAL DIRECT APPLICATIONS
PROGRAM PLAN

TABLE OF CONTENTS

1.0 INTRODUCTION

The direct applications of geothermal energy can make a significant contribution to energy use patterns in many places in the United States. THe excellent potential for direct applications can be achieved with additional modest support on the part of responsible federal agencies. Although direct application of geothermal energy for residential, commercial, and some industrial processing exists today, the potential can be expanded many times as the knowledge of the resource base increases and as innovative engineering is applied to use patterns. It is the purpose of the program described herein to provide the DOE Geothermal Resource Applications Office support and data to enhance both the near-term and long-term commercialization efforts. The placement of high-risk, front-end capital into the geothermal industry economy will also help develop a self-sustaining infrastructure.

The ET direct applications plan contained herein is a balanced program, addressing needs in three areas: resource base development, technology development, and techno-economic data development. It is the aim of this program to expand the uses of hydrothermal energy by developing resource information as well as the technology for utilization. An effort is planned to widen the low- to moderate-temperature resource data base. Technology development in the plan is focused in four areas: (a) development of components to extend the use potential of the energy source, (b) modifications of existing high-temperature geothermal processes to accept lower heat conditions, (c) beneficial uses of energy-expended fluid, and (d) development of support technology requirements. The techno-economic data base activities will help develop on-line systems in the public and private sectors through the Program Opportunity Notices and a DOE cost-shared approach to take advantage of targets of opportunity. Special projects are also included.

2.0 PROGRAM PLAN SUMMARY

The ET program plan for supporting the DOE RA direct applications commercialization effort is summarized below as to justification, strategy, and benefits. The strategy is expanded in Section 3.0; i.e., the elements of work to be performed, schedules, and costs. Sections on the team makeup to perform the work of Section 3.0 and benefits to be derived are also provided.

2.1 Justification

Geothermal energy, in direct applications, has the potential of replacing a great deal of fossil energy usage and providing a more appropriate thermodynamic matching of energy to work to be performed. Thirty-seven states in the U.S. have indications of geothermal energy that may be economically developed. The medium- and low-temperature (50-150°C) hydrothermal resources contain about 5 times as much recoverable energy as the high-temperature (above 150°C) resources using today's technology. Presently, the majority of the hydrothermal resources in this country do not permit efficient generation of electricity. In most cases, geothermal energy can be used in straightforward applications of today's technology base. Limited R&D is required to broaden this application base, but, in all cases, direct applications would be an efficient utilization of this important alternate energy resource.

2.2 Strategy

If the direct application of hydrothermal energy national goals are to be met, either in the near- or long-term, significant investment must be made by industry. The primary thrust of the ET/DGE direct applications pre-commercial program to encourage such investment is three-fold:

(1) Resource Base Development

The low- to moderate-temperature resource base for widespread direct applications utilization is not well-defined (Figure 1).

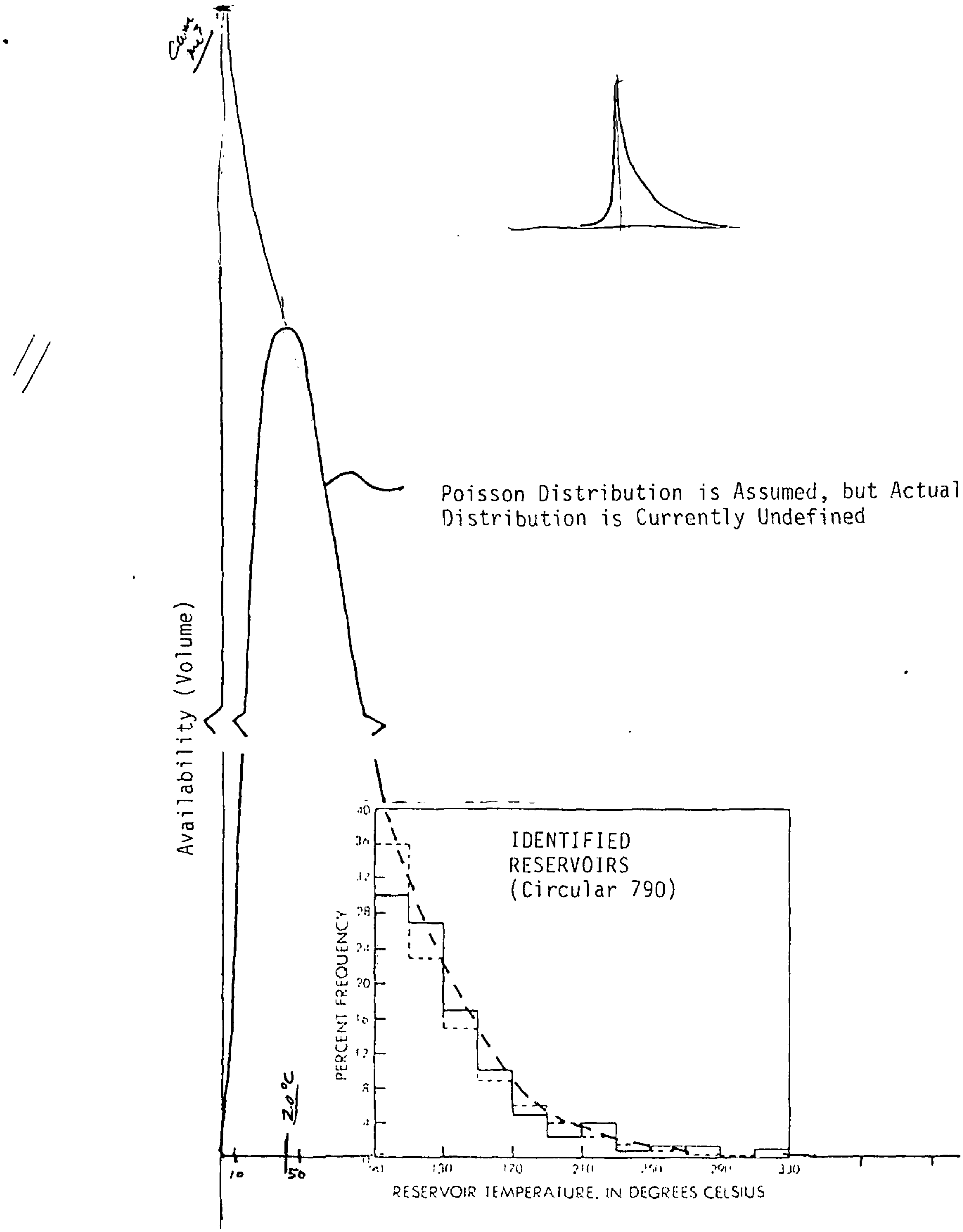


Figure 1. Hydrothermal Resource Temperature/Occurrence Profile

An element for resource definition and mapping is included in the ET plan to provide the basic resource data necessary for initial business decisions. The resource considerations include: state-coupled, industry cost-shared drilling, regional cooperative support, and data acquisition and resource development programs.

(2) Technology Development — Exploration & Assess

Technology development is provided to expand the utilization potential beyond that currently considered to be feasible within the industry. This activity includes technology development activities in areas of identification of technical barriers, development of components and systems, and pre-commercialization evaluations.

(3) Techno-Economic Data Development

The techno-economic data base development focuses upon information collection through the development of on-line operating systems in the public and private sectors through the use of field experiments. This element is on a cost-shared basis wherein DOE will leverage the federal funds while assisting in infra-structure development through placement of high-risk, front-end capital into the geothermal economy.

DOE's goals for geothermal energy use have been quoted as quads for 1985 and quads for 2000. If all the PON projects which have been funded come to fruition, the aggregate geothermal energy use will approximate quads.

Table I illustrates the approximate national energy use by temperature range. Table II illustrates the temperature range for energy end uses (Reference 1).

TABLE I

ENERGY USE vs. TEMPERATURE

Use	Temp (°F) use °C	Quads	% Total
1978 Total		75	100
Space/Water Heating	165° <	17	23
Industrial (Food Proc.)	165-210°	2	3
Other Industrial	210-300°	5	6
Air Conditioning	Electric	2	3

TABLE II use °C

TEMPERATURE (°F) END USES

% Energy Use at or below this temp.	167° / 20%	200° / 23%	250° / 27%	300° / 32%	400° / 42%

Tables I and II illustrate the obviously high pay-off potential in a vigorous federal geothermal direct heat program, with particular attention centered on the space conditioning, water heating and lower-grade industrial processing market, which represent about 50% of the total use for temperatures below 300°F. °C

Space heating requirements for U.S. buildings ~~is~~ are approximately 14 Quads annually. As Table III indicates, geothermal energy could potentially supply about 3-1/2% of this demand, which represents a benefit to about 10% of the U.S. population which lives within 40 miles of about 225 known geothermal resources in eleven western states (Reference 2).

It should be observed that these figures represent present potential demand. Most of the western states are among the fastest growing in the country and so the longer term projected demand is all the more significant in terms of fossil fuel displacement.

Although a national market analysis has not been completed, the analysis of 11 western states shows the large potential which exists for direct applications of the hydrothermal resource. Analysis of current energy use within that region indicates that the prime market sectors for the direct use of geothermal energy are space conditioning (both cooling and space/water heating) and low- to moderate-temperature industrial processing. Currently, greater than 75% of these market sectors are being served by fossil fuels, with electricity claiming the majority of the remaining sales. Energy competition projections for the region indicate a higher dependence upon coal in the future, which may encounter environmental or growth constraints. A cross-matching of the hydrothermal resources, as known today and projected in the future, on a county-by-county geographical basis with the potential user sectors, reveals that all 10 states within the region have significant amounts of resources which correlate with potential market areas, and the majority of the industrial and population centers are colocated with hydrothermal resources. The largest potential user segments are space conditioning and water heating. The current energy use for this is 288 x 10^{12} Btu per year and this could grow to 2504 x 10^{12} Btu per year by the year 2020.

TABLE III

POTENTIAL EXISTING DEMAND FOR GEOTHERMAL SPACE HEATING

Distance from Resources	Total Population	Heat Demand (10^{12} Btu)	Barrels of Oil Equivalent (10^6)
0-5	120,000	1.9	0.4
5-10	330,000	5.7	1.3
10-20	3,950,000	74.9	17.4
20-30	6,070,000	86.3	20.0
30-40	14,210,000	180.1	41.8
40-50	9,670,000	129.9	30.1
	34,350,000	478.8	110.0

Current energy supply requirements for the industrial sector are somewhat smaller than the energy needs for residential/commercial space conditioning, but the region's growth potential is excellent, and it appears that penetration can readily be made in the industrial sector. Current energy use in the low- to moderate-temperature heating processing sector which can be served by hydrothermal energy is 74×10^{12} Btu per year, with a growth pattern of 177×10^{12} Btu per year by 1985, 480×10^{12} Btu per year by 2000, and 1476×10^{12} Btu per year by the year 2020.

From the foregoing considerations, it can reasonably be observed that substantial long-term markets for hydrothermal energy exist in the western region; that commonly found coincidence of resource occurrence with user locations promise favorable economics in competition with other energy supplies; and that hydrothermal energy can be a near-term, partial solution to the region's energy needs.

Increasing attention is also being paid to East Coast market possibilities. Of the four principal resource areas studied for energy demands, the residential and commercial market approaches the equivalent of 20 million barrels of oil annually. Other demands are shown in Table IV (Reference 3).

In the U.S., direct applications of hydrothermal energy are minimal, a result of our former abundance of inexpensive fossil fuels. But with the emerging need for alternative energy choices for the future, the nation can no longer delay implementing the significant contributions that the direct utilization of geothermal resources can make to energy supply. Reducing resource uncertainties, assisting industry in developing confidence in the applications of hydrothermal fluids, removing unnecessary barriers, solving environmental problems, demonstrating possible uses, and providing incentives are necessary activities in furthering the objective of more widespread direct applications geothermal resource utilization practices.

TABLE IV

SECTOR ENERGY DEMAND (10^{11} Btu/yr)*

Resource Area	Residential & Commercial	Military	Agriculture	Industrial
S. E. New Jersey	290	25	0.2	5.2
Delaware	125	8	14.5	14.8
Norfolk (VA)	280	97	0.5	8.3
E. North Carolina	80	15	9.5	9.0

* These figures also do not include projected growth.

Although no technological breakthroughs are required in the utilization of geothermal energy for these direct heat uses, technological advances are needed to reduce costs and increase distances over which geothermal energy can be competitive. Significant cost reductions would be achieved in the areas of well-drilling costs, stimulating well flow rates, pipeline and component construction, materials development, and defining and identifying resources close to the market. This direct heat applications plan addresses all these elements, categorized by resource assessment, technology development, and techno-economic field project data development.

