PROPOSED SCOPE OF PHASES II and III

STATE COUPLED PROGRAM

RESERVOIR CONFIRMATION

for

LOW- AND MODERATE-TEMPERATURE GEOTHERMAL RESOURCES

by

Phillip M. Wright

Earth Science Laboratory
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

with contributions by DOE/ID and EG&G, Idaho

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PROPOSED SCOPE OF PHASES II AND III
STATE COUPLED PROGRAM

RESERVOIR CONFIRMATION for LOW- AND MODERATE-TEMPERATURE GEOTHERMAL RESOURCES

PROGRAM SUMMARY

An ambitious program of DOE cost-shared reservoir confirmation is recommended as a vital ingredient to the development of hydrothermal direct heat utilization in the United States. Development is presently hampered by lack of resource knowledge and the high costs and risks of reservoir confirmation. There is presently no adequate infrastructure in the private sector for direct heat development of the magnitude indicated as possible by the predicted large size and widespread occurrence of the resource and of the magnitude indicated as being needed by the Nation's urgent requirement for alternate energy sources.

The program would consist of DOE cost-shared surface exploration and drill confirmation of hydrothermal reservoirs. Users and developers in the private sector would share costs with DOE and would perform the work. DOE's cost share would be low for a successful project (a project that interprets a hydrothermal resource having previously determined temperature and production characteristics) but would be high for unsuccessful projects. Development of the hydrothermal resource, once confirmed, would proceed by private investment, perhaps aided by PON or Loan Guarantee funds.

This program would result in development of an estimated 25 percent of the total infrastructure that will be needed in order for private users to develop about 1.5 Quads of direct heat uses by the year 2000, an amount well within the DOE stated goal of 0.5-2.0. The remaining 75 percent of infrastructure development would come from users once the total economic picture of direct heat use is developed as a result of the recommended program. As a result of this program, about 0.15 Quads of direct heat utilization would result by 1987, in line with DOE's near-term goals.

The total cost to DOE would be about $251 million during the years FY80 to FY86 inclusive. During this interval private capital in the amount of $255 million would be required. The peak year of the program would be 1983 when DOE would budget $69 million and private capital would supply $145 million. Further details of the recommended program are summarized in Table 1 at the end of this report.

It is believed that a program of the proposed magnitude will be required if appropriate infrastructure is to be developed so that hydrothermal energy can make a significant contribution to the Nation's energy supply.

INTRODUCTION

Most geothermal geoscientists agree that there are many more low- and moderate-temperature (30°C to 150°C) geothermal resources than there are high-temperature (>150°C) geothermal resources. U.S. Geological Survey Circular 790, Assessment of Geothermal Resources of the United States--1978, documents the distribution of resources as a function of temperature down to 90°C, with the conclusion that there is an exponential increase in the number of known occurrences as temperature of the resource decreases. This means that the geographic distribution of lower temperature resources is wider and that the possibility of co-location with a user is increased as temperature decreases. The above exponential relationship has also been documented for a number of other natural resources. For example the quantity of copper ore above a certain cutoff grade is known to increase approximately exponentially as the cutoff grade is decreased, both within individual deposits and for the world's copper resource as a whole.

Considering the relationship stated above, it is possible that direct heat utilization of low- and moderate-temperature geothermal resources will ultimately contribute more power on line than will electrical generation from high-temperature geothermal resources simply because lower temperature resources are so much more plentiful and widespread.

There is very little use presently being made of low- and moderate-temperature geothermal resources. The main reasons for this appear to be 1) lack of enough knowledge of the resource itself to attract users, and 2) the present high risk level and high costs associated with reservoir confirmation. By contrast, utilization of a geothermal resource, once it is discovered and confirmed, usually consists of reasonably straightforward engineering.[1]

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[1]Low-temperature geothermal resources generally have low salinities. Special high-temperature equipment and special techniques to handle high salinities are problems usually encountered only with high-temperature resources. Most direct heat geothermal applications can use off-the-shelf equipment and techniques.

