GL01345

Department of Energy

NOVEMBER 7, 1979

(DRAFT)

ET Requirements to Accelerate Commercialization of Hydrothermal Energy

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UURI

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EXECUTIVE SUMMARY

- 48 INDUSTRY PEOPLE SURVEYED INDICATED THAT THE TOP FIVE TECHNICAL REQUIREMENTS TO ACCELERATE COMMERCIALIZATION OF HYDROTHERMAL ENERGY ARE:

  1. INCREASE RESERVOIR CONFIDENCE (RESERVOIR ENGINEERING AND ASSESSMENT TECHNIQUES)
  2. REDUCE FIELD DEVELOPMENT COSTS AND IMPROVE WELL FLOW RATES
  3. REDUCE THE RISK AND COST OF EXPLORATION
  4. DETERMINE THE ECONOMICS AND RELIABILITY OF A COMMERCIAL-SIZE BINARY PLANT (50 MWE)
  5. CONTROL SCALING

- THOSE PEOPLE FROM INDUSTRY THAT ARE PRIMARILY INTERESTED IN DIRECT HEAT APPLICATIONS STRONGLY ENDORSE ITEMS 1, 2, AND 3 ABOVE PLUS:

  1. ESTABLISH CONFIDENCE IN THE ECONOMICS AND RELIABILITY OF DIRECT HEAT SYSTEMS
  2. REDUCE THE COST OF HARDWARE FOR DIRECT HEAT APPLICATIONS

EXECUTIVE SUMMARY

THE MAJOR THRUST OF THIS REVIEW WITH INDUSTRY WAS TO IDENTIFY AND PRIORITIZE TECHNICAL REQUIREMENTS FOR ACCELERATED COMMERCIALIZATION OF HYDROTHERMAL ENERGY. THE FOLLOWING ADDITIONAL INFORMATION WAS OBTAINED:

- APPROXIMATELY 75% OF THOSE CONTACTED BELIEVE THE MAJOR BARRIERS TO COMMERCIALIZATION ARE NON-TECHNICAL ISSUES RATHER THAN TECHNICAL.

- THE MOST FREQUENT NON-TECHNICAL ISSUES MENTIONED BY INDUSTRY ARE:

  1. FEDERAL AND STATE REGULATION APPROVALS
  2. INADEQUATE TAX AND RATE OF RETURN INCENTIVES
  3. LEGAL/FINANCIAL ASPECTS ASSOCIATED WITH RESERVOIR RISKS
  4. SLOW RESOLUTION OF ENVIRONMENTAL RESTRAINTS

INTRODUCTION

This document has been prepared by the Division of Geothermal Resource Management to identify the technology that requires continued DOE support to accelerate the commercialization of hydrothermal energy. A number of independent research and development projects have already been successfully completed, and these have provided a basis for hydrothermal energy commercialization. Industry is now beginning to realize the benefit of this energy source, and large investments are being committed to hydrothermal energy use even though all of the technical and institutional problems are not yet resolved. This document identifies the major technical requirements that will have the largest impact on accelerated resource commercialization and provides information for the development of detailed technical program plans and budgets. Institutional barriers such as length of time to obtain permits, leasing, and tax considerations have been included in this document inasmuch as some of the industrial participants indicated that the major barriers to commercialization were non-technical in nature rather than technical.

The methodology used in the preparation of this document is outlined below.

Methodology for Document Preparation

1. Establish Team -- After authorization for the document by DOE/ID, a team was established for performance of the task. Task management was assigned to EG&G's Hydrothermal Commercialization Branch, and team members were chosen from EG&G and the University of Utah Research Institute (UURI).
2. Review Current DOE-Sponsored Hydrothermal Energy Technology (ET) Programs -- Team members reviewed and summarized the current programs that were documented on the Management Information System (MIS) Project Description Sheets. This effort involved a study of the scope, cost, schedule, and justifications for each DOE-funded technology project. (This information is presented in tabular form in the Appendix.)
3. Obtain Opinions and Identify Technical Barriers to Commercialization of Hydrothermal Energy -- Input was obtained through contact with established technical working groups, advisory committees, Geothermal Resources Council (GRC) meetings, Electric Power Research Institute (EPRI) meetings, review of papers, and from "one-on-one" contact with knowledgeable individuals.
4. Prepare Prioritization Matrix -- The technology required for accelerated commercialization that was identified in Step 3 was then assembled in matrix form for the purpose of prioritization. The system used incorporates the principles presented in a paper by M. J. Gelpi entitled "Forcing a Good Decision," whereby many variables can be evaluated independently. Only two alternatives are considered at a time, but the final solution considers all possible pairs and results in a numerical ranking for each variable. The "short form" that allows all of the decisions to be recorded on one sheet is the invention of an EG&G manager.
5. Have "Industry" Rate the Matrix -- The requirements were then rated by a selected sample of knowledgeable individuals from utilities, developers, A&E firms, direct heat users, and the financial community. The results from these independent individuals are the subject of the balance of this document.