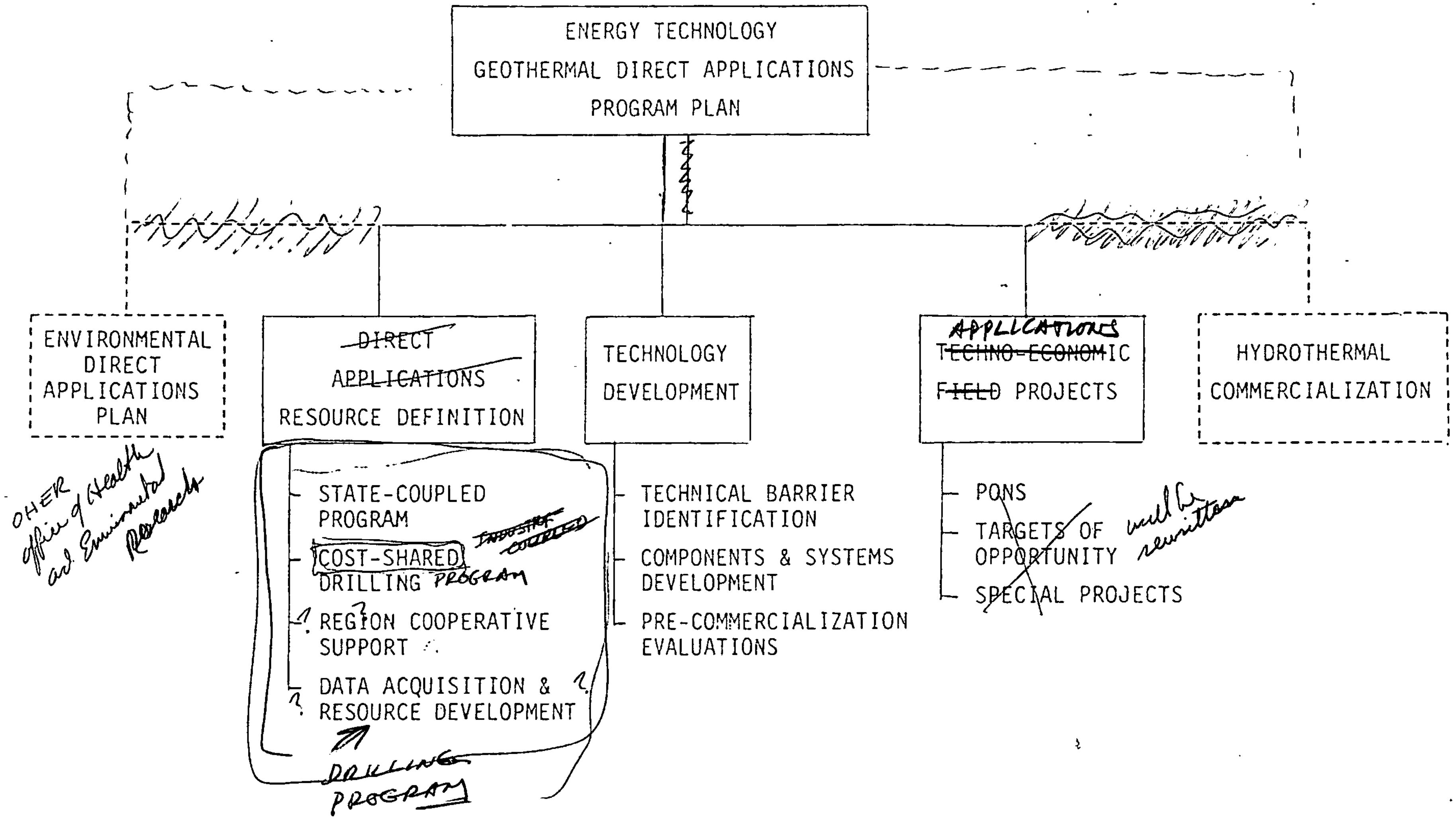


Figure 2. Work Breakdown Structure for ET/DA Plan

(to be completed - see individual sections for costs and schedules)

Figure 3. Summary - ET Program Plan Costs and Schedules

(PRELIMINARY AND UNDER REVIEW)

	FY-79	FY-80	FY-81	FY-82	FY-83	FY-84	FY-85	

State Coupled Program *

(1) △ (2) △ (3) △

1. Phase 1 - overall resource definition state-by-state
2. Phase 2 - site specific investigations
3. Phase 3 - ~~transfer to GR contractors~~ drilling - start FY81
4. Phase 4 – industry (commercialization)

*[5.0 MM nationally]
FY-79: ~~2.3~~ MM 6.8
FY-80: ~~2.7~~ MM 7.1
FY-81: ~~2.7~~ MM 12.5
FY-82: ~~2.2~~ MM 15.5
FY-83: ~~2.0~~ MM 15.5
FY-84: ~~1.8~~ MM 15.5
FY-85: ~~1.6~~ MM 15.5
desired funding level

Bob Gray & Lawrence

Industry Cost-Shared

(1) △ (2) △ (3) △

1. Program specifications, selection of "target areas, issue RFPs
2. Drilling, information dissemination, program evaluation
3. Repeat (1) and (2) if program results are positive

FY-80: 200 K
FY-81/82: 6 MM/yr
FY-83/85: 6 MM/yr

Bob Gray eliminate

Region Co-op Support

(1) △ (2) △ (3) (4) △

1. Plan development, solicit responses for pilot project(s)
2. Conduct pilot project(s)
3. Evaluation
4. Initiate 3-year program if pilot results warrant

FY-79: 100K
FY-80: 1.5 MM
FY-81: 6.0 MM
FY-82/84: 5 MM/yr

Data Acquisition & Resource Development

(1) △ (2) LOE →

1. Formulate plan
2. Level of effort bounty program, information dissemination

FY-80: 100 K
FY-81/85: LOE at 3 MM/yr
81 = 500K
82-85 = 1,000K

Total Costs ($)

FY-79	2.4 MM
FY-80	4.5 MM
FY-81	22.7 MM
FY-82	16.2 MM
FY-83	13.0 MM
FY-84	15.8 MM
FY-85	12.6 MM

* The milestones and budget for the state-coupled program do not include an approximate $2.7 MM being spent on resource definition outside the western states.

Figure 4. Direct Applications Resource Definition - Costs and Schedules

programs (power production). Notable exceptions are the PON and PRDA activities. For much of the geothermal resource base, the potential for on-line replacement of fossil fuel is generally conceded to be much greater from direct applications of hydrothermal energy than from geothermal electric developments. The direct applications technology development activity is to support commercialization in the numerous potential applications that currently exist and to increase the use potential in new and untried processes, thus enlarging the future potential for hydrothermal energy as a viable alternate energy source.

The principal areas of activity are in the identification of technical barriers, technology development, and pre-commercialization evaluations (all discussed in following sections). Technical barriers from the industry standpoint are part of the reason for the lack of industry-initiated geothermal resource application developments; other reasons involve economic and resource uncertainties. The industry nominally understands the technology, economics, and applications of high-temperature reservoirs for electric projects, but no such understanding exists of the potential of the lower temperature reservoirs for direct applications. To develop this kind of familiarity within industry, and desire on the part of industry for implementation actions, will require a concerted effort on the part of the federal ET program to search out industry concerns and address those concerns through experimental work demonstrations and analyses. Following barrier identification, component and system tests with analyses directed toward conventional and innovative applications should help resolve the problem of industry indecision. Part of these tests are to be directed at lowering unit and process operating temperature requirements to those more suited to geothermal sources, i.e., many process temperatures today are based on the fossil-fuel source in use, not on the technical basis that lower-temperature processes in redesigned equipment would not suffice.

Data derived from these tests and analyses will provide industry with pre-commercialization data, economics, and techniques. Industry may require further pilot or demonstration-size facilities to validate the pre-commercialization results. This final step of commercial interaction is addressed in Section 3.3 of the program plan.

3.2.1 Technical Barrier Identification

Technical barrier identification, which is encompassed within the technology development work, is an important part of the ET program. Many applications of geothermal heat are considered straightforward applications of existing technology, but there are many applications, such as industrial drying with low-to-moderate temperature geothermal fluids, where the technical questions need further examination.

The objectives are to identify the technical barriers to geothermal development, identify new use potentials for commercialization, specify technical requirements for components/systems development to address identified technical questions, perform case studies on promising new geothermal applications, and provide a supportive role either analytically or through existing experimental and demonstration results to address industry commercialization uncertainties.

The methodology in technical barrier identification involves: 1) feedback from RA commercialization; 2) compilation of existing studies in generic operations such as drying-crystalization-evaporation process steps; 3) interfacing with industry for technical problem searchout; 4) symposiums or committees of experts; and 5) publications of status. The publication can be designed for transmittal to target industries to trigger a response mechanism.

Item 3 will involve several steps for target selection: 1) large energy use surveys (or recompiling existing studies); 2) co-location identification; 3) contact with influential organizations of the selected industry; 4) process selections; and 5) design/modification/testing needs.

3.2.2 Components and Systems Development

To advance the commercialization of geothermal heat in direct applications, a number of incentatives need be addressed. Loan guaranties, engineering and economic studies, steps to reduce legal and institutional barriers, and field projects are all important program elements, but the technical feasibility of harnessing this energy resource remains a concern and a factor of indecision for private enterprise, as noted earlier. In private enterprise, new technologies and new applications of known technology are often verified in pilot tests simulating actual process conditions, so that potential operating difficulties can be identified and process alternatives and feasibility evaluated prior to commitment of capital funds. Small scale and pilot testing continues to be an important antecedent to demonstration and full-scale applications of industrial processes. Without this type of opportunity for testing and/or small-scale demonstrations of technical feasibility, many potential users of geothermal resources may ignore the geothermal option. Components testing, systems development, and DOE-supported research activities continue to be needed for convincing arguments on technical feasibility.

The components and systems development work element of the ET plan will respond to the needs identified through the barrier identification work, and an element of activity will be directed to new and innovative technologies that may have an important impact on upcoming geothermal use patterns.* The work should include private participants, contracting organizations, and DOE laboratory facilities. Private industry is an obvious preference in cases where a commercialization follow-on exists in the near term. A cost and schedule for the program is indicated in Figure 5.

It is noted that some activity in direct applications research and technology has been conducted [redacted] by DOE. This has included beneficial uses of geothermal fluids in aquaculture and agriculture, as well as hardware research and technology. This experimental work has aided the commercialization effort. Technology development activity allows private interests to become familiar with or participate in geothermal projects and provides answers to many technical questions. This R&T program activity has led to many of the existing PRDAs, PONs, and other private development

* Interrelated with previously identified case studies; also includes new industry and community concepts for geothermal resources.

in several Western areas. A tabulation of activity areas for research considered [redacted] is given in Appendix A. Much of this has not been implemented, but might be considered with other participants in the ET plan. However, some of the work may not receive priority for implementation.

(PRELIMINARY AND UNDER REVIEW)

	FY-79	FY-80	FY-81	FY-82	FY-83	FY-84	FY-85	
Technical Barrier Identification	Barrier Review/ID (Specifies Technical Requirements) (FY-79 – FY-85)							LOE: 60 K/yr
		Case Studies (New and Innovative Concepts) (FY-80 – FY-85)						FY-80-FY-82: 100 K/yr FY-83-FY-85: 60 K/yr
		Barrier Removal (Supports Industry/Commercialization) (FY-80 – FY-85)						LOE: 60 K/yr
Components and Systems Development	(FY-79 – FY-85)							FY-79: 0.5 MM FY-80: 1.0 MM FY-81: 1.2 MM FY-82: 1.2 MM FY-83: 1.0 MM FY-84: 0.8 MM FY-85: 0.5 MM
Pre-Commercialization Evaluations	(Costs and schedule incomplete and not included in this draft)							

Total Costs (S)	
FY-79	0.7 MM
FY-80	1.2 MM
FY-81	1.4 MM
FY-82	1.4 MM
FY-83	1.4 MM
FY-84	1.0 MM
FY-85	0.7 MM

Figure 5. Technology Development - Costs and Schedules

3.3 Techno-Economic Field Projects

The development of a techno-economic data base is an essential element for commercialization of hydrothermal resources. This data base will be established through the implementation of public and private sector operating systems that utilize hydrothermal resources.

Currently, the PON field experiment program provides the major thrust for the development of this data base. The PON program is a necessary element of the Direct Applications Program Plan in order to establish an industrial infrastructure, focus public interest, and to absorb the front-end risks inherent in new applications and/or resource development. A modification of the PON solicitation and selection criteria is included in the plan to provide for those elements relating to: energy market impact potential, transferability, growth potential, cost-sharing ratio, geographic/resource expansion potential, total DOE investment, and energy intensiveness. The improvement of selection criteria will provide a more effective use of funds and improve the program balance.

In addition to the PON field experiments, a "target of opportunity" program is outlined to provide for more flexibility in meeting technology development needs and national utilization goals. This program will add continuity and stability to the complete utilization effort by providing some degree of leveling to the cyclic PON solicitation and evaluation procedure.

As another means of concentrating national utilization interest and producing techno-economic data, a "special projects" program is described. Special projects will be identified and evaluated primarily for the significance of new techno-economic data expected, magnitude of the resource potential and the energy intensiveness of each project. These projects will more than likely involve other government agencies and be funded on a cost-shared basis between DOE and those other agencies.

3.3.1 PON Program

Two solicitations of Program Opportunity Notices for Geothermal Direct Application Field Experiment projects have been made. The first selection of eight projects was made in FY-1978, and the second selection, consisting of fifteen projects, was completed in the first quarter of FY-1979. Contracts are in place and field operations have been initiated for the first group of successful PON applicants. Contract negotiations have been initiated for the second group selected.

The PON program will continue to be the major near-term thrust of a national direct applications program. The purpose of the PON program is to provide an opportunity for interested parties, with federal assistance, to engage in direct heat utilization or combined electric/direct use utilization projects for demonstrating single and/or multiple uses of geothermal energy for industrial processing, space-heating, cooling, agricultural or aquacultural uses, and domestic hot water heating. These field experiments will continue to be needed to (1) provide visible evidence of the viability of various direct heat applications in a number of geographical regions; (2) to obtain reliable objective and technical, economic, institutional and environmental data under field operating conditions that will facilitate decisions on the utilization of geothermal energy by interested developers and users; and (3) to demonstrate a variety of different types of applications. In the future, PON solicitations must also be reserved for new and highly promising market sectors, which economic analysis shows to be particularly promising for geothermal, or which, by nature of geographic population concentration with respect to hydrothermal systems, holds great potential for energy replacement with geothermal.

The first two PON announcements have resulted in considerable public attention being focused toward the food processing industry, district heating systems, and individual retrofit space heating projects. By structuring subsequent PON announcements to prioritize different application considerations to maximize new technology confirmation and national geothermal utilization, a significant acceleration of the total geothermal program can be effected.

Based on apparent industrial interest being expressed and the large market potential represented, the third PON announcement should stress any industrial process application.

The fourth PON should stress applications located at new resources, to insure continued growth as new resources are confirmed and developed. Space conditioning (both heating and cooling) will have a second-order importance for selection consideration, since the first two PONs have resulted in several space conditioning experiments.

The remoteness of many identified resources to existing population centers will force industrial and total community development around viable geothermal resources in the future. The fifth PON should be structured to stress this totally integrated, new community/industrial utilization technique.

3.3.2 Target of Opportunity Program

As it stands, the rate of geothermal direct application development, on a national scale, parallels the cycle for PON announcements. To minimize this cyclic effect, a Target of Opportunity program is outlined that will supplement and enhance the technologic impact of the PON.

The PON program, as originally structured and administered in a competitive selection process, will be reserved primarily to demonstrate new use concepts and structured to encourage particular types of applications. The Target of Opportunity program will be made available on a continual basis for worthy projects and will not be directed at any particular application. A selection procedure will be established that provides for a definitive selection process that evaluates each proposal against energy replacement criteria, geologic/resource expansion potential, transferability of results, energy intensiveness, total DOE investment, and cost-sharing ratios. A procedure to announce the program intent must be devised to assure wide distribution and to indicate funding guidelines for each fiscal year, as Congressional budgets are approved. Providing this additional avenue for project implementation will accelerate national geothermal development and utilization, while greatly expanding the techno-economic data base and industrial infrastructure. It will also result in more timely proposals and better prepared project teams.