Lack of resource knowledge occurs on two levels of detail:

1. On a regional scale, the locations of low- and moderate-temperature resources are poorly known; Phase I of the State Coupled Program has the objective of correcting this deficiency. Maps and compilations of information are only now becoming available in preliminary form through this program;
2. On a site-specific scale, the lateral limits, depth, temperature, productivity, and longevity of very few low- and moderate-temperature geothermal reservoirs are known. Very little surface exploration and drilling have been done.

The present high risk level for reservoir confirmation stems partly from the lack of resource knowledge stated in (2) above and partly from the fact that geothermal reservoirs are never uniform or continuous, so that dry holes can be drilled in the middle of the best of geothermal resources (e.g., The Geysers). The high costs of reservoir confirmation result mainly from the high cost of drilling. Present developers for electrical power generation of high-temperature reservoirs are generally large companies that can finance reservoir confirmation by spreading the high risk and cost over many projects. These large companies are usually not interested in development or utilization of lower temperature reservoirs because of the relatively small scale of such projects. Small developers, the ones most likely to be interested in low- and moderate-temperature geothermal resources, are unable to spread risk and cost in the same way that a large company can, and a single dry well can mean financial disaster for them.

For the above reasons, it is not expected that the direct heat user in the private sector will perform needed reservoir confirmation for low- and moderate-temperature hydrothermal resources in the near future. The result will continue to be very little use being made of the large hydrothermal resource base that exists in the United States.

PRESENT DOE RESOURCE DEFINITION AND CONFIRMATION PROGRAMS

At the present time, DOE/DGE is supporting the State Coupled Program, whose primary focus has been compilation and publication of maps and reports that identify potential low- and moderate-temperature geothermal resource areas on a regional scale (Phase I). A smaller portion of this program has been addressed to detailed exploration and drilling of a few select sites. The program proposed herein concerns a change in emphasis of the State Coupled Program toward a much larger portion of reservoir confirmation activities (Phases II and III). This is the next logical step in the State Coupled Program after regional data have been compiled and assessed.

The Industry Coupled Program of DOE/DGE is a cost-sharing program with industry which has the objective of increasing the amount of exploration and reservoir assessment that industry is able to do for high-temperature resources suitable for electrical power production. In the process of exploration for high-temperature resources, data on low- and moderate-temperature resources are automatically generated at specific sites. This program is currently active at only about 15 sites which have specific high-temperature potential, whereas low- and moderate-temperature reservoir confirmation is needed at many more sites which have no current interest to the large developer.

The DOE Geothermal Direct Application Field Experiment program, known as the PON program, has the goal of demonstrating direct heat use of geothermal energy at sites where the risk associated with reservoir confirmation is low or where the reservoir is already confirmed. This program is currently active at 22 of the 23 sites for which funds have been allocated, and future PON solicitations are planned. As it is currently operating, the PON program is actually performing reservoir confirmation activities. This is being done without the benefit of appropriate exploration guidance. Because the purpose of the PON program is not reservoir confirmation, and because few confirmed reservoirs are known today, the program proposed herein would not overlap the PON program but rather would replace inappropriate PON reservoir confirmation activities with an aggressive, exploration-oriented program that would provide reservoirs needed for continuing the PON program along the originally intended lines.

RECOMMENDED DOE RESERVOIR CONFIRMATION PROGRAM

There is a clear need for a federal program to stimulate site-specific, detailed reservoir exploration and confirmation. Once a reservoir is confirmed it is highly likely that little federal stimulation would be needed to ensure its use. The reservoir confirmation program should include funds for detailed surface exploration aimed at drill site selection and for sufficient drilling to confirm reservoirs in resource areas where private capital would finance utilization and full field development.