DOE-SPONSORED HYDROTHERMAL ENERGY TECHNOLOGY (ET) PROGRAMS

RESERVOIR ASSESSMENT

- Exploration Technology
  - Industry Coupled Programs
  - State Coupled Programs
  - Site-Specific Case Studies
  - Exploration Technology Development
- Reservoir Engineering

WELL DRILLING & STIMULATION

- Drilling & Completion
- Stimulation

HYDROTHERMAL TECHNOLOGY

- Geoscience Technology
  - Log Instrumentation
  - Well Log Interpretation
  - Subsidence
  - Induced Seismicity
  - Rock Properties
- Conversion Technology
  - Supply & Injection Systems
  - Power Cycles
  - Heat Exchangers
  - Well-Head Generators
  - Test Facilities
- Materials Technology
  - Corrosion/Erosion
  - Scaling
  - Materials
  - Cementing/Cements
  - Instrumentation
  - Computer Modeling
  - Materials Design Handbook
  - Inservice NDE Methods

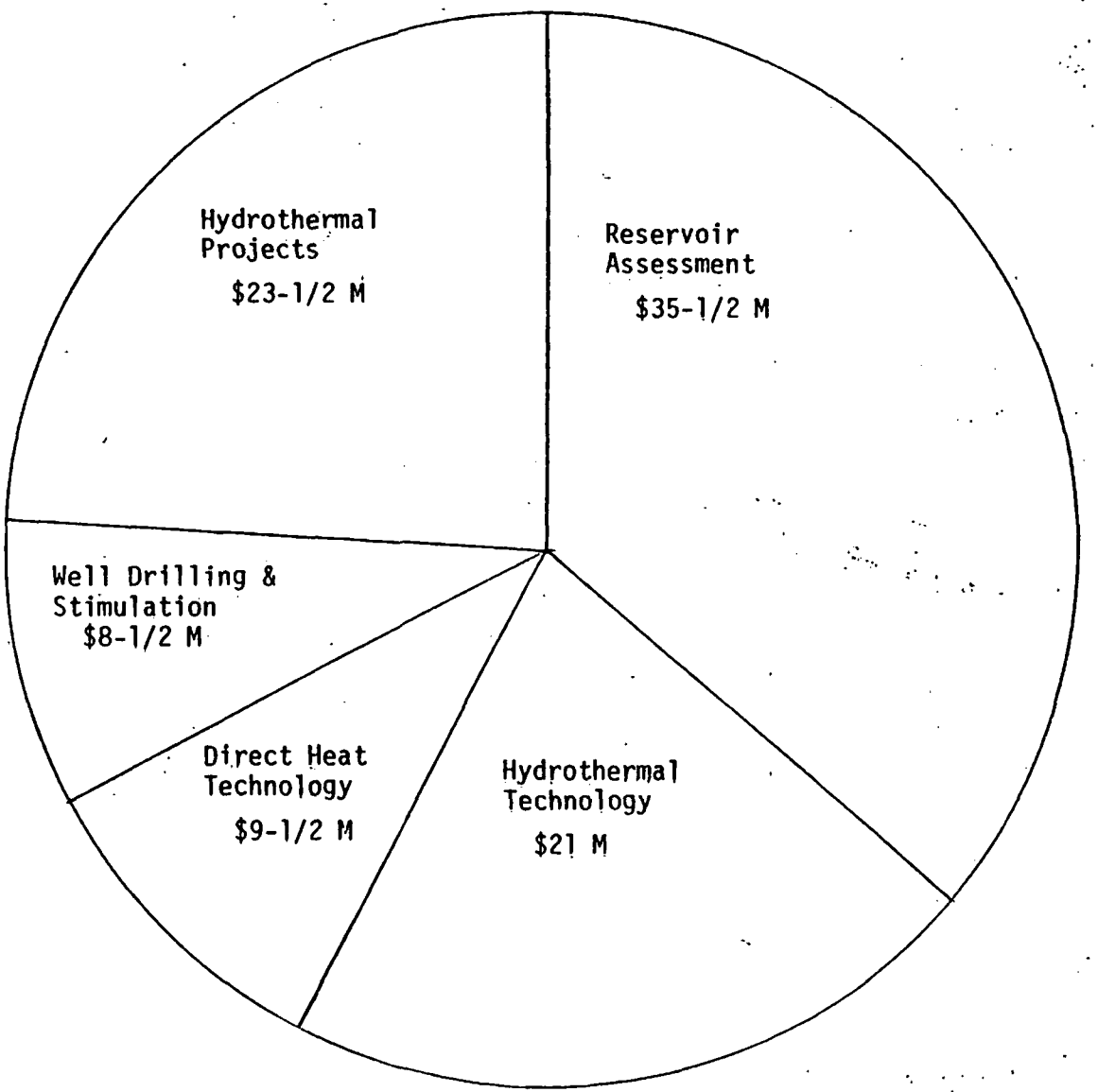
DIRECT HEAT TECHNOLOGY

- Space Conditioning
- Industrial Processing
- Agribusiness
- District Heating
- Support Activities

HYDROTHERMAL PROJECTS

- GLEF
- HGP-A