With the introduction of this program element, cost-shared proposals can be evaluated objectively with regard to their overall value to the total direct application data base. Financial support and other incentives can also be made available to applicants, based on unique project considerations and their value to national goals. For example, the cost-shared arrangements between DOE and proposers, in addition to being a known definitive application criteria, can remain flexible to the ultimate outcome of the project. In high-risk areas (proving the resource), if the project objective cannot be met, then a project can be terminated and the incurred costs to that point can be provided by DOE as a grant, with the proposer under no obligation to repay.

To be more specific, a funding plan can be implemented that would encourage the participant to bear as much of the project cost as possible, with DOE removing most of the risk. This can be implemented by terms in each individual contract requiring a high participation by the contractor if the project is successful, but a low participation if it is unsuccessful. This approach is particularly amendable to geothermal projects because most of the risk occurs early during resource development.

DOE could contract to share in a project on a sliding scale inversely proportional to the Btu's produced by the well. The share could be established based on a well test defined in the contract. With such a contract, the participant would be able to obtain financing (this could be done in a variety of ways, depending on the participant), and carry the project through the well testing phase. At this point, the cost share by DOE would be established for continuation, or, if unsuccessful, DOE would assume costs to date and terminate the contract.

Because of the high risk usually occuring during the early phases, DOE funds for a given project would not be committed for more than six months to one year, depending on the project size and complexity. Of course, DOE's final share of the project would need to be sufficient to make the project economically sound for the participant and commercial lending institution. In most cases, DOE's share would include those items like publicity, special monitoring, reporting, technical evaluation, economic evaluation, etc., which would not be part of a normal commercial venture.

3.3.3 Special Projects

Special projects are also expected from time to time in the area of techno-economic field project work. Current activities in this category are as follow:

Hill AFB (Utah) Evaluation	FY-79:	0.5 MM
INEL Deep Well	FY-79:	2.6 MM
Williams AFB (Arizona)	FY-79:	Under Technical Assistance
Community Project Brokering Assistance		(expected)

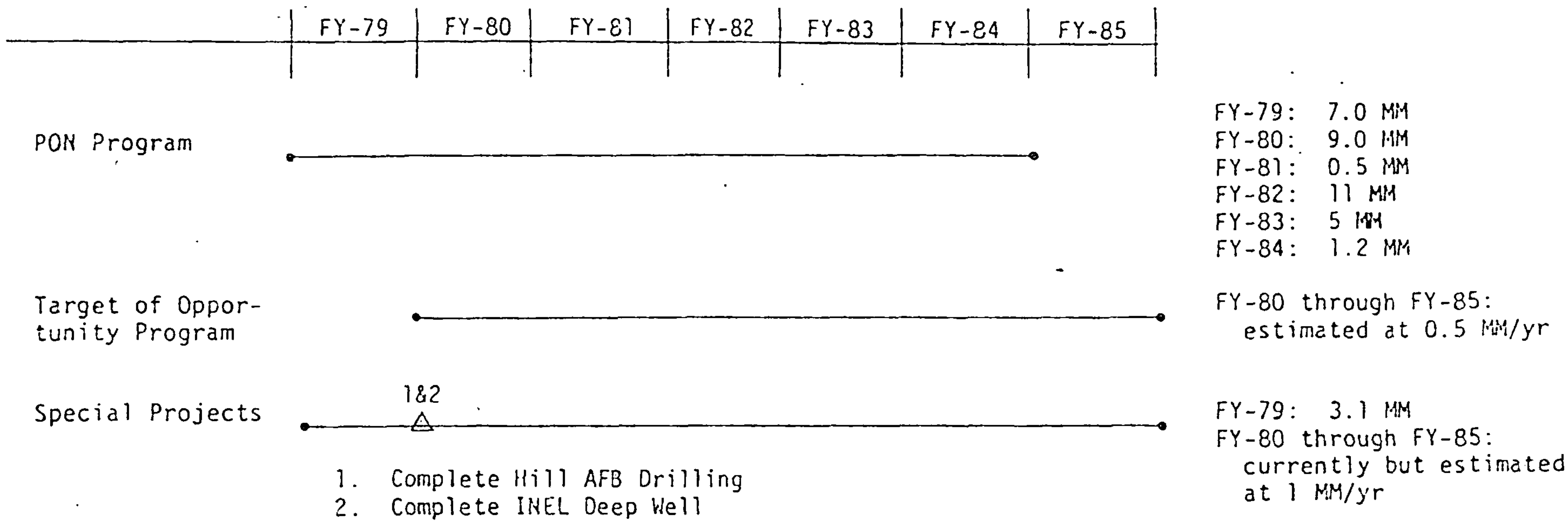
Generally, special projects can be considered similar to targets of opportunity discussed earlier. The payoff potential of such projects in terms of commercialization is sufficiently great to warrant attention and support outside the normal program elements such as the PONs.

3.3.4 Information Dissemination*

Newletter
Mailing lists
Lists of A&E Firms
Library Lending Service
Program to Get Abstracts to Small Users
Problem-Oriented Project Experience File

* Section under consideration.

(PRELIMINARY AND UNDER REVIEW)



Total Costs	$
FY-79	10.1 MM
FY-80	10.5 MM
FY-81	16.5 MM
FY-82	12.5 MM
FY-83	6.5 MM
FY-84	2.7 MM

Figure 6. Techno-Economic Field Projects - Costs and Schedules

4.0 ET/DA TEAM

The Department of Energy Geothermal Direct Use Program overall management control will be retained by the Division of Geothermal Energy within the Energy Technology Organization. The direct use program will have multiple elements which span from planning through resource definition, technology developments to demonstration projects. A variety of agencies and organizations are and will continue to be involved in the control and execution of the program. The ET staff will rely upon the field offices to implement the program, with Idaho and San Francisco Operations assigned to carry out specific functions and to coordinate these activities with the appropriate participants.

The ET direct use geothermal headquarters staff will interface with the Resource Applications (RA) staff. The principal management responsibility for some of the ET/DA program elements have been assigned to the field offices, in order to decentralize the program and enhance the effectiveness of the ET progrsms. The direct applications program elements and the appropriate team members include:

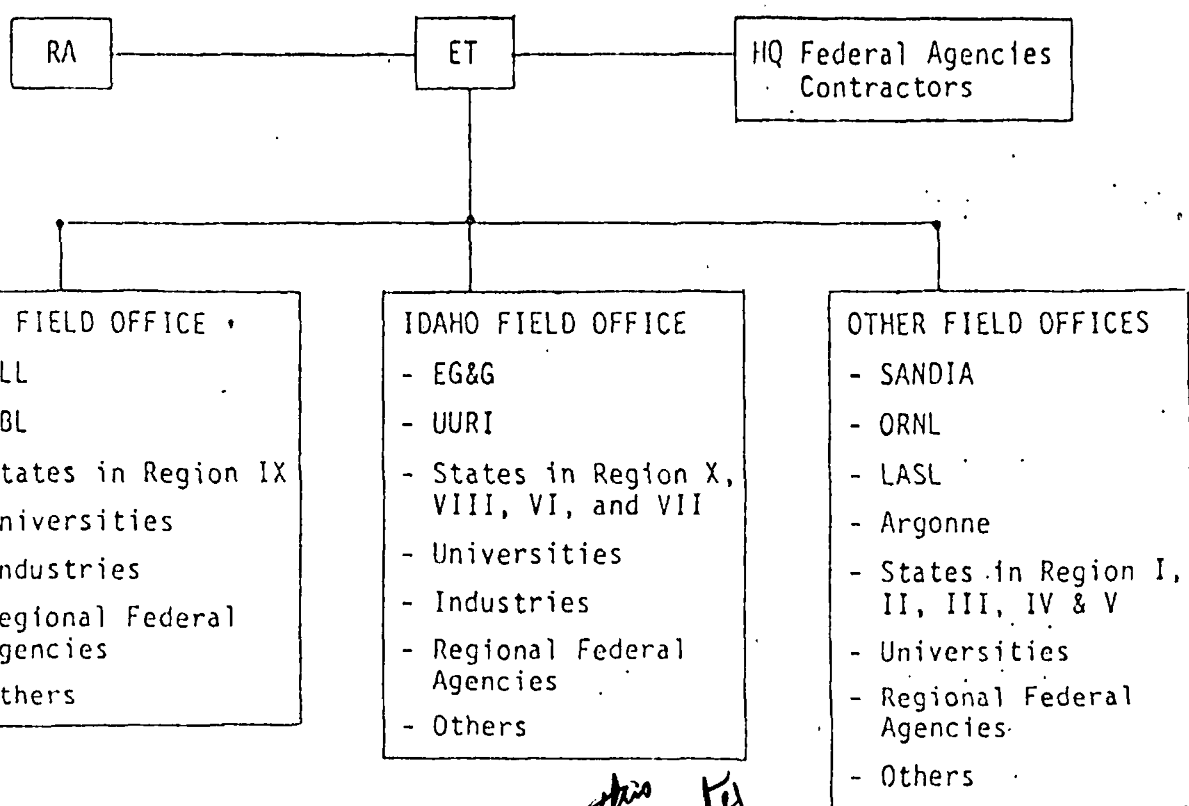
1) Resource Definition - The Resource Definition Program is composed of several tasks which are being conducted by a variety of contractors. This program includes tasks for subsidence, log interpretation, instrument development, stimulation, reservoir assessment, rock properties, exploration technology, and reservoir engineering. The principal parties involved in these activities are the University of Utah Research Institute, Los Alamos Scientific Laboratory, Sandia, and Livermore Berkeley Laboratory. The majority of the management responsibility for these tasks has been delegated to the field, but other reservoir definition work, including the industry-coupled, drilling, and brine chemistry activities, is currently being managed by the DGE-HQ staff.

2) Technology Development - The technology development programs include the identification of technical barriers, the component and system development, and the evaluation of precommercial activities. The principal party involved to date in the technical development has been EG&G, through the Idaho Office. These programs have been related to materials testing, component development, and field experiments. As this element of the national direct applications program evolves and activities related specifically to identifying technical barriers and developing components and systems are initiated, the appropriate team members will be identified. The program responsibility will be assigned to the appropriate field office.

3) Techno-Economic Field Projects - These activities are primarily the result of PON solicitations and targets of opportunities which are presented to the Department of Energy. The PON program is a controlled solicitation developed to provide non-federally conducted experiments in selected areas dealing with a specific technology. PON tasks are formal announcements awarded at specified times. The solicitation portion of this program has been the responsibility of the SAN Office, with the contracting and monitoring handled by the SAN and ID Offices. The monitoring responsibility for the ID Office contracts have been assigned to EG&G.

   The management team for the targets of opportunity program have not been identified, as the details for this activity have not been fully established.

The ET Headquarters staff will insure that the ET programs and plans are conducted in cooperation with the RA activities, including special programs related to barrier removal, incentives, and planning. The overall organization for carrying out the ET/DA tasks is presented below:



needs modif. - this treatment of states not appropriate for resource areas

This chart indicates only the principal participants as presently exist and is not intended to be inclusive nor represent the principal participant which may ultimately be involved as the ET/DA program evolves.

5.0 BENEFITS

(Section not completed at this time)

REFERENCES

1. Jay Kunze, "Fluid Heat Management for Direct Geothermal Energy Applications", A Symposium of Geothermal Energy and Its Direct Uses in the Eastern United States, GNC Proceeding, April 1979.

2. Paul Lienaw, "Space Conditioning with Geothermal Energy", A Conference on the Commercialization of Geothermal Resources", GNC Proceedings, November 1978.

3. Wm. Toth, "Geothermal Energy Markets on the Atlantic Costal Plain", A Symposium of Geothermal Energy and Its Direct Uses in the Eastern United States, GDC Proceeding, April 1979.

4. C. M. Blvanster, et. al., "Geothermal Energy Potential for District and Process Heating Applications in the U.S. - An Economic Analysis", Battelle Pacific Northwest Laboratories, August 1977.

APPENDIX A

DOE
[redacted] COMPONENTS AND SYSTEMS DEVELOPMENT WORK ELEMENTS EITHER IMPLEMENTED OR BEING EVALUATED

COMPONENTS AND SYSTEMS DEVELOPMENT WORK ELEMENTS

Work Element	Description	Justification
Wetlands Development	Research (and demonstration) for utilizing artificially created wetlands (marshes) to dispose of geothermal fluids. Use of aquatic plants as biological filters to remove minerals and metals. Fish culture, water fowl populations and muskrat raising as possible economic by-product, algae production for fuel conversion also possible.	Fluid disposal is currently unresolved and an overriding concern for geothermal developers, particularly for small developments where re-injection costs not feasible. Disposal regulations (state, clean water, local) very restrictive, and wetlands could be environmentally acceptable geothermal fluid disposal solution.
Aquaculture	Examining the commercial feasibility of culturing aquatic species directly in geothermal fluids - includes spawning, rearing and marketing evaluations.	Excellent utilization of lower temperature geo-fluid directly or after other heat removal application; converts geo to transportable high protein product. Very high conversion efficiency for energy in, to energy out; huge potential for future application; may be highly beneficial for aquaculture future in U.S.; can be integrated with other operations, fluid disposal, etc.
Agriculture/ Irrigation	Examine beneficial use of geo-fluid after a primary heat extraction process; examine crop behavior, tolerances, etc; examine soil alterations and mitigating practices; contribute to understanding environmental implications of geo-fluid disposal.	The use of geo-fluids for irrigated crop production, following industrial or power plant heat extraction processes, may reduce or eliminate need for costly re-injection, provide additional source of water for arid geothermal development areas, and may enhance competitive economics of geo-energy.