Objectives

The objectives of the proposed program are:

1. To foster economically viable use of low- and moderate-temperature geothermal resources by the industrial and private sectors by the year 1985, at which time the program would phase out, and
2. To develop an infrastructure of exploration, confirmation and utilization engineering consultants, contractors, and equipment manufacturers that will facilitate increased economic use of low- and moderate-temperature geothermal resources without the need for federal support beyond 1985.

It is believed that a program of the magnitude proposed herein will be required if both of these objectives are to be achieved.

Strategy

Both of the above objectives can be achieved by a DOE program to fund private users and developers on a variable cost-share basis to carry out confirmation of low- and moderate-temperature hydrothermal reservoirs. Private capital would then take over to finance the installation and operation of utilization systems, the high front-end risk having been assumed by the confirmation program. During the course of the proposed program, an infrastructure would be developed in the private sector which would be able to carry on without federal support beyond 1985. The program would enable development of the knowledge and experience base necessary, but presently lacking in the private sector, to decrease the present high risk and cost factors associated with reservoir exploration, confirmation and testing. Hard data, now unavailable, on the economics of hydrothermal direct heat utilization for the entire sequence from exploration to reservoir confirmation to equipment installation and operation would be generated. In addition, direct heat utilization economics would be favorably changed during the course of the program by the decrease in risk and cost factors of the sequence noted above. By the end of the program, market forces would determine the extent of further development.

Program Size

The required size of the program must be based upon what is needed for development of a self-sustaining infrastructure in the private sector and upon generation of the knowledge and experience base necessary to predict economics accurately. Only in this way will development carry forth when the recommended program is phased out.[2] The infrastructure developed by the program must be large enough that substantial growth in direct heat application can occur both in the short term and in the mid- and long-terms; in other words, so that DOE's direct heat utilization goals of 0.1-0.2 Quads by 1985 and 0.5-2 Quads by 2000 can be achieved.

Let us assume that in order to make a desirable impact on the Nation's energy supply, direct heat utilization of hydrothermal resources must be 1.5+ Quads by the year 2000 and that 1.5 Quads must be developed by private industry between 1986 (the DOE program recommended here would phase out in 1985) and the year 2000. This would require development of an average of:

[2] Of course development will carry on beyond the proposed federally stimulated program only if the economics of such development are favorable.

$$1.5\ Q \times 33{,}400\ \text{MWt-yr/Q} \div 15\ \text{yrs} = 3340\ \text{MWt-yr/yr.}$$

Let us further assume that the average yearly distribution of utilization system sizes brought on line is as follows:

Utilization System Size	Number	Contribution
100 MWt	4	400 MWt
50	15	750
25	50	1250
10	75	750
5	40	200
	184	3350 MWt

This means that private users would be required to bring 184 reservoir confirmation projects to a successful conclusion each year between 1986 and the year 2000. Assuming an average 25 percent success rate for reservoir confirmation projects, about 735 projects would have to be initiated per year, or an average of about 15 projects per year per state.

The infrastructure needed for industry to perform this task would be large indeed, and there is no need for federal support for its entire development. Suppose instead that the total infrastructure develops along the lines shown in Figure 1. This figure shows the schedule for reservoir confirmation projects to the year 2000. Obviously the required infrastructure is approximately proportional to the number of projects per year. Figure 1 shows that the recommended DOE program should peak in 1983, when about 200 DOE-funded reservoir confirmation projects would be initiated. Assuming Figure 1 to be a viable scenario for the DOE program, the following project schedule would be indicated:

Year	FY80	FY81	FY82	FY83	FY84	FY85	FY86
Number of Reservoir Confirmation Projects Initiated	0	100	165	200	130	65	0

Thus the DOE program would fund initiation of a total 660 projects during 5 years and would support the development of about 25 percent of the total infrastructure needed to reach the year 2000 direct heat utilization goals. The remaining 75 percent of infrastructure development would be completed by the private sector. Infrastructure development beyond 1985 would, of course, depend upon the overall economics of direct heat utilizaton at that time, which can not now be evaluated but which will be amenable to evaluation in 1985 as a result of data generated by the recommended DOE program.