- Raft River
- Valles Caldera
- GCTF

Dollar Value of Current DOE/ET Programs



NOTE: Dollar values shown are the total FY 1979 authorized amounts (B/A's) to the nearest million as summarized from the existing MIS Project Description Sheets.

PROBLEM AND BARRIER IDENTIFICATION

After the in-depth review of the current DOE-funded technology projects was completed, attention was directed to the identification of technical problems and barriers to commercialization of hydrothermal energy.

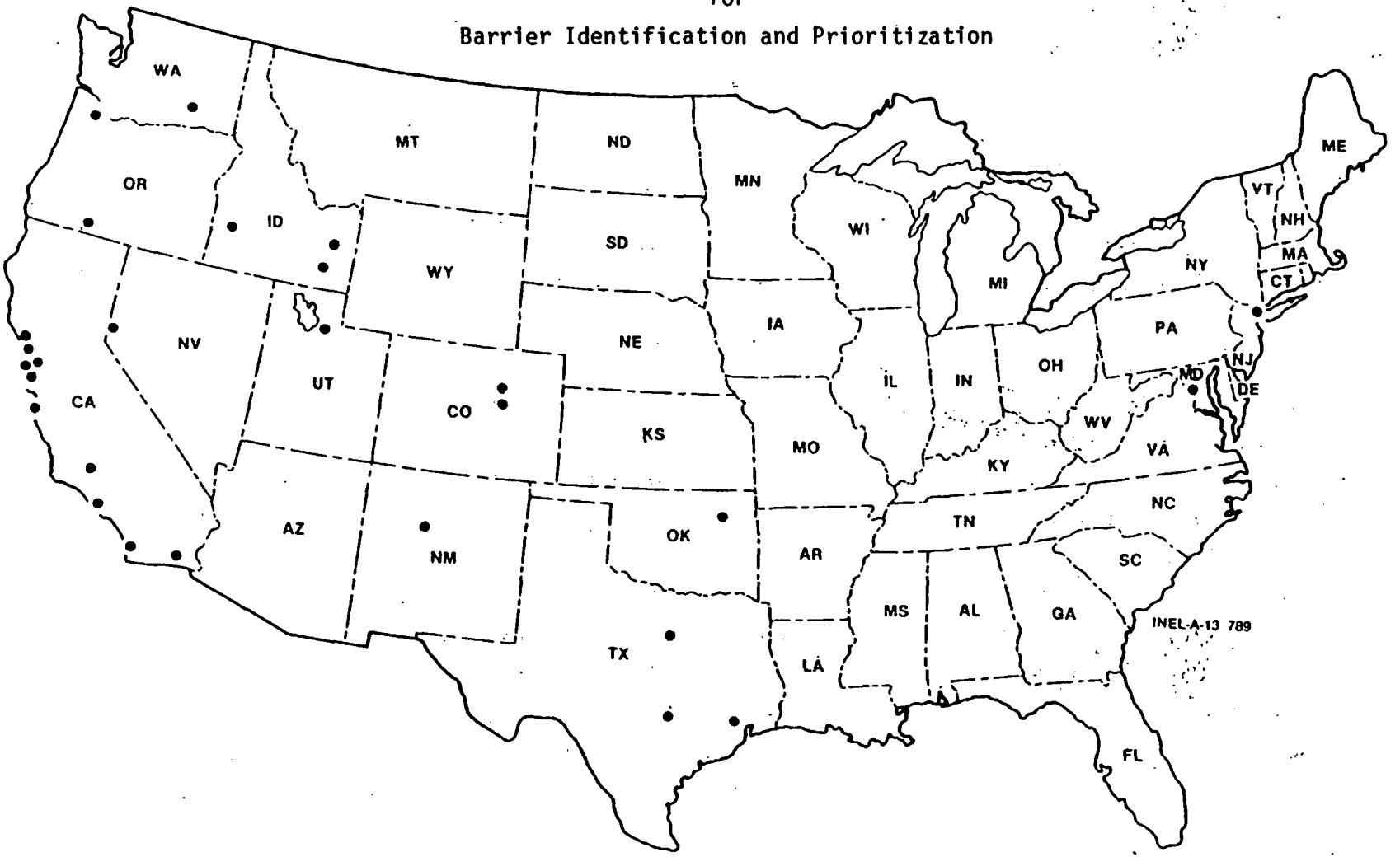
The team obtained input through established working groups, advisory committees, Geothermal Resources Council (GRC) meetings, Electric Power Research Institute (EPRI) meetings, review of papers, and from "one-on-one" contact with knowledgeable individuals. Although industry provided the primary input to the list of problems and barriers, opinions were also recorded from individuals in government and from the National Laboratories. Both electric and direct heat interests made contributions.