Work Element	Description	Justification
Geothermal Drying	Examine/demonstrate equipment and techniques for using geothermal heat in industrial/agriculture drying applications.	A large potential application for geothermal heat is in industrial/agriculture moisture removal operations (crop drying, waste concentration, evaporation and crystallization, etc). Penetrating this use category and substituting for conventional fueled techniques is a significant objective that can be advanced by innovative engineering, research and technology demonstrations, and the substitution of low source temperature drying techniques.
Space Conditioning	To examine and demonstrate the use of geothermal fluids to power air conditioning equipment (absorption); examine operating conditions and parameters.	Absorption refrigeration cycles are expected to be an important utilization of geothermal energy. No conventional off-the-shelf units currently available for most geothermal fluid operating ranges and little effort being made by industry to satisfy the need. Stimulation to penetrate the approximate 4 Quad per year U.S. market is needed.
High Temperature Heat Pump	Evaluate high temperature heat pumping to produce high temperature steam. Equipment, operating fluids, economics and efficiencies to be examined.	Future industrial developments around geo-resource expected to require high temperature steam for part of needs. High temperature heat pumps appear to be competitive with fossil fuel generators in producing this high temperature source. Little industry effort on-going in this area. Federal program needed to examine and demonstrate potential.
Residential/Industrial Heat Exchanger Evaluations	Examine design and operating parameters for various heat exchanger equipment elements.	Heat exchanger applications for geothermal fluids expected to be central part of many direct heat uses for the future. No background of techno-economic data exists for accurate evaluation of problems to be faced. Federal programs should take the lead.

Work Element	Description	Justification
Essential Oil Extraction	Demonstrate the use of geo-fluids to substitute for fossil fluids in the essential oil extraction field.	No or little private initiative in this area and application is a good candidate for geo-heat. Federal incentive needed.
Heat Dissipation and Soil Warming	Demonstrate effectiveness of buried pipe grid for power plant cooling and overall economics of system including soil warming/crop growing.	May be competitor to expensive air-cooled cooling towers in water scarce geothermal locales. Area where federal program should take the lead.
Geothermally Assisted Biomass Conversion	Demonstrate potential of enhancing economics of biomass-to-fuels using geo-heat.	Viable biomass-to-liquid fuels program important to U.S. interests. No program in industry coupling geo assist. Prime candidate for government demo and stimulation.
Down Hole Heat Exchanger Evaluations	To evaluate design and operating parameters for downhole Hx's.	Downhole heat exchangers could become an important tool for direct applications but no viable program of design evaluation, optimization, etc., exists. Federal program needs to take the lead.
Materials Testing for Direct Applications	Study of candidate structural materials for direct applications of low-temperature geothermal fluids.	Materials selection for direct applications requires engineering tests to provide baseline selection data. No private organizations currently developing this important data.
Component Test Facility	Provide modular unit capability for geothermal direct use experimental and component testing.	Single facility offers many advantages over individually constructed test facilities. Testing facility could contribute to earlier private involvement in direct heat tests and applications. Providing such test capability is a logical government function.

JUL 26 1979

DOE Form AD-10A
(12-77)

U.S. DEPARTMENT OF ENERGY

memorandum

DATE: JUL 23 1979

REPLY TO
ATTN OF:

SUBJECT: Geothermal Direct Heat Applications Program Plan

TO: Rudolph A. Black, RA

We have now put together a plan which incorporate programs to be undertaken by both the Division of Geothermal Energy and the Geothermal Resource Manager.

The draft of the plan enclosed is based upon work prepared for the Division of Geothermal Energy by INEL, both the San Francisco and Idaho Operations Offices, and the University of Utah Research Institute. It also incorporates information and materials developed in consultation with staff of the Geothermal Resource Manager's Office.

With your concurrence, I would now like to solicit responses from industry and non-government groups involved in direct heat applications of geothermal energy, by setting up a meeting to discuss the plan with them.

Please let me know as soon as possible if you think the plan is now suitable for such outside comments.

John W. Salisbury
Deputy Director
Division of Geothermal Energy

Enclosure

cc:
Clay Nichols, IDO
Tom Heenan, SAN
R. Stiger, INEL
M. Wright, UURI-ESL

→ Jack Salisbury —
comments by DNW and staff
See also separate discussion
sheet. Reads reasonably well, but
needs considerable work yet. Resource
Definition programs are not right.
Mike

GEOTHERMAL DIRECT HEAT APPLICATIONS PROGRAM PLAN

DIVISION OF GEOTHERMAL ENERGY AND
GEOTHERMAL RESOURCE MANAGER

JULY 10TH, 1979

DRAFT

NATIONAL GEOTHERMAL DIRECT HEAT APPLICATIONS PROGRAM PLAN

PREPARED FOR
DIRECTOR OF THE DIVISION OF GEOTHERMAL ENERGY
AND THE GEOTHERMAL RESOURCE MANAGER

BY
DIRECT HEAT APPLICATIONS SECTION
DIVISION OF GEOTHERMAL ENERGY

JULY 10, 1979

EXECUTIVE SUMMARY

The National Geothermal Direct Heat Applications Program Plan is a major new initiative of the Department. It builds on existing program elements by expanding resource definition to a level which assures that the full potential for direct uses can be reached by the year 2,000. Participative development with prospective users will spread the risk of acquiring the resource information and will assist in building a self-sustaining and expanding commercial infrastructure that will exploit the resource.

The program is composed of four major elements: resource definition, utilization development, planning and analysis, and private sector development. It proposes that major funding increases be applied to a coordinated and cost-shared program of reservoir confirmation. This primary activity will be supplemented by support for applications at these sites.

The plan provides that the Department will work closely with state and local governments, citizen groups, financiers, and developers to ensure that the required analysis and institutional modification takes place in a timely fashion.

TABLE OF CONTENTS

INTRODUCTION

The National Geothermal Direct Heat Applications Program Plan describes the goals and strategies for the development of the direct uses of geothermal heat. It consists of the tasks which the Division of Geothermal Energy and the Geothermal Resource Manager will undertake in implementing these strategies. It includes the manpower and financial resources which must be committed to achieve the national goals.

This plan concerns itself strictly with direct uses of geothermal heat and excludes any consideration of electrical generation from these resources. It focuses on the low- to moderate-temperature geothermal resevoirs, but it does not exclude direct applications of high temperature resources.

plan is not an effort

The plan is a major new effort and at the same time a continuation of present activities of both the Division and the Resource Manager. It is based on an increased understanding both of the nature and distribution of the resource and of market realities. Development of direct heat applications of geothermal energy is an integral part of the overall commercialization strategy of the DOE, along with technology development for hot dry rock and a vigorous geopressured resource program.

implies that these three programs are the most important ones.

STRATEGY

The objectives of the Department of Energy for the utilization of geothermal resources of all types include the development of 0.1 to 0.2 Quads* per year of direct heat applications by 1985 and 2 to 4 Quads per year by the year 2,000. This level of direct use of geothermal resources could displace the equivalent of some 13 million barrels of oil in 1985 and 180 million barrels in 2,000.

If the program is not expanded then present projections for direct heat applications amount to only about 0.02 Quads, or 10% of the 1985 goals. The principal factors which account for the difference between the goals and the expected utilization are the high cost and high risks of resource assessment, which is critical for investment in utilization projects.

The economic viability of a particular utilization depends primarily on the temperature, the fluid availability, and the lifespan of the geothermal reservoir. Detailed information of this sort is available for only a few sites in the country. This means that potential investors and developers in general can not make a decision about the use of geothermal energy on the basis of existing information. These investors and developers must undertake expensive reservoir confirmation at unquantified risk levels before they can evaluate the relative economics of the use of geothermal energy as compared to the use of other fuels or energy sources.

* ~~(a Quad is 10 to the 15th BTU)~~
(1 Quad = 10^{15} BTU)

Before geothermal energy will ever be commercialy viable for direct heat applications it will be necessary to accumulate adequately detailed information on the location and characteristics of the resource. At the present time only those projects with very high rates of projected return justify private investment in resevoir confirmation. Only electrical generation projects to date have offered sufficient potential profit to justify exploration and confirmation. This situation is reenforced by the provisions of the National Energy Act.

Potential direct heat applications of geothermal energy do not ordinarily offer the same levels of profitability which induce large resource firms to explore and develop the resources. Large direct heat projects, which typically use less than one thermal megawatt, are much smaller than the 450 megawatts of thermal power which is necessary for operation of a 50 megawatt electrical generating facility, the minimum economic size.

The commercial and industrial firms who could utilize geothermal resources are also ordinarily smaller than the resource companies, and thereby less able to absorb the attendant risk. In fact, industrial and commercial users are not in the risk taking buisness as are the resource development companies. It follows, therefore, that these potential users will not ordinarily choose to invest in reservoir confirmation in order to evaluate a geothermal direct use project.

If the number of direct applications of geothermal resources is to rise to levels commensurate with the potential, then some mechanism must be developed and deployed which deals directly with the diseconomies of aquisition of the requisite information. After carefull consideration of several potential strategies which might meet this critical issue, the DOE has selected a strategy based on direct participative development of the resource information. This option was chosen because it assists in the development of a commercial infrastructure which can take the initiative in exploiting the resource.

In contrast to a resource definition program which supports exploration and drilling of confirmation holes at every potentially valuable reservoir, a participative development program concentrates funding and effort on those reservoirs which are situated in areas where commerical and industrial users are willing to make use of the geothermal resource if it is economical. This ensures that the impact of the resource information on private investment decisions is maximized, and that the federal investment in resource confirmation has the greatest opportunity for return from a commercial application.

how does involving the public alleviate the risk?

The involvement of the public in developing this critical information alleviates the risk which, along with the costs of reservoir ~~information~~ confirmation have detered private investment. By combining this risk-spreading role with the participative development process the public investment has the surest opportunity of leading to actual projects and uses. This approach helps build the infrastructure which is necessary for a self-sustaining and expanding commercial sector.

This basic strategy is complemented by intensive analytic and commercialization efforts, as well as continued technology development of devices and systems that have the potential for affecting the economics of direct heat applications. DOE will continue its innovative institutional work with state and local governments, and with investors and developers to assist in creating a decision-making environment which actively promotes effective and economic projects.

The overall strategy will be subject to adjustment and modification in the course of implementing the national program. This first plan should be viewed as the basis for a continuing process of refinement in the allocation of public resources to the development of significant levels of direct heat utilization of geothermal resources.

WORK ELEMENTS

Implementation of the participative development strategy will involve four work elements. The most important elements are the group of resource definition activities and the group of utilization development activities. These elements are supported by planning and analysis and private sector development. The basic work breadown structure of the plan is illustrated in Figure 1.

1. RESOURCE DEFINITION

The three components of resource definition are the spearhead program, the bounty program, and the cooperative development program.

1.1 ~~Spearhead Program~~ State Coupled Program

There are two ongoing phases of the spearhead program: Phase I, general resource inventory; and Phase II, field work. The general resource inventory of low-and moderate-temperature resources has concentrated on the western states and eastern seaboard, and will be expanded to cover the rest of the country in upcoming years. Field work has concentrated on reservoirs ~~which~~ that are colocated with potential uses. It includes thermal gradient holes and some test wells at promising sites.

FIGURE 1
WORK BREAKDOWN STRUCTURE

NATIONAL GEOTHERMAL DIRECT HEAT APPLICATIONS PROGRAM PLAN

Resouce Definition	Utilization Development	Planning & Analysis	Private Sector Development
* Spearhead Program	* Applications Projects	* Site Specific Planning	* Market Assessment
* Bounty Program	* Technology Development	* State & Local Support	* Geothermal Loan Guaranty
* Cooperative Development	* Utilization Analysis	* Economic Analysis	* Outreach
		* Interagency Coordination	
		* Federal Policy Review	

This is not appropriate for the State Coupled Program.

The most important component of the spearhead program is a major expansion of the test well portion of Phase II. It would consist of an drilling program aimed at specific low and moderate temperature hydrothermal reservoirs with economic potential for which no test wells have been drilled. The function of Phase II is to provide the resource data which will enable the private sector to decide to invest in the cost shared cooperative development program.

1.2 Bounty Program

A substantial amount of information on low-to moderate-temperature reservoirs exists from prior exploration by major resource companies for high temperature geothermal reservoirs in the western states, as well as from prior oil and gas exploration. Ongoing exploration in these areas will continue to produce information which will be usefull for decision-making for direct heat applications investment. A bounty will be used to obtain the logs and well records from these activities. The data will be published as part of the general resource information which the Department makes available.

1.3 Cooperative Development

The single most important element of the national plan is the cooperative reservoir confirmation program which will start in FY-81. It is designed to provide the requisite information for private investment decision-making at reasonable cost and risk levels. It will be the basis for most direct heat application projects.

The cooperative development program consists of an agressive drilling program aimed at confirming specific low-and moderate-temperature hydrothermal reservoirs. The reservoirs chosen for confirmation will be those which combine economic potential with developer interest. It will involve commercial and industrial participants in a variable cost sharing program based on both the economic value of the resource and the sucessfull character of the confirmation well. The Department's share is expected to vary from 10% for sucessfull wells to 100% for unsucessfull wells. The program will use competetive bidding procedures and contracts which can serve as collateral for private development financing.

The amount of exploration and drilling which will be required to enable private investment to reach the national goals is quite large. The Department estimates that 700 confirmation wells must be drilled over a five-year period. This quantity of project starts should yield about 300 sucessfull wells suitable for exploitation by the private participants. Cost sharing will serve to leverage public investment in these wells.

2. UTILIZATION DEVELOPMENT

The three components of this element are the programs for applications projects, technology development, and analysis.

2.1 Application Projects

The Department currently sponsors a number of cost-shared applications projects which were solicited under the Program Opportunity Notice format. They focus primarily on individual retrofit space heating, district heating, and food processing. Future solicitations are expected to stress industrial process heat applications and integrated industrial and community development systems. Future solicitations will also require increased emphasis on energy market impact potential, growth potential, resource expansion potential, transferability, cost sharing ratio, total DOE investment, and energy intensiveness.

The primary functions of the application projects are to provide examples of various direct application systems; to obtain reliable technical, economic, institutional and environmental information on these systems; and to stimulate commercial planning by private and public investors.

The importance of this mechanism for performing these functions is likely to decrease as the participative development process gets underway. During each year the sucessfull reservoir confirmation wells will provide many potential examples of commercial direct applications projects of every sort. These projects are a source of additional information and should stimulate additional investment. The magnitude and focus of the applications projects program will be adjusted annualy on the basis of an analysis of its comparative effectiveness in providing these functions.

2.2 Technology Development

This component of the utilization development element is aimed at expanding the types and numbers of industrial and commercial processes which can efficiently use low-to moderate-temperature geothermal fluids. In addition, ongoing work in drilling and stimulation techniques, in the managment of reinjection, in testing and analysis, in surface exploration systems, in conversion equiptment, and in materials will support the direct heat program.