Program Ingredients

So far we have determined, using a number of assumptions, that the DOE program should consist of 660 reservoir confirmation projects to be performed over the interval FY81 to FY85 inclusive. In order to determine other program requirements and benefits and to estimate an annual cost, we must assume a more detailed success rate for early phases of the program. Figure 2 shows a decreasing success rate over the life of the DOE program from 60 percent in early phases to 25 percent in later phases. The success rate decreases with time because the projects funded early on would be those where good resource data exist, where there are favorable surface geothermal manifestations, or where there are other factors which increase odds of success. Later projects would be more "wildcat" in nature, and the success rate would be even lower than 25 percent were it not for the development of exploration technology and experience as the program progresses.

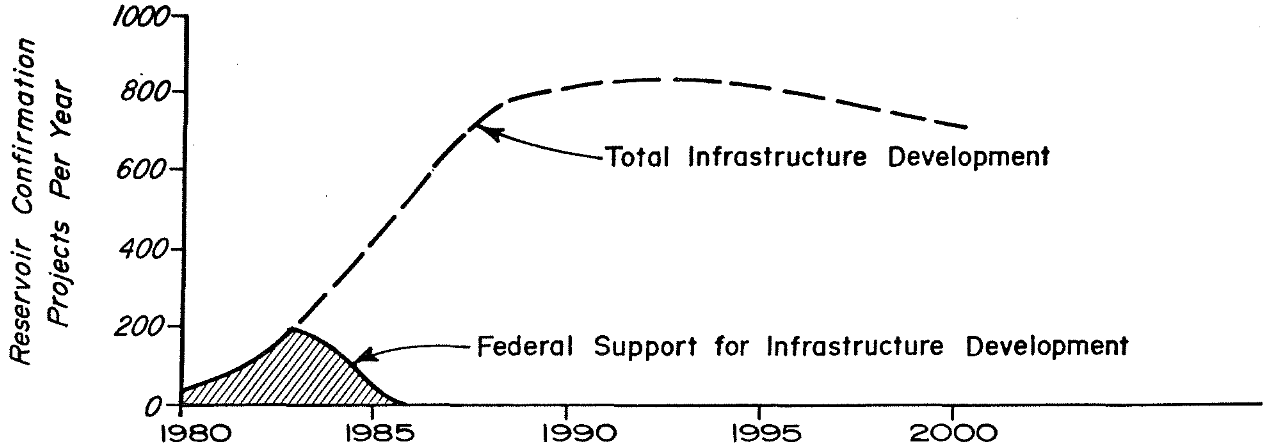

Figure 1

POSTULATED INFRASTRUCTURE DEVELOPMENT

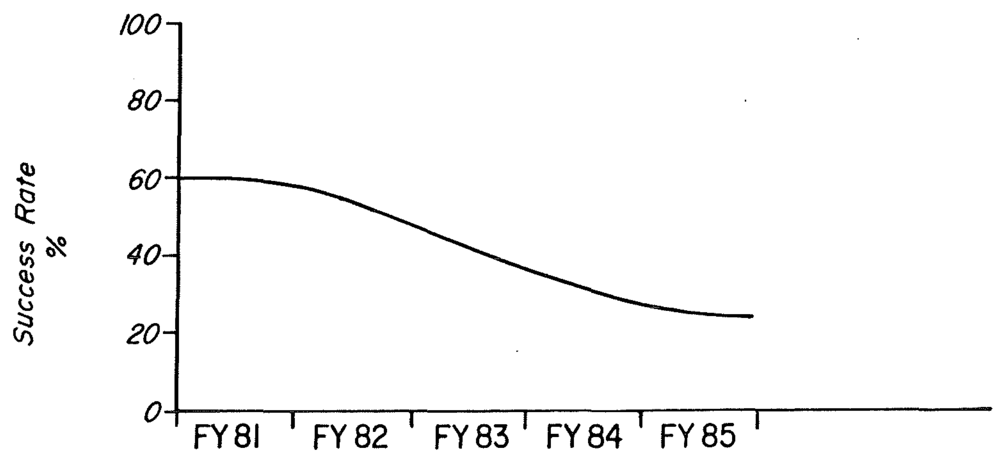

Figure 2

POSTULATED SUCCESS RATE

Another necessary ingredient is specification of a typical reservoir confirmation project. Here there will be a great diversity. Some projects will require deep drilling in complex geologic environments where exploration problems are difficult whereas others will only amount to shallow holes in simple environments. The following four typical confirmation projects are offered not as end members to the wide range of projects anticipated but perhaps as being average or typical. More complex and expensive, and less complex and expensive projects will both be experienced.

	Cost
Confirmation Program 1--Deep holes, complex geology/Surface geology, geochemistry, geophysics/Temperature gradient holes	$ 200K
(6000 ft total @ $50/ft)/Production well (5000 ft @ $160/ft)	300
and Testing ($150K)	950
	$1450K
Confirmation Program 2--Deep holes, simple geology/Surface geology, geochemistry, geophysics/Temperature gradient holes	$ 60K
(3000 ft total @ $40/ft)/Production well (5000 ft @ $140/ft)	120
and Testing ($150K)	850
	$1030K
Confirmation Program 3--Shallow holes, complex geology/ Surface geology, geochemistry, geophysics/	$ 160K
Temperature gradient holes (4000 ft total @ $30/ft)	120
Production well (1500 ft @ $120/ft) and Testing ($70K)	250
	$ 530K