The team made no attempt to "judge" the opinions prior to their being added to the list other than to meet the basic requirement of being technical barriers and not institutional in nature.

The final result of the process was the 26-item list shown on the prioritization matrix. The technology requirements to accelerate commercialization of hydrothermal energy appear in random order on the list to eliminate any bias in the prioritization process, and some items were combined to make the number of decisions as small as possible.

The map on the facing page shows where the "one-on-one" contacts were made when obtaining input for the barrier identification or later for the prioritization of the technical requirements.

"One-on-One" Contact Locations
for
Barrier Identification and Prioritization



PRIORITIZATION PROCESS

The following is a list of the industries and individuals who participated in the prioritization of technical requirements to accelerate commercialization of hydrothermal energy. An example of the decision matrix which was completed by one of these individuals is shown on the opposite page.

Developers

AMAX Exploration - Dolan
Aminoil - Jenkins
Anadarko - Edmiston
Chaffee Geothermal - Dick
Chevron - Butler
Consultant - Meidav
Energy Services - Kunze
Geothermal Power - Metcalf
Getty Oil - Shaw
Hydrothermal Energy Corp. - Atkinson
IEC - Huttrer
McCullock - Chantler & Russell
Phillips Pet. Co. - Berge
R.G.I. - Rex & Wellbaum
Southland Royalty Co. - McMurdie
Union - Otte

Utilities

EPRI - Roberts
Idaho Power - Turner
PG&E - McKenzie
Public Service of NM - Maddox
SDG&E - Lacy
Sierra Pacific - Richards
Southern Cal Ed. - Crane
Utah Power & Light - Evans
WPPSS - Johnson

Financial Firms

Bank of America - McCormick
Bank of Montreal - Woods
Chase Manhattan Bank - Fyke
First Security Bank of Idaho - Garvin

Direct Heat

City of Boise - Hanson
FMC - Sheffield
Geothermal Energy Corp. - Rodzianko
Holly Sugar - Newton & Orleans
Medo-Bell - Belcastro
Northwest Geothermal Corp. - Howe
Ore-Ida - Rolf
Simplot - Alsager
WESTEC - Sherwood
Weyerhauser - Gjertsen