The principle activity of this task will consist in providing assistence in the development and field testing of both systems and components for particular industrial and commercial processes that can be reconfigured to utilize lower temperature heat. These processes will be selected on the basis of technical potential, economic sensivity to fuel costs, economic contribution to the overall process, and innovation. The selection of the processes, systems, and components will be done in conjunction with the present industrial and commercial users of process heat, the relevant process design engineers, and interested industrial and commercial applicants. The emphasis of the program will be on those processes and systems which have a high potential for significant levels of near-term application.

2.3 Utilization Analysis

This component is composed of two tasks: applications analysis and barrier identification. expand

2.3.1 Applications Analysis

This task will provide a mechanism for updating the technical data base on direct heat applications. Data will be developed on the expand existing and upcoming applications projects, on the projects which will result from the participative development process, and on those projects which result from unassisted private initiative.

2.3.2 Barrier Identification

An examination will be undertaken of the technical obstacles to direct heat applications which result from excessive costs, inefficiency, or lack of critical components or systems. It will require an extremely close working relationship with private sector plant and program managers.

3. PLANNING AND ANALYSIS

The five components of this element are site specific development planning, state and local planning, economic studies, interagency coordination, and federal policy analysis.

3.1 Site Specific Development Planning

The Department will cooperate with state and local government agencies, citizen's groups, the financial community, and the industrial and commercial community to formulate development plans for specific reservoirs which will be selected on the basis of their proximity to present or possible markets. The plans will delineate consensus goals for reservoir development, public and private actions implied by these goals, and schedules and resources.

This task obviously is an integral part of the participative development process. It is the means whereby the Department identifies the critical reservoirs for confirmation. It is also the means by which both public and private groups identify the opportunity for action.

3.2 State and Local Planning Support

The Department will cooperate with state and local governments in supporting the development of institutions which will undertake planning and coordination within these governments; and between them and the private sector. These institutions would be similar in scope and purpose to the California Geothermal Resources Board or the GRIPS Commission - (Geothermal Resource Impact Projection Study).

They would participate in the reservoir specific planning process, in the development of data bases for land and water use regulation, and in the generation of state and local institutional programs. They would also serve to coordinate with federal programs.

3.3 Economic Studies

The Department will develop detailed analyses of the comparative market value of geothermal resources in the relevant utilization markets. It will evaluate total programatic costs to both the public and private sector which would result from achievement of the national direct heat utilization goals. It will undertake an assessment of the net energy production of direct heat use developments, and the consequent national benefit/cost ratio.

3.4 Interagency Coordination

The Department will continue to support the activities of the Interagency Geothermal Coordinating Council and the Budget and Planning Working Group. These entities provide critical forums for addressing issues that affect more than one agency's responsibilities and programs. The IGCC is the offical source of recommendations to the Congress on items of legislation which affect geothermal development.

3.5 Federal Policy Analysis

This element is one major source of the integrated program which the Department will present to the IGCC. This is an ongoing function of the Department which analyzes the impact of federal legislation and regulation on the development of geothermal resources. Electrical generation has been a primary focus of the analysis, but the new emphasis will be on direct heat uses. Environmental issues, tax issues, leasing policies, and lending policies will come under consideration.

4. PRIVATE SECTOR DEVELOPMENT

This element has three components: market assessment, the Geothermal Loan Guarranty Program, and an outreach program.

4.1 Market Assessment

The function of this activity is to provide the detailed information and analysis which will enable the Department to assist in the formation of the infrastructure which is necessary for a selfsustaining and expanding commercial sector. The entire aim of the national direct heat program is to assist in the development of such an infrastructure which will then take the initiative in exploiting the resouce.

Market assessment is one mechanism which enables public managers to (intelligently) allocate their resources to those particular strategies which not only bring direct heat uses on line, but do so in such a way as to encourage private buisness activity. This assessment will be undertaken in conjunction with corporate planners and financial managers.

4.2 Geothermal Loan Guaranty Program

The Geothermal Loan Guaranty Program (GLGP) is an ongoing activity of the Department. It offers a 75% federal guaranty of the investment in geothermal resource utilization systems, including coverage of some of the reservoir confirmation and development work associated with the project.

This program will be reassesed as a part of the national direct heat plan. An increased emphasis will be placed on involvment of the GLGP as a constituent of reservoir development planning which will aid the medium-to small-scale potential direct heat user.

4.3 Outreach

This element of the program includes all of those activities in which the Department interacts with professional associations and with the public in desseminating information. Presently these activities include work with ASHRAE - the Association of Heating, Refrigeration and Air Conditioning Engineers, and with ASME - the American Society of Mechanical Engineers. The DOE will continue ~~and~~ to expand its existing support of seminars and programs with the Geothermal Resources Council and other groups. It will coordinate the participative development program with an effective public awareness program.

This activity also includes limited direct assistance to potential users so that they can evaluate the resource and process criteria and make an initial determination of the economics of an application. Assistance is presently being provided to potential users in the Western states, but the program will be made available on a nationwide basis.

need a milestone chart, too

COSTS AND SCHEDULES

!. RESOURCE DEFINITION

	FY 79	FY 80	FY81	FY 82	FY 83	FY 84	FY 85
Planned	9.9M	7.2M	13M	16.5M	16.5M	16.5M	16.5M
Additional		10M	32.1M	58.5M	75.5M	55.9M	30.2M

2. UTILIZATION DEVELOPMENT

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Planned	9.3M	11.5M	18.7M	12.3M	9.4M	6.4M	4.3M
Additional				25.6M	31.2M	26.8M	13M

3. PLANNING AND ANALYSIS

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Planned							
Additional							

4. PRIVATE SECTOR DEVELOPMENT

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Planned							
Additional							

A. TOTAL PLANNED COSTS

	TO 1985
1. RESOURCE DEFINITION	96.3M
2. UTILIZATION DEVELOPMENT	71.9M
3. PLANNING AND ANALYSIS	
4. PRIVATE SECTOR DEVELOPMENT	
PROGRAM TOTAL	

B. TOTAL ADDITIONAL COSTS

	TO 1985
1. RESOURCE DEFINITION	261.7M
2. UTILIZATION DEVELOPMENT	96.6M
3. PLANNING AND ANALYSIS	
4. PRIVATE SECTOR DEVELOPMENT	
PROGRAM TOTAL	

C. ANNUAL PROGRAM TOTALS

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Planned							
Additional							

JUSTIFICATION AND BENEFITS

1. JUSTIFICATION

The U.S. Geological Survey assessment of geothermal resources for 1978, Circular 790, shows an exponential increase in the occurence of reservoirs as the temperature of the resource decreases. See Figure 1. Current technology limits cost-competitive electric power generation to the higher temperature resource. It follows that the potential for direct heat utilization is greater than the potential for electrical production.

The increase in reservoir occurence with declining temperature implies that the probability of resource colocation with users and markets increases similarly. Figure 2, taken from Circular 790, shows the best present knowledge about the distribution of resources of 90 degrees Centigrade or hotter. It illustrates the relative areas of distribution for high-and low-to mid-temperature resources.

Colocation is unimportant unless the resource can supply heat at temperatures which are usefull for space heating and commercial and industrial processes. Geothermal resources ranging up to 150 degrees

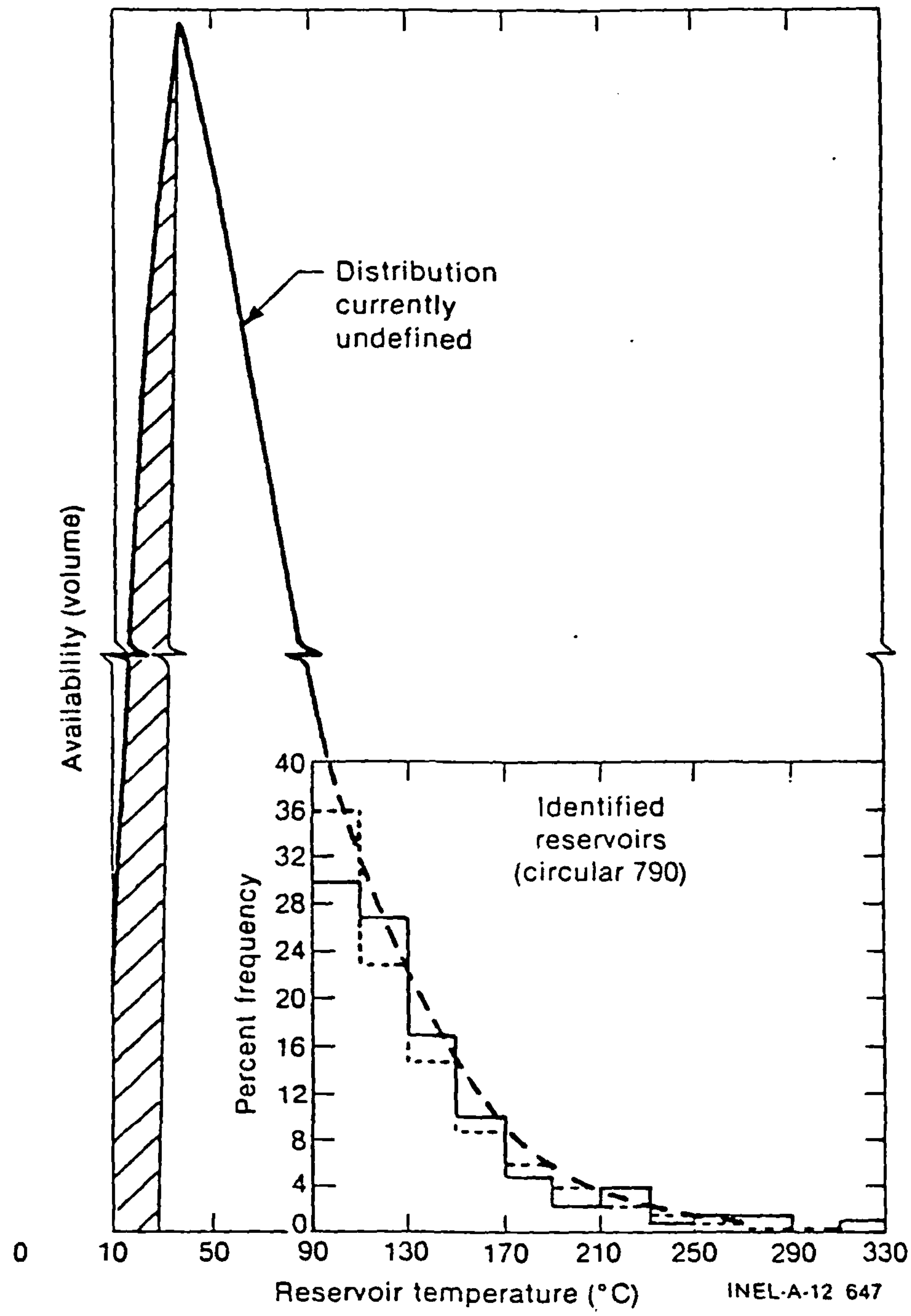


Fig. 1 Geothermmal resource temperature/occurrence profile.

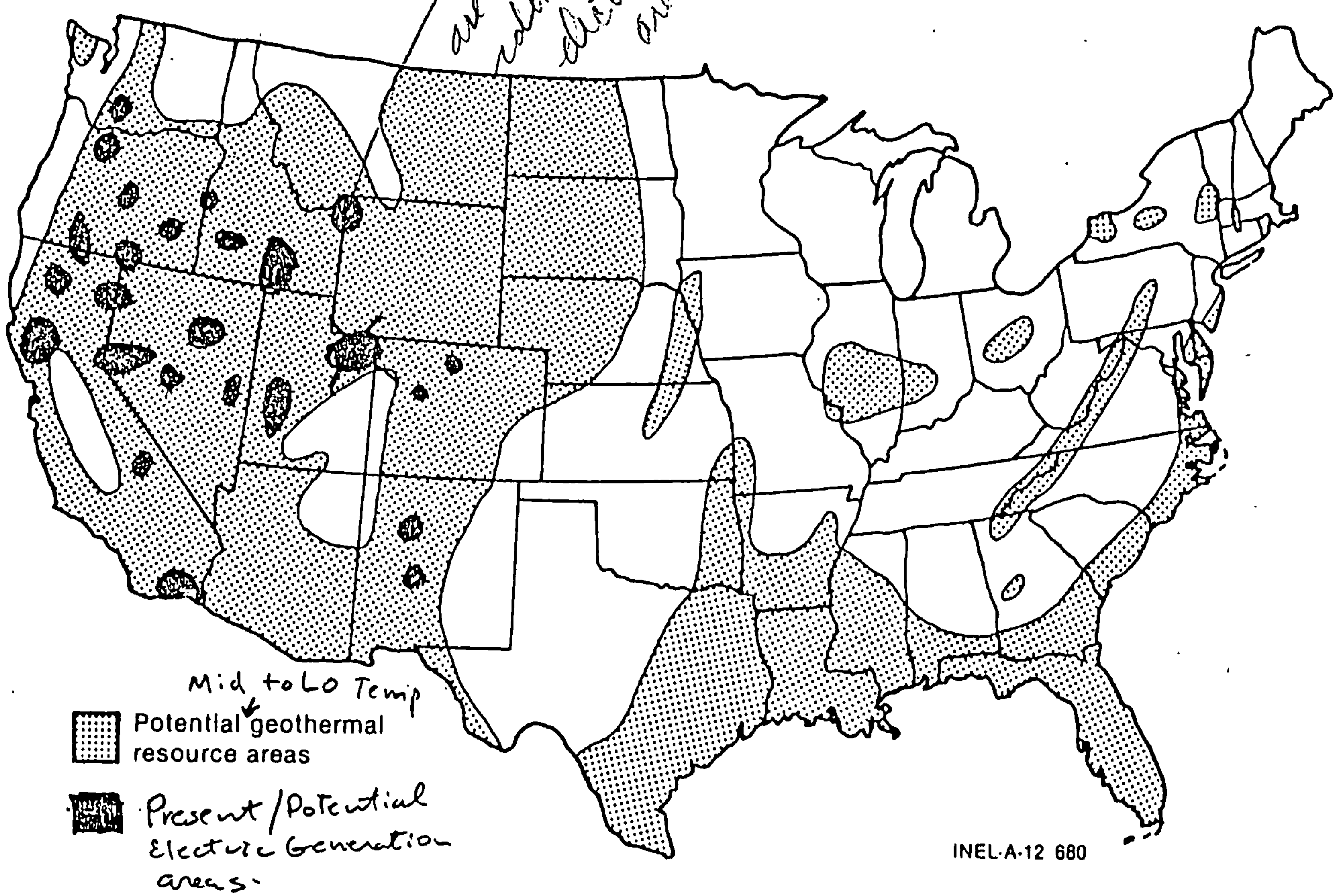


Fig. 2 Location of favorable resource areas for direct heat uses.