Confirmation Program 4--Shallow holes, simple geology/ Surface geology, geochemistry, geophysics/	$ 40K
Temperature gradient holes (1300 ft total @ $30/ft)	40
Production well (1500 ft @ $80/ft) and Testing ($70K)	190
	$ 270K

For sites where a successful production well is drilled, a post-confirmation program of reservoir engineering, hydrology, and injection well drilling and testing would be needed. A typical range of programs might be as follows:

Post-Confirmation Program 1--deep well	
Engineering and Hydrology	$ 20K
Injection well (5000 ft @ $150/ft) and Testing ($70K)	820
	$ 840K

Post-Confirmation Program 2--shallow well	
Engineering and Hydrology	$ 20K
Injection well (1500 ft @ $100/ft) and Testing ($50K)	200
	$ 220K

Implementation and Management

The program proposed herewith is in every aspect an exploration program. It must be managed and performed by geoscientists who have an exploration background. An average of 132 projects must be initiated per year during FY81-85 inclusive. Management and performance of a program of this scope will be complex. Thorough planning will be needed.

It is recommended that the program be implemented through a series of competitive procurements directed at the non-federal, private sector. The procurements would specify that acceptability of proposals would be based on 1) having a user tied to the project (preferably as project manager), 2) having a clear land and environmental situation so that no snags would develop along the way, and 3) having a well-conceived exploration and reservoir confirmation program under the direction of appropriate geoscientific expertise. Once proposals are evaluated and accepted, a variable cost-share contract would be negotiated with the proposer. This contract would specify 1) a definition of success on the project based upon technical achievement (generally upon temperature, quantity, and quality of fluids encountered and/or other quantifiable results), and 2) the share of the cost to be paid by DOE in case of success or in case of failure. The DOE cost share for a successful project would be about 10 percent initially and would decrease to 5 percent later on. It would be paid mainly for data which the project generates -- the data would be interpreted and published as case studies for the purpose of technology transfer and economic model development. For an unsuccessful project the DOE share would initially be 100 percent but would decrease to about 90 percent in later years.