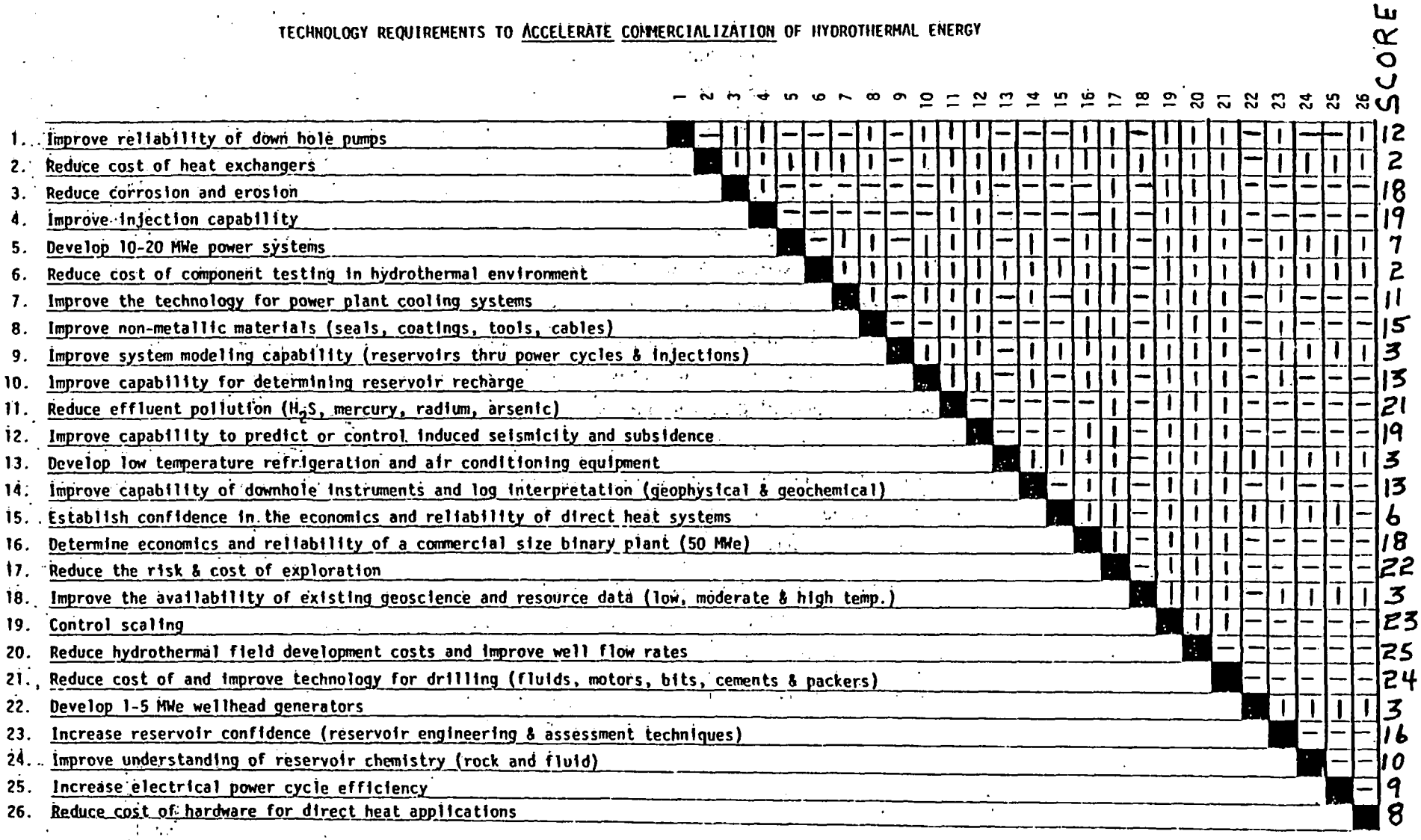
A&E Firms

Bechtel - Cochrane/Fick/Hankin
BDM Corp. - Mansure
Ben Holt Co. - Holt
CH_2M Hill - Little
Coury & Assoc. - Coury
Parsons - Shepherd
Radian Corp. - Conover
Rogers Engr. - Kuwada
Terra Tek - Harison