Exclude Elec. Gen. Sites

correspond very well to the temperature ranges for much of the direct heat use in the United States. Figure 3 illustrates the cumulative percentage of national energy use by temperature. It shows that fully 32% of total heat usage is at 150 degrees centigrade or less.

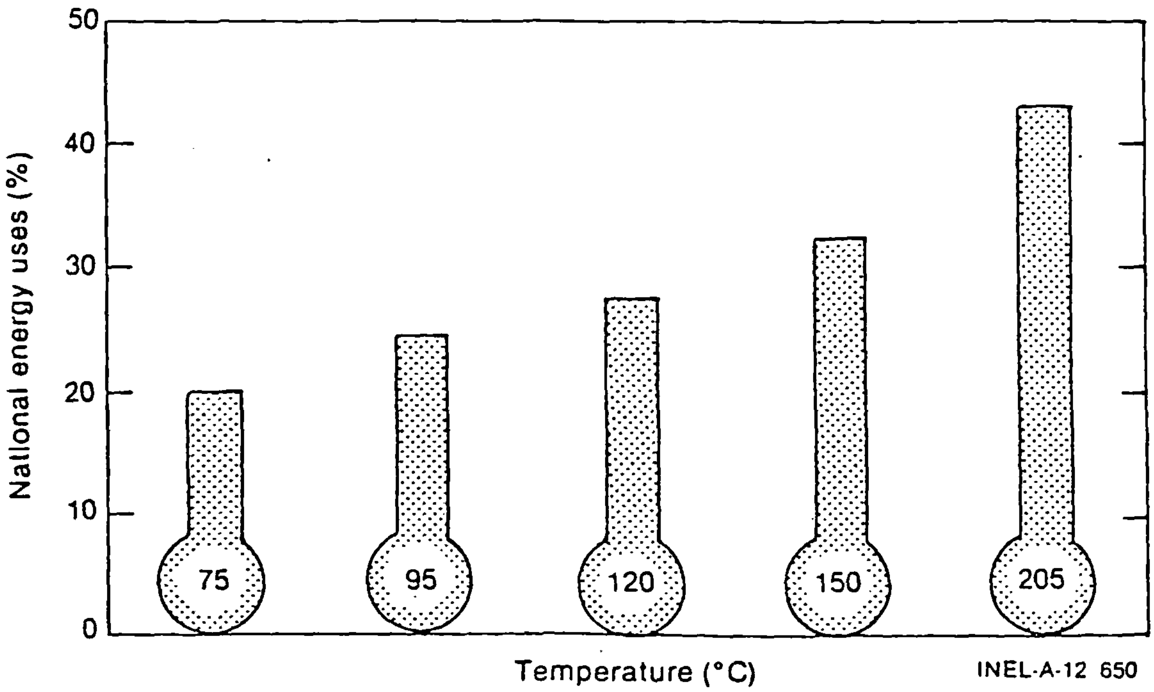


Fig. 3 Cummulative Percent of national energy uses relative to temperature.

use instead Fig, p10 ID/EG&G/UURI version, June 78 document

in the U.S ?

The total hydrothermal direct use potential, is in the range of 1,100 to 1,600 Quads. The ultimate usefulness of this resource can only ~~fully~~ be assessed when detailed market penetration analyses are completed, and these analyses are themselves dependent on resource and economic data that will not be available until the participative development process has been underway for some time. Preliminary analyses done for the 10 western states indicate the potential for 2.5 Quads of space heating use and 1.5 Quads of industrial use by the year 2,000. no comma in dates

2. BENEFITS

The national importance of direct heat applications of geothermal resources can not be assessed by simple calculations of energy provided, used, or displaced. Geothermal resources are entirely within the boundaries of the United States and offer a resouce not subject to external political interuption. Consequently they are an integral element in the national program to diminish our dependence on imports.

Use of the heat content of geothermal fluids offers the potential of greater thermodynamic efficiency in our use of all energy resources. These low-to medium-temperature fluids can be delivered to a task at a temperature which is very close to that needed by the task

very awkward

allowing higher temperatures resources to be displaced from low temperature tasks.

The decentralized character of geothermal use implies another important savings in lowered transportation costs. Present energy delivery systems for fuels and electricity often have substantial losses from transportation which will not be incurred when the direct heat user is at or near the production site.

There is another important feature of the decentralized nature of direct heat use. The benefits and costs of use are realized at the local and regional level. Analysis shows that 3.3 billion dollars of tax revenue could accrue to local and state governments if Department goals for development are reached by the year 2,020.

National income from taxes and royalties could be as much as 64 billion dollars under these circumstances. The GNP could be increased by 50 billion dollars or more during the next forty years. This level of investment and use could lead to as much as a 750 million dollar a year decrease in our balance of payments.

These benefits can be gained without incurring associated environmental degradation, since geothermal resource use is ordinarily environmentaly benign.

STATUS

The present direct heat applications program includes a significant utilization component with 22 projects. These projects include industrial and process heating, space heating and cooling, district heating, agricultural, aquacultural and livestock applications. They include engineering and economic analyses and commercial operations.

Direct heat are supported by a state coupled resouce assesment program in the 14 western states. This assessment program operates in cooperation with the U.S. Geological Survey in providing regional scale maps and reports on the occurence of low to moderate temperature resources. It has been supplemented by resource assessment directly through contractors for the eastern seaboard, and by the industry coupled program in which the Department obtaines data from wells drilled for high temperature resources.

The ongoing activities of the Division of Geothermal Energy include many technical elements which have the potential for assisting in the commercial development of materials, components, and systems which could lower the costs of direct use. The ongoing activities of the Geothermal Resource Manager in planning and development are assisting in developing the institutional and commercial infrastructure that will undertake exploitation of this resource.

JAN 1 4 1980

NATIONAL GEOTHERMAL DIRECT HEAT APPLICATIONS MANPOWER AND EXPENDITURE REQUIREMENTS THROUGH 1987

PRELIMINARY DRAFT

PREPARED FOR
DEPARTMENT OF ENERGY
RESOURCE APPLICATIONS
GEOTHERMAL RESOURCE OFFICE

BY

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PRELIMINARY DRAFT

NOVEMBER 1979

PRELIMINARY DRAFT

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FIGURES

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A. SUMMARY

About 6800 MW of geothermal direct heat applications power could be operative on a national basis in 1987, assuming the implementation of a federal user-coupled development program in 1981. The program could result in district heating, industrial park, and single industry projects, ranging in size from 100 MWt to less than 5 MWt, and costing from $300 to $799 per kW for the geothermal system portion of a facility. This will represent expenditures of about $18 million for the user-coupled development program, and over $3 billion for installation of the geothermal hardware systems. Considering both retrofitting and construction of new facilities, a total of over $20 billion could be spent by industry and the federal government from now through 1987. Considering that about nine percent of the U.S. labor force will be directly employed in some energy production/distribution capacity in 1987, and the geothermal energy portion being less than one percent of the total energy scene, the budding infrastructure of developers, financiers, builders, and operators could readily grow out of available national financial and manpower resources to meet the need.

B. BACKGROUND

There are many more low- and moderate-temperature (30 to 150°C) geothermal resources than high temperature (>150°C) resources, and there appears to be an exponential increase in the number of known occurrences as the temperature of the resource decreases. It is therefore possible that direct heat utilization of low- and moderate-temperature geothermal resources will ultimately contribute more power on line than will electrical power generation from high temperature resources.

The use of low- and moderate-temperature resources is presently limited because of the lack of resource knowledge, high risk levels, and high costs associated with reservoir confirmation. Small developers, the ones most likely to be interested in low- and moderate-temperature resources, cannot spread the risk and cost the same way as a large company. Therefore, without federal assistance, only a limited use of these resources is expected in the near future.

A federal program is needed to stimulate reservoir confirmation by absorbing part of the risks and costs. The program would help foster economic use of low- and moderate-temperature geothermal resources by the private sector about 1986 by developing the infrastructure of manpower and financing needed but now lacking in the private sector. An estimated 25% of this infrastructure should be developed through the DOE user-coupled program so that private industry would produce about 1.5 quads of direct use geothermal energy by the year 2000. By 1987, the program would develop 0.15 quads while private industry produces 0.05 quads. Assuming that DOE support efforts start in 1981, peak in 1983, and end in 1986, 660 projects would be initiated during this period.

C. INTRODUCTION

In this document, the manpower and expenditure requirements through 1987 for national geothermal direct heat applications are generally defined and discussed. The conclusions are based on a study of three basic geothermal systems; district heating, industrial park, and single industry. These have been studied from the standpoint of predicted number, size, cost, and when they could be operational. This forecast is predicated upon the implementation of a federal user-coupled development program spending about $250 million through 1986, the major elements of which are discussed. Also provided is information on the number of earth scientists, drilling, contractors, designers, engineers, and operators needed. Both federal and private industry manpower and expenditure needs are discussed. Lastly, this report addresses employment levels required to operate geothermal facilities after they become operational.

D. GENERAL APPROACH

The general approach to this effort is described below:

1. Projects Planned.
   - The number, size, and type of projects necessary to develop an early self-sustaining national geothermal industry were identified. Current and presently planned projects were reviewed, and projected on-line dates determined. Estimates of type, size and schedule for development projects to 1987 were made.

2. Reservoir Confirmation Scenarios Developed.
   - The quantity and timing of first drill holes needed to confirm the existence of viable geothermal reservoirs for the above projects were estimated. Drilling success ratios were assumed, and development activities are identified and costed for both federal and industrial participation.

3. Project Costs Estimated.
   - Typical systems costs were developed from existing data for current operational systems, federal PON and PRDA program projects, and from other available sources. These data were used to estimate costs anticipated for work beyond the reservoir confirmation stage.

4. Manpower Needs Estimated.
   - The type and quantity of manpower required for the development of geothermal reservoirs, and for the construction and initial operation of geothermal facilities, were projected for each year between 1981 and 1987.

E. GENERAL ASSUMPTIONS

1. Projections are based upon a DOE user-coupled program cost of $250 million through 1986. Any increase or decrease in this amount should cause the numbers of this report to change proportionally.

2. Development of three generic geothermal systems, single industry, industrial park, and district heating, were assumed in order to estimate development, manpower and expenditure requirements through 1987.

3. Success ratios were assumed for the reservoir confirmation drilling necessary for the discovery and development of geothermal reservoirs.

4. The private sector, with other currently active federally assisted programs, were assumed to develop about 25% of the geothermal energy placed on line, while the federal user-coupled development program stimulates the development of 75% of the direct applications geothermal energy placed on-line by 1987.

5. Facility design being done in a current year will be for a project that will be operational three years later.

6. Labor and material costs are split evenly over the years of design and construction. "Other" costs identified are mostly plant testing and initial start-up efforts, and are considered to occur in the year the plant goes on-line.

7. Projections include a 25% retrofit factor for areas where geothermal reservoirs are colocated with existing facilities.

8. A ratio of gross capital assets to employment is used to determine employment levels for operating facilities once they become operational.

F. DEVELOPMENT

1. Forecasted Projects

- The number, size, and types of facilities postulated to be operational in 1987, assuming the implementation of the federal development program, are shown in Table I.

- The projects identified in Table I are expected to become operational between 1980 and 1987 as shown in Tables II, III, and IV, and summarized in Table V. It is assumed that some of these direct applications projected will develop at existing electric generation sites.

2. Average Development Times

Average resource development and facility construction times have been assumed, and are shown in Table VI.

3. Reservoir Confirmation and Development

- User-Coupled Development Program: A program consisting of DOE cost-shared geothermal surface exploration and drilling for reservoir confirmation to support the projects previously identified should result in about 6800 MWt (5400 MWt from this program while private industry is developing 1800 MWt) of direct heat applications energy on-line in 1987, and over 66,000 MWt by the year 2000. About 660 projects are needed to assure these results. The quantity of projects, their success ratios, and their cost share values are shown in Table VII.

TABLE I

ESTIMATED PROJECT SIZE AND TYPE DISTRIBUTION

SIZE	DISTRICT HEATING	INDUSTRIAL PARK	SINGLE INDUSTRY	TOTAL UNITS
GOVERNMENT ASSISTED				
100 MWt	1	5	0	6
50 MWt	4	13	6	23
25 MWt	18	18	35	71
10 MWt	39	15	60	114
5 or less MWt	23	0	50	73
				287
PRIVATE				
100 MWt	0	1	1	2
50 MWt	2	4	1	7
25 MWt	2	4	7	13
10 MWt	7	5	21	33
5 or less MWt	46	0	69	115
				170

TABLE II

SINGLE INDUSTRY PROJECTS OPERATIONAL EACH FISCAL YEAR

	FISCAL YEAR							
	80	81	82	83	84	85	86	87
° First Hole Stimulated								
100 MWt								
50 MWt					1* - 50** MWt	1 - 50 MWt	2 - 100 MWt	2 - 100 MWt
25 MWt					4 - 100 MWt	8 - 200 MWt	10 - 250 MWt	13 - 325 MWt
10 MWt		3 - 30 MWt	5 - 50 MWt	10 - 100 MWt	14 - 140 MWt	15 - 150 MWt	7 - 70 MWt	5 - 50 MWt
< 5 MWt	3 - 15 MWt	6 - 30 MWt	10 - 50 MWt	9 - 45 MWt	8 - 40 MWt	6 - 30 MWt	5 - 25 MWt	4 - 20 MWt
Sub-Total	3 - 15 MWt	9 - 60 MWt	15 - 100 MWt	19 - 145 MWt	27 - 330 MWt	30 - 430 MWt	24 - 445 MWt	24 - 495 MWt
Sub-Total Cumulative	3 - 15 MWt	12 - 75 MWt	27 - 175 MWt	46 - 320 MWt	73 - 650 MWt	103 - 1080 MWt	127 - 1525 MWt	151 - 2020 MWt
° Industry								
100 MWt								
50 MWt							1 - 50 MWt	
25 MWt					1 - 25 MWt	2 - 50 MWt	2 - 50 MWt	2 - 50 MWt
10 MWt		1 - 10 MWt	1 - 10 MWt	2 - 20 MWt	4 - 40 MWt	4 - 40 MWt	4 - 40 MWt	5 - 50 MWt
< 5 MWt	2 - 10 MWt	4 - 20 MWt	10 - 50 MWt	9 - 45 MWt	9 - 45 MWt	10 - 50 MWt	12 - 60 MWt	13 - 65 MWt
Sub-Total	2 - 10 MWt	5 - 30 MWt	11 - 60 MWt	11 - 65 MWt	14 - 110 MWt	16 - 140 MWt	19 - 200 MWt	20 - 165 MWt
Sub-Total Cumulative	2 - 10 MWt	7 - 40 MWt	18 - 100 MWt	29 - 165 MWt	43 - 275 MWt	59 - 415 MWt	78 - 615 MWt	98 - 780 MWt

* Number units operational this year.
** Total MWt Direct Applications Power-on-Line.