Once the cost-share contract is negotiated, DOE would have effectively assumed the main risks in bringing direct heat use on line. At that point the contractor would simply take the DOE-backed contract to the bank and borrow money for the project, which he then would perform. When the project is completed, DOE would pay the contractor the previously agreed cost share, completing the DOE obligation. DOE would not have continuing obligation or be responsible for marketability of the geothermal fluid nor for the economics of the end use. Utilization of the resource would proceed using private capital or, alternatively, the project would become a PON candidate or a candidate for a federal Loan Guarantee. This proposed funding scheme has advantages over full federal funding, which would double the total cost to DOE, and over existing federal programs such as the Loan Guarantee program, which obligate DOE depending on the economics of the end use of the resource.

DOE would require management assistance for this program. Principal tasks would be proposal evaluation and contract monitoring. The evaluation and monitoring teams could be composed of geoscientists from UURI and from the present State Coupled resource assessment teams, whereas utilization and reservoir engineers could be supplied by EG&G, Idaho, and by members of the present Operations Research Program state teams. UURI could coordinate the geoscientific aspects of the project and EG&G could coordinate the engineering aspects. The respective state team members would help provide state-level management assistance. This arrangement would guarantee high-quality exploration and confirmation projects in areas where good utilization potential has been identified.

Consideration of the size and structure of the DOE staff required for management is not given in this study but would have to be given if this recommended program is implemented.

Costs and Schedule

Table 1 gives an estimate of the program costs and a proposed schedule. Costs are quoted in 1978 dollars on the basis of the several assumptions listed above. A detailed explanation is given below. It should be noted that exploration costs are escalating yearly, with drilling costs presently rising nearly 20 percent per year. On the other hand, it is likely that some of the confirmation costs will decrease (in terms of 1978 dollars) as knowledge and experience are gained. These opposing factors have not been evaluated here.

The schedule for initiation and an estimate of success for reservoir confirmation projects are given at the top of Table 1. It is expected that utilization of confirmed reservoirs will begin in late 1983, allowing about two years for additional privately funded drilling and construction of facilities after the initial confirmation hole. This schedule (line 5) predicts about 0.1 Quads (3300 MWt) on line by 1985 and 4500 MWt by 1986.

The pass-through budget and schedule for the reservoir confirmation program are shown in Table 1. Line 1 gives the number of projects that will need to be initiated in each year. The decreasing success rate shown in line

2, which has been discussed in conjunction with Figure 2 (p. 11), leads to the successes, failures, and cumulative energy developed, shown in lines 3, 4, and 5 respectively. A 10% initial DOE cost share for successful confirmation projects is assumed and will decrease to 5% in the later years. A 100% cost share, which decreases to 90% in later years, is assumed for confirmation projects that are failures.

The data shown in lines 7-17 are calculated with 60% project completion for the projects initiated in any particular year and 40% carried over to the next year. Programs that take two years to complete are listed in the table as initiating in one year but are calculated in the costs for the year of their completion. This means that although 100 projects begin in FY81, only 60 of the projects are included in the costs for FY81; 40 projects are carried over to and calculated in the costs for FY82. It is felt that most costs for two-year programs will be incurred in the gradient hole and production hole drilling phases, and that these phases are likely to be deferred to the second year.

The percentages of confirmation projects shown for programs 1-4 (lines 7-10) are consistent with the utilization system sizes shown on page 9, assuming that the larger utilization systems will often be developed with higher temperature, deeper systems requiring deeper drilling.

The number of post-confirmation programs identified in lines 11 and 12 is calculated assuming the success rate of line 2 for the 60% of the confirmation projects initiated and completed during a year. The number of carry-over two year confirmation projects that are successful is then added to the number of one year confirmation projects, and the total number of post-confirmation projects is calculated. This means that for FY82, the number of post-confirmation programs includes successful confirmation projects for FY82 as well as successful confirmation projects from FY81 which took two years to complete.