Decision Matrix of a Participant

8/8/79

TECHNOLOGY REQUIREMENTS TO ACCELERATE COMMERCIALIZATION OF HYDROTHERMAL ENERGY



SUMMARY OF ALL INDUSTRIES SAMPLED

A total of 48 individuals from five different industrial groups completed the survey on the Technology Requirements to Accelerate the Commercialization of Hydrothermal Energy. The industries that were polled were developers, utilities, A&E firms, direct heat users and financial firms. Each individual survey was scored with a numerical value for each element or technical requirement in the matrix. The score could range from 0 to 25. The scores for the corresponding elements from each individual in a given industrial group were summed to obtain a composite score for that technical element. The technical elements were then ranked in order of the highest to lowest composite scores. This was done for each of the five industrial groups which gave a ranking of importance of the various technical requirements for each of the five groups. The scores for each technical element in the five industrial groups were then summed to obtain an overall score for each element. This total score for each element determined the ranking of that element for all the industries sampled and the results are shown on page 13.

"Increase Reservoir Confidence" rated in the top five technical requirements for all individual groups, and "Reduce Hydrothermal Field Development Costs and Improve Well Flow Rates" was rated in the top five by 4 out of 5 industrial groups. In the top 10 technical requirements, "Determine Economics and Reliability of a Commercial Size Binary Plant (50 MWe)" also rated by all five of the industrial groups. "Develop 10 - 20 MWe Power Systems," "Reduce the Risk and Cost of Exploration," and "Control Scaling," were also rated by 4 out of the 5 industrial groups. Charts showing the results of the top five and ten technical requirements by industrial groups are shown in the Appendix. The Appendix also includes a short description of each of the technical requirement elements.

SUMMARY OF ALL INDUSTRIES SAMPLED

Ranking	Technology Requirements to Accelerate Commercialization
1.	Increase reservoir confidence (reservoir engineering & assessment techniques)
2.	Reduce hydrothermal field development costs and improve well flow rates
3.	Reduce the risk and cost of exploration
4.	Determine economics and reliability of a commercial size binary plant (50 MWe)
5.	Control scaling
6.	Reduce cost of and improve technology for drilling
7.	Improve injection capability
8.	Improve capability for determining reservoir recharge
9.	Develop 10-20 MWe power systems
10.	Reduce effluent pollution (H_2S, mercury, radium, arsenic)
11.	Increase electrical power cycle efficiency
12.	Reduce corrosion and erosion
13.	Establish confidence in the economics and reliability of direct heat systems
14.	Improve capability of downhole instruments and log interpretation
15.	Improve reliability of downhole pumps
16.	Improve systems modeling capability
17.	Develop 1 - 5 MWe wellhead generators
18.	Improve understanding of reservoir chemistry
19.	Improve capability to predict or control induced seismicity and subsidence
20.	Improve availability of existing geoscience and resource data
21.	Reduce cost of heat exchangers
22.	Improve technology for power plant cooling systems
23.	Improve non-metallic materials (seals, coatings, tools, cables)
24.	Reduce cost of hardware for direct heat applications
25.	Develop low temperature refrigeration and air conditioning equipment
26.	Reduce cost of component testing in hydrothermal environment

ELECTRIC APPLICATIONS SUMMARY

A separate priority listing of the technology requirements for Electric Applications was extracted from the survey data by taking the scores of those individuals whose primary interests are in using hydrothermal resources for producing electrical power. The top five technical requirements for Electric Applications agreed with the summary or overall top five and 9 out of 10 in the top 10 were the same. The 50 MWe binary demonstration power plant was high on the prioritization list. There is fairly good agreement between individuals in the electric field, which indicates that the problem areas are fairly well defined. Those elements that have the same ranking had identical numerical scores. Additional charts and graphs summarizing these results are given in the Appendix.

ELECTRIC APPLICATIONS SUMMARY

Ranking	Technology Requirements to Accelerate Commercialization
1.	Increase reservoir confidence (reservoir engineering & assessment techniques)
2.	Reduce hydrothermal field development costs and improve well flow rates
3.	Determine economics and reliability of a commercial size binary plant (50 MWe)
4.	Control scaling
5.	Reduce risk and cost of exploration
6.	Reduce cost of and improve technology for drilling (fluids, motors, bits, cements & packers)
7.	Improve injection capability
8.	Reduce effluent pollution (H_2S, mercury, radium, arsenic)
9.	Improve reliability of downhole pumps
10.	Improve capability for determining reservoir recharge
11.	Increase electrical power cycle efficiency
12.	Reduce corrosion and erosion
13.	Develop 10 - 20 MWe power systems
14.	Improve capability of downhole instruments and log interpretation
15.	Improve system modeling capability
16.	Improve understanding of reservoir chemistry
17.	Improve the technology for power plant cooling systems
18.	Develop 1 - 5 MWe wellhead generators
19.	Reduce cost of heat exchangers
20.	Improve non-metallic materials (seals, coatings, tools, cables)
20.	Improve capability to predict or control induced seismicity and subsidence
22.	Establish confidence in the economics and reliability of direct heat systems
23.	Improve the availability of existing geoscience and resource data
24.	Reduce cost of component testing in hydrothermal environment
25.	Develop low temperature refrigeration and air conditioning equipment
26.	Reduce cost of hardware for direct heat applications.