TABLE III

INDUSTRIAL PARK PROJECTS OPERATIONAL EACH FISCAL YEAR

	FISCAL YEAR							
	80	81	82	83	84	85	86	87
° First Hole Stimulated								
100 MWt						1* - 100** MWt	2 - 200 MWt	2 - 200 MWt
50 MWt						2 - 100 MWt	5 - 250 MWt	6 - 300 MWt
25 MWt					2 - 50 MWt	3 - 75 MWt	5 - 125 MWt	8 - 200 MWt
10 MWt		1 - 10 MWt	2 - 20 MWt	4 - 40 MWt	4 - 40 MWt	2 - 20 MWt	1 - 10 MWt	1 - 10 MWt
< 5 MWt	--	--	--	--	--	--	--	--
Sub-Total		1 - 10 MWt	2 - 20 MWt	4 - 40 MWt	6 - 90 MWt	8 - 295 MWt	13 - 585 MWt	17 - 710 MWt
Sub-Total Cumulative		1 - 10 MWt	3 - 30 MWt	7 - 70 MWt	13 - 160 MWt	21 - 455 MWt	34 - 1040 MWt	51 - 1750 MWt
° Other								
100 MWt							1 - 100 MWt	1 - 100 MWt
50 MWt						1 - 50 MWt	1 - 50 MWt	2 - 100 MWt
25 MWt			1 - 25 MWt			1 - 25 MWt	1 - 25 MWt	1 - 25 MWt
10 MWt				1 - 10 MWt	1 - 10 MWt	1 - 10 MWt	1 - 10 MWt	1 - 10 MWt
< 5 MWt	--	--	--	--	--	--	--	--
Sub-Total			1 - 25 MWt	1 - 10 MWt	1 - 10 MWt	3 - 85 MWt	4 - 185 MWt	5 - 235 MWt
Sub-Total Cumulative			1 - 25 MWt	2 - 35 MWt	3 - 45 MWt	6 - 130 MWt	10 - 315 MWt	15 - 550 MWt

* Number units operational this year.
** Total MWt Direct Applications Power-on-Line.

TABLE IV

DISTRICT HEATING PROJECTS OPERATIONAL EACH FISCAL YEAR

	FISCAL YEAR							
	80	81	82	83	84	85	86	87
° **First Hole Stimulated**								
100 MWt								1 - 100 MWt
50 MWt						1* - 50** MWt	1 - 50 MWt	2 - 100 MWt
25 MWt					2 - 50 MWt	3 - 75 MWt	5 - 125 MWt	8 - 200 MWt
10 MWt		2 - 20 MWt	3 - 30 MWt	10 - 100 MWt	10 - 100 MWt	7 - 70 MWt	4 - 40 MWt	3 - 30 MWt
< 5 MWt	2 - 10 MWt	2 - 10 MWt	4 - 20 MWt	4 - 20 MWt	4 - 20 MWt	2 - 10 MWt	2 - 10 MWt	2 - 10 MWt
Sub-Total	2 - 10 MWt	4 - 30 MWt	7 - 50 MWt	14 - 120 MWt	16 - 170 MWt	13 - 205 MWt	12 - 225 MWt	16 - 440 MWt
Sub-Total Cumulative	2 - 10 MWt	6 - 40 MWt	13 - 90 MWt	27 - 210 MWt	43 - 380 MWt	56 - 585 MWt	68 - 810 MWt	84 - 1250 MWt
° **Other**								
100 MWt								
50 MWt				1 - 50 MWt				1 - 50 MWt
25 MWt						1 - 25 MWt	1 - 25 MWt	
10 MWt			2 - 20 MWt	1 - 10 MWt	1 - 10 MWt	1 - 10 MWt	1 - 10 MWt	1 - 10 MWt
< 5 MWt	1 - 5 MWt	2 - 10 MWt	5 - 25 MWt	7 - 35 MWt	7 - 35 MWt	8 - 40 MWt	8 - 40 MWt	8 - 40 MWt
Sub-Total	1 - 5 MWt	2 - 10 MWt	7 - 45 MWt	9 - 95 MWt	8 - 45 MWt	10 - 75 MWt	10 - 75 MWt	10 - 100 MWt
Sub-Total Cumulative	1 - 5 MWt	3 - 15 MWt	10 - 60 MWt	19 - 155 MWt	27 - 200 MWt	37 - 275 MWt	47 - 350 MWt	57 - 450 MWt

* Number units operational this year.
** Total MWt Direct Applications Power-on-Line.

TABLE V

SUMMARY OF PROJECTS OPERATIONAL EACH FISCAL YEAR

	FISCAL YEAR							
	80	81	82	83	84	85	86	87
Summary								
° Single Industry								
Total	5* - 25** MWt	14 - 90 MWt	26 - 120 MWt	30 - 210 MWt	41 - 440 MWt	46 - 570 MWt	43 - 645 MWt	44 - 660 MWt
Total Cumulative	5 - 25 MWt	19 - 115 MWt	45 - 275 MWt	75 - 485 MWt	116 - 925 MWt	162 - 1495 MWt	205 - 2140 MWt	249 - 2800 MWt
° Industrial Park								
Total		1 - 10 MWt	3 - 45 MWt	5 - 50 MWt	7 - 100 MWt	11 - 380 MWt	17 - 770 MWt	22 - 945 MWt
Total Cumulative		1 - 10 MWt	4 - 55 MWt	9 - 105 MWt	16 - 205 MWt	27 - 585 MWt	44 - 1355 MWt	66 - 2300 MWt
° District Heating								
Total	3 - 15 MWt	6 - 40 MWt	14 - 95 MWt	23 - 215 MWt	24 - 215 MWt	23 - 280 MWt	22 - 300 MWt	26 - 540 MWt
Total Cumulative	3 - 15 MWt	9 - 55 MWt	23 - 150 MWt	46 - 365 MWt	70 - 580 MWt	93 - 860 MWt	115 - 1160 MWt	141 - 1700 MWt
GRAND TOTAL	8 - 40 MWt	21 - 140 MWt	43 - 300 MWt	58 - 475 MWt	72 - 755 MWt	80 - 1230 MWt	82 - 1715 MWt	92 - 2145 MWt
GRAND TOTAL CUMULATIVE	8 - 40 MWt	29 - 180 MWt	72 - 480 MWt	130 - 955 MWt	202 - 1710 MWt	282 - 2940 MWt	364 - 4655 MWt	456 - 6800 MWt

* Number units operational this year.
** Total MWt Direct Applications Power-on-Line.

TABLE VI

AVERAGE PROJECT DEVELOPMENT TIME

ACTIVITY	TIME (YEARS)
Resource Development	0 to 2
District Heating	3[a]
Industrial Park	3[a]
Single Industry > 25 MWt	3[a]
Single Industry 5 to 25 MWt	2[a]

[a] After the first producing well.

TABLE VII

FEDERALLY ASSISTED DRILLING SITE PROJECTS SUCCESS RATIOS

ITEM	FISCAL YEAR 80	81	82	83	84	85	86	87	TOTAL
Projects Initiated (%)	0	15	25	30	20	10	0	0	100%
Projects Initiated (No.)	0	100	165	200	130	65	0	0	660
Average Success Ratio	0	60	54	41	31	25	0	0	---
Number of Successes	0	60	89	82	40	16	0	0	287
Number of Failures	0	40	76	118	90	49	0	0	373
% Govt Share* Success/ Failure	0	10/ 100	10/ 100	5/95	5/92	5/90	0	---	

* Assumed percentage of DOE's cost sharing with industry for successful/ unsuccessful resource definition costs. A definition of project success based upon technical achievement (generally temperature, quantity and quality of fluids encountered and/or other quantifiable results, and the cost share ratios, would be made a part of the DOE contract with the developer).

- Surface exploration, temperature gradient drilling and an initial production drill hole, based on the cost share ratios already described, would require federal and industry expenditures as shown in Table VIII. Industry and federal expenditures are shown graphically in Figure 1.

- The manpower and equipment required for reservoir confirmation, including surface exploration, temperature gradient drilling, and an initial production drill hole, are shown in Table IX.

- The manpower, equipment, and expenditure needs of industry, over and above the reservoir confirmation work just discussed, are shown in Tables X and XI.

TABLE VIII

RESERVOIR CONFIRMATION - GEOSCIENCE PORTION
EXPENDITURES
($ Thousands)

ITEM	79	80	81	82	83	84	85	86	TOTALS
	FISCAL YEARS								
No. of Projects	0	0	100	166	200	130	65	0	
FEDERAL PARTICIPATION									
Surface Exploration	0	0	2,840	7,080	10,440	9,710	5,950	1,720	37,740
Gradient Hole Drilling	0	0	3,190	7,970	11,750	10,920	6,690	1,930	42,450
Production & Injection Well Drilling & Testing	0	0	11,710	29,220	43,060	40,060	24,530	7,090	155,670
Sub-Totals	0	0	17,740	44,270	65,250	60,690	37,170	10,740	235,860
INDUSTRY PARTICIPATION									
Surface Exploration	0	0	4,950	10,320	11,980	8,230	4,190	1,160	40,830
Gradient Hole Drilling	0	0	5,550	11,610	13,490	9,260	4,720	1,300	45,930
Production & Injection Well Drilling & Testing	0	0	20,400	42,570	49,440	33,960	17,310	4,790	168,470
Sub-Totals	0	0	30,900	64,500	74,910	51,450	26,220	7,250	255,230
MANAGEMENT ASSISTANCE TO DOE									
Management Costs	0	960	2,160	3,600	3,840	3,040	1,760	160	15,520
TOTAL DOE COSTS (Excluding DOE Staff)	0	960	19,900	47,870	69,090	63,730	38,930	10,900	251,380
TOTAL DOE AND INDUSTRY COSTS	0	960	50,800	112,370	144,000	115,180	65,150	18,150	506,610

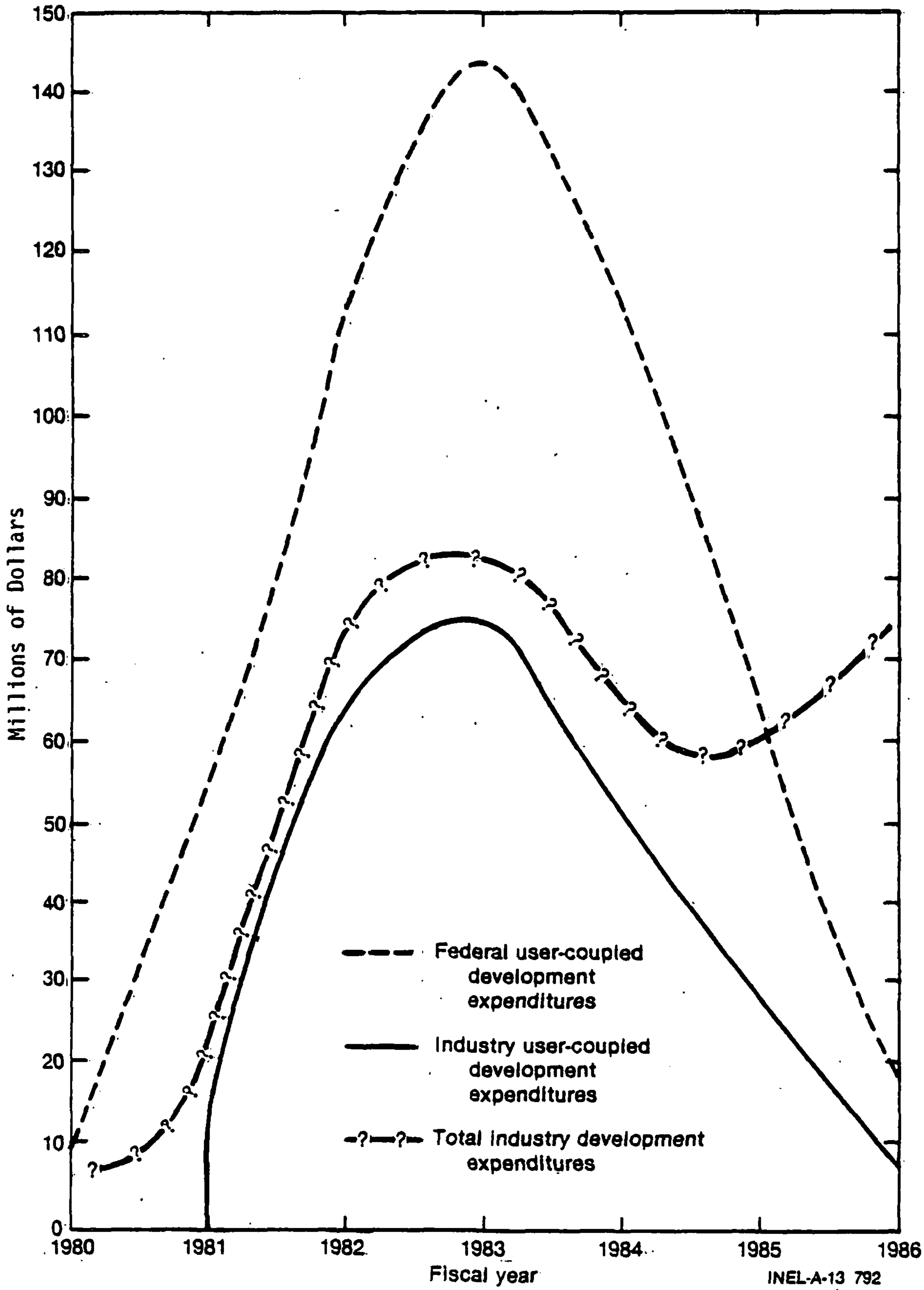

Fig. 1 Expenditures by industry and the federal government for the user-coupled development program.