DOE confirmation costs in line 13, and private investment costs in line 14, are calculated using the success rate shown in line 2 and the cost-share percentages shown in line 6 for confirmation programs 1 thru 4 (lines 7-10). The assumption is also made that DOE will cost-share 10% of the post-confirmation programs shown in lines 11 and 12 during FY81 and 82, and 5% of the post-confirmation programs in FY83-86. The costs in lines 13 and 14 have been rounded to the nearest $10,000.

Line 15 shows the number of projects initiated. Line 16, projects terminated, includes for any particular year the 60% of the projects initiated and completed in one year, and the 40% of the previous years' projects that carry over to a second year. The number of confirmation projects in progress shown for each year thus includes all the projects begun in that year as well as the projects carried over from the previous year.

Line 18 estimates the number of proposals that will be received, and lines 20 and 21 present information on management assistance that DOE will need. Geoscientists and engineers will be needed to review proposals, monitor contracts and collect, interpret and publish the geoscientific, engineering and economic data that the program will generate. Costs for management assistance, not including DOE staff requirements, are shown in line 21.

Final estimated cost totals are shown for DOE in Line 22 and for the combined DOE and private sector investment in Line 23. Total program costs are $251 million for DOE and $255 million for private investors, for a grand total of more than $506 million by 1986. This is indeed an ambitious program.

TABLE 1: RECOMMENDED PROGRAM COSTS AND SCHEDULE

	ITEM	FY80	FY81	FY82	FY83	FY84	FY85	FY86	TOTALS
	Program Schedule								
1.	Confirmation Projects Initiated	0	100	165	200	130	65	0	660
2.	Average Success Rate, %	-	60	54	41	31	25	-	43(av)
3.	Successes	-	60	89	82	40	16	-	287
4.	Failures	-	40	76	118	90	49	-	373
5.	MWt on Line, cumulative	0	0	0	800	2,000	3,300	4,500	4,500
	Confirmation Program Budget								
6.	% DOE Costshare, succ./fail.	-	10/100	10/100	5/95	5/92	5/90	5/90	-
7.	No. Confirm Prog 1 @ $1450K	0	7	15	21	17	10	3	73
8.	No. Confirm Prog 2 @ $1030K	0	7	15	21	17	10	3	73
9.	No. Confirm Prog 3 @ $ 530K	0	23	54	72	62	36	10	257
10.	No. Confirm Prog 4 @ $ 270K	0	23	55	72	62	35	10	257
11.	No. Post Confirm Prog 1 @ $840K	0	8	18	19	13	7	2	67
12.	No. Post Confirm Prog 2 @ $220K	0	28	59	66	43	19	4	219
13.	DOE Confirm Costs (to private sector)	0	17,740	44,270	65,250	60,690	37,170	10,740	$235,860K
14.	Private Investment	0	30,900	64,500	74,910	51,450	26,220	7,250	$255,230K
	Management Assistance to DOE								
15.	Confirmation Projects Initiated	0	100	165	200	130	65	0	660
16.	Confirmation Projects Terminated	0	60	139	186	158	91	26	660
17.	Confirmation Projects in Progress	0	100	205	266	210	117	26	-
18.	No. Proposals Received	300	400	500	400	200	100	0	2,250
19.	No. Geoscientists, Prop Eval/Proj Monitor	8/0	8/10	10/20	8/26	6/21	4/12	0/0	-
20.	No. Engineers, Prop Eval/Proj Monitor	4/0	4/5	5/10	4/10	3/8	2/4	0/2	-
21.	Management Costs, $K	960	2,160	3,600	3,840	3,040	1,760	160	$ 15,520K
22.	Total DOE Costs (excluding DOE staff)	960	19,900	47,870	69,090	63,730	38,930	10,900	$251,380K
23.	Total DOE and Private Capital Needed	960	50,800	112,370	144,000	115,180	65,150	18,150	$506,610K