TABLE IX

RESERVOIR CONFIRMATION MANPOWER & EQUIPMENT REQUIREMENTS

FEDERAL USER COUPLED DRILLING PROGRAM

ITEM	FISCAL YEAR 80	81	82	83	84	85	86
Drill Rigs & Crews							
Deep Production	0	9	19	24	19	11	4
Shallow Production	0	19	42	53	42	23	6
Deep Gradient	0	12	46	60	43	23	6
Shallow Gradient	0	10	39	50	36	19	5
Geologists	10	50	100	130	100	60	20
Geochemists	5	25	50	65	50	30	10
Geophysicists	5	25	50	65	50	30	10
Legal, Land, Environmental People	15	50	100	130	100	40	10
Management	12	27	45	50	38	22	10
TOTAL	47	177	345	440	338	182	60

TABLE X

RESERVOIR DEVELOPMENT BY INDUSTRY
MANPOWER AND EQUIPMENT NEEDS

	FISCAL YEARS							
ITEM	81	82	83	84	85	86	87	TOTAL
Drill Holes	0	70	230	300	350	350	200	1500
Drill Rigs	0	17	60	75	88	88	50	
Support Manpower	30	50	150	200	220	220	100	970

TABLE XI

RESERVOIR DEVELOPMENT BY INDUSTRY
EXPENDITURES
($ millions)

	FISCAL YEARS							
ITEM	81	82	83	84	85	86	87	TOTAL
Drilling Costs	0	50	140	170	200	200	120	880
Support Manpower	2	3	10	12	13	13	7	60
TOTAL	2	53	150	182	213	213	127	$940 M

4. Facility Development

- Introduction: The construction of facilities, for which the geothermal reservoirs are being developed, will result in the utilization of manpower, and the expenditure of capital, in approximated amounts as shown later. The diversity of geothermal systems, resource temperatures, flow, quality, distance from the facility, the mix of future systems, and other factors make a "typical" geothermal system or facility difficult to define. However, certain bases are set to discover the possible impact the implementation of a federal development program would have in the market place, and to ascertain the availability of manpower and finances to run it.

- Average Costs: "Average" costs for three generic systems are selected. Following is a summarization of the considerations and assumptions used to select these costs.

Single Industries - $300/kW

- Available cost data for a large number of existing and planned geothermal systems were reviewed.
- Single industry PON costs were reviewed.
- Space heating cost estimates, developed by EG&G Idaho Inc., were reviewed.
- Engineering judgement was used to say that the installation of a single industry facility would be less costly than that of the other two systems.

Industrial Parks - $500/kW

- Available cost data for existing systems were reviewed.
- Industrial park PON costs were reviewed.

- Engineering judgement was used to say that the diversity of users and the cost of construction coordination will result in greater costs than for a single industry.

District Heating Systems - $700/kW

- Available cost data for existing systems were reviewed.
- District heating PON costs were reviewed.
- Danish Board of District heating data[1,2] were reviewed.
- Potential "utility" classification will increase costs.
- Installations are assumed to cost from $400/kW for high density applications to $1000/kW for low density, providing an "average" cost of $700/kW.

Total Plant Systems - $2,000/kW

- This includes a "basic," "average" plant complete with an operating geothermal system. Total costs of a few present industrial facilities were compared with their energy use to arrive at an average cost.
- The geothermal system is assumed to cost $400/kW, which is a reasonable average for the three generic geothermal systems.

Retrofit - $300/kW

The retrofit of existing plant systems, where the facility is in proximity to a geothermal resource (a high potential in the western U.S.), is expected to occur. The cost of this is estimated to be $300/kW, and is considered as a portion of the projects included in Tables II, III, and IV projections.

- Projected Expenditures and Manpower Requirements: The average costs are applied against the projected facilities of Tables II, III, and IV to develop yearly expenditures and manpower needs through 1987. It is assumed that facility design being performed in a current year is for a project that will be operational three years later. Labor and material costs are split evenly over the years of design and construction. Plant testing and start-up is assumed to occur in the year the plant becomes operational. Design and construction costs are shown for the year in which they are expected to occur. Expenditures are apportioned, by percentage, for design, labor, material, administration, and other (plant testing and initial start-up) costs. Labor costs are assumed to be $17 per hour for laborers, and $30 per hour for engineers and technical people. Project cost estimates were reviewed to develop these percentage breakdowns. The expenditures and manpower requirements through 1987 for the geothermal system portion of each facility are shown in Table XII. Table XIII lists this information for complete "average" facilities with their plant, equipment and operating geothermal system.

- <u>Operating Plant Needs</u>: Employment/investment ratios and coefficients were evaluated to provide a key to determine the manpower requirements for single industry, district heating, and industrial park operating systems. A ratio consisting of assets-per-employee was selected. Assets-per-employee is regarded as gross capital investment. An undepreciated investment base, drawing upon any mix of debt/equity/government subsidy, is assumed. The geothermal applications capital intensity, relative to labor intensity, will be well above the manufacturing industries current median average of $44,005, but not as intensive as for crude oil production and petroleum refining ($240,000 per employee). A weighted base of $175,000 per employee was therefore selected as reasonable for the three geothermal applications being investigated. All values are considered current dollars, and asset inflation is not considered. Asset depreciation is ignored because of the dramatically different applications, and the absence of differentiating the various ownership entities' tax status. Table XIV reflects the derivation of the total employees that will be involved in the operation of the geothermal facilities once they are on-line.

G. CONCLUSIONS

The total 1978 United States energy consumption is about 78 quads. Allowing for an annual compound growth rate of three percent for energy use, and three and one-half percent for the present labor force, we find that the projected use of 0.2 quads of geothermal energy in 1987 is about two-tenths of one percent of the total energy that will be used in that year. About seven percent of the total U.S. labor force is directly employed in some energy production/distribution capacity, and with the present emphasis on energy, it is reasonable to assume that, by 1987, nine percent of the U.S. labor force will be directly employed in this field. At this level of activity, about six tenths of one percent of the total energy-related labor force will be involved in geothermal energy development in 1987. Therefore, it is reasonable to assume that, as the geothermal world expands its size, adequate numbers of personnel and resources will be available from the existing market place for geothermal energy development.

H. REFERENCES

[1] Mogens Larsen, "Fundamentals and Economic Principles in District Heating Planning", Danish Board of District Heating, 1979, pp. 11-14.

[2] Peter Margen, "Large District Heating Systems, Newest Techniques, Applications to U.S. Regions", District Heating Workshop Data, Swedish Trade Commission, 1978.

TABLE XII

PROJECTED EXPENDITURE REQUIREMENT THROUGH FY 1987
FOR FACILITY DEVELOPMENT
GEOTHERMAL SYSTEMS ONLY

($ MILLIONS / MANYEARS)

LABOR TYPE	% OF TOTAL	FISCAL YEAR 80	81	82	83	84	85	86	87
Welders & Steelworkers	1.00	0.85/25.00	1.36/40.00	2.19/64.41	3.21/94.41	4.32/127.06	5.36/157.65	6.55/192.65	7.76/228.29
Painters	0.05	0.04/1.18	0.07/2.06	0.11/3.24	0.16/4.70	0.22/6.47	0.27/7.94	0.33/9.70	0.39/11.47
Laborers & Machine Operators	1.50	1.28/44.11	2.04/60.00	3.29/96.76	4.82/141.76	6.48/190.59	8.04/236.47	9.83/289.12	11.64/342.35
Pipe Fitters	7.20	6.12/180.00	9.79/287.94	15.77/463.82	23.11/679.71	31.10/914.71	38.59/1135.00	47.16/1387.06	55.87/1643.29
Electricians	0.80	0.68/20.00	1.09/32.06	1.75/51.47	2.57/75.59	3.46/101.76	4.29/126.18	5.24/154.12	6.21/182.65
Office Support	13.00	11.05/325.00	17.68/520.00	28.47/837.35	41.73/1227.35	56.16/1651.76	69.68/2049.41	85.15/2504.41	100.88/2967.06
Design & Engineering	12.60	13.26/221.00	19.85/330.83	29.78/493.33	40.45/674.17	50.11/835.17	56.82/947.00	62.88/1048.00	74.50/1241.67
Draftsmen	10.00	11.05/325.00	16.32/480.00	24.09/708.53	32.10/944.12	38.88/1143.53	42.88/1261.18	45.85/1348.53	54.32/1597.65
Inspectors	2.80	1.53/25.50	2.45/40.83	3.94/65.67	8.99/149.83	16.42/273.67	20.37/339.50	24.89/414.83	29.49/491.50
Construction Management	7.90	2.47/41.17	6.67/111.17	15.11/251.83	25.36/422.67	38.45/640.83	58.42/973.67	84.50/1408.33	100.10/1668.33
Project Management	2.30	1.96/32.67	3.13/52.17	5.04/84.00	7.38/123.00	9.94/165.67	12.33/205.50	15.07/251.17	17.85/297.50
Construction Coordination	1.10	0.94/15.67	1.49/24.83	2.41/40.17	3.53/58.83	4.75/79.17	5.90/98.33	7.21/120.17	8.54/142.33
Health & Safety	1.10	0.94/15.67	1.49/24.83	2.41/40.17	3.53/58.83	4.75/79.17	5.90/98.33	7.21/120.17	8.54/142.33
Quality Control	1.10	0.94/15.67	1.49/24.83	2.41/40.17	3.53/58.83	4.75/79.17	5.90/98.33	7.21/120.17	8.54/142.33
Material	37.55	31.92/N/A	51.07/N/A	82.23/N/A	120.54/N/A	162.22/N/A	201.27/N/A	245.95/N/A	291.39/N/A
TOTALS		85/1228	136/2031	219/3240	321/4714	432/6300	536/7735	655/9370	776/11,100

TABLE XIII

PROJECTED EXPENDITURE REQUIREMENT THROUGH FY 1987
FOR FACILITY DEVELOPMENT
PLANT & GEOTHERMAL SYSTEM

($ Million / Manyears)

LABOR TYPE	% OF TOTAL	FISCAL YEAR 80	81	82	83	84	85	86	87
Welders & Steelworkers	1.00	5.38 / 158.23	8.61 / 253.18	13.86 / 407.68	20.32 / 597.56	27.34 / 804.22	33.93 / 997.83	41.46 / 1219.36	49.12 / 1444.62
Painters	0.05	0.25 / 7.47	0.44 / 13.04	0.70 / 20.51	1.01 / 29.75	1.39 / 40.95	1.71 / 50.26	2.09 / 61.39	2.47 / 72.60
Laborers & Machine Operators	1.50	8.10 / 279.19	12.91 / 379.76	20.82 / 612.43	30.51 / 897.26	41.01 / 1206.32	50.89 / 1496.72	62.22 / 1829.96	73.67 / 2166.87
Pipe Fitters	7.20	38.74 / 1139.29	61.96 / 1822.49	99.81 / 2935.71	146.72 / 4302.16	196.84 / 5789.58	244.25 / 7183.88	298.50 / 8779.27	353.62 / 10,400.74
Electricians	0.80	4.30 / 126.79	6.90 / 202.92	11.08 / 325.77	16.27 / 478.44	21.90 / 644.08	27.15 / 798.65	33.17 / 975.49	39.31 / 1156.07
Office Support	13.00	69.94 / 2057.06	111.90 / 3291.29	180.20 / 5299.93	264.13 / 7768.40	355.46 / 10,454.67	441.03 / 12,971.56	538.95 / 15,851.44	638.51 / 18,779.74
Design & Engineering	12.60	83.93 / 1398.80	125.64 / 2093.96	188.49 / 3122.49	256.02 / 4267.10	317.17 / 5286.13	359.64 / 5993.95	397.99 / 6633.22	471.54 / 7859.04
Draftsmen	10.00	69.94 / 2057.06	103.30 / 3038.12	152.48 / 4484.58	203.17 / 5975.72	246.09 / 7237.87	271.41 / 7982.53	290.90 / 8535.40	343.81 / 10,112.18
Inspectors	2.80	9.68 / 161.40	15.51 / 258.43	24.94 / 415.65	56.90 / 948.34	103.93 / 1732.17	128.93 / 2148.84	157.54 / 2625.63	186.65 / 3110.91
Construction Management	7.90	15.63 / 260.58	42.22 / 703.64	95.64 / 1593.94	160.51 / 2675.25	243.37 / 4056.08	369.76 / 6162.76	534.84 / 8913.90	633.57 / 10,559.55
Project Management	2.30	12.41 / 206.78	19.81 / 330.21	31.90 / 531.67	46.71 / 778.52	62.91 / 1048.59	78.04 / 1300.69	95.38 / 1589.76	112.98 / 1883.00
Construction Coordination	1.10	5.95 / 99.18	9.43 / 157.16	15.25 / 254.25	22.34 / 372.36	30.06 / 501.10	37.34 / 623.37	45.64 / 760.60	54.05 / 900.87
Health & Safety	1.10	5.95 / 99.18	9.43 / 157.16	15.25 / 254.25	22.34 / 372.36	30.06 / 501.10	37.34 / 622.37	45.64 / 760.60	54.05 / 900.87
Quality Control	1.10	5.95 / 99.18	9.43 / 157.16	15.25 / 254.25	22.34 / 372.36	30.06 / 501.10	37.34 / 622.37	45.64 / 760.60	54.05 / 900.87
Material	37.55	202.03 / N/A	323.24 / N/A	520.47 / N/A	762.95 / N/A	1026.76 / N/A	1273.92 / N/A	1556.72 / N/A	1844.33 / N/A
TOTALS		538 / 6752	875 / 12,860	1386 / 20,510	2038 / 29,835	2741 / 39,804	3400 / 48,953	4156 / 59,300	4923 / 70,250

TABLE XIV

GEOTHERMAL FACILITIES EMPLOYMENT LEVELS
REQUIRED TO OPERATE PLANTS BEYOND START-UP
BASED ON ASSETS-PER-EMPLOYEE

FISCAL YEAR	ASSETS PER EMPLOYEE ($ THOUSANDS)	PLANT & GEOTHERMAL SYSTEMS INVESTMENT ($ MILLIONS)	PLANT & GEOTHERMAL SYSTEMS EMPLOYEES
1980	175	538	3,075
1981	175	875	5,000
1982	175	1,386	7,920
1983	175	2,038	11,645
1984	175	2,741	15,660
1985	175	3,400	19,430
1986	175	4,156	23,800
1987	175	4,923	28,130
	TOTALS	20,057	114,660