DIRECT HEAT APPLICATIONS SUMMARY

A separate listing of the technology requirements for Direct Heat Applications was also extracted from the survey data. For this compilation the scores were used from those individuals whose primary interests are in direct applications of hydrothermal resources. Three out of five of the top five technical requirements and 8 out of 10 of the top 10 technical requirements agreed with the all-industry summary. To "Establish Confidence in the Economics and Reliability of Direct Heat Systems" was high on their priority list. Many of the technical requirements such as "Reduce the Risk and Cost of Exploration," "Increase Reservoir Confidence," "Reduce Hydrothermal Field Development Costs and Improve Well Flow Rates," etc, are applicable to both Direct Heat and Electric Applications. There appears to be relatively consistent agreement between the two groups on the ranking of these requirements. Those elements that have the same ranking had identical scores. Additional charts summarizing these results are given in the Appendix.

DIRECT HEAT APPLICATIONS SUMMARY

Ranking	Technology Requirements to Accelerate Commercialization
1.	Establish confidence in the economics and reliability of direct heat systems
2.	Reduce the risk and cost of exploration
3.	Increase reservoir confidence (reservoir engineering & assessment techniques)
4.	Reduce hydrothermal field development costs and improve well flow rates
5.	Reduce cost of hardware for direct heat applications
6.	Improve capability for determining reservoir recharge
7.	Develop 10 - 20 MWe power systems
8.	Control scaling
8.	Reduce cost of and improve technology for drilling
10.	Improve injection capability
10.	Develop 1 - 5 MWe wellhead generators
12.	Determine economics and reliability of a commercial size binary plant (50 MWe)
13.	Increase electrical power cycle efficiency
14.	Improve the availability of existing geoscience and resource data
15.	Reduce corrosion and erosion
15.	Improve capability of downhole instruments and log interpretation
17.	Develop low temperature refrigeration and air conditioning equipment
18.	Improve understanding of reservoir chemistry
19.	Improve system modeling capability
20.	Reduce effluent pollution (H_2S, mercury, radium, arsenic)
21.	Improve capability to predict or control induced seismicity and subsidence
22.	Improve reliability of downhole pumps
23.	Reduce cost of heat exchangers
24.	Improve non-metallic materials (seals, coatings, tools, cables)
25.	Improve the technology for power plant cooling systems
26.	Reduce cost of component testing in hydrothermal environment

DEVELOPERS

Sixteen developers responded to the survey and fairly good agreement existed between individuals.

There was unity between all groups in placing "Reservoir Confidence" high on the priority list. This group agreed on 3 out of 5 in the top five technical requirements and 8 out of 10 in the top 10. The three technical requirements that ranked in the overall top 5 were "Reduce the Risk and Cost of Exploration," "Reduce Hydrothermal Field Development Costs and Improve Well Flow Rates," and "Increase Reservoir Confidence." In addition to the above three elements, the following were in the overall top 10 requirements: "Reduce Cost of and Improve Technology for Drilling," "Determine Economics and Reliability of a Commercial Size Binary Plant (50 MWe)," "Control Scaling," "Develop 10-20 MWe Power Systems," and "Improve Injection Capability.". Those elements with the same ranking had identical numerical scores. Additional charts summarizing these results are given in the Appendix.

DEVELOPERS

Ranking	Technology Requirements to Accelerate Commercialization
1.	Reduce the risk and cost of exploration
2.	Reduce hydrothermal field development costs and improve well flow rates
3.	Reduce cost of and improve technology for drilling
4.	Increase reservoir confidence (reservoir engineering & assessment techniques)
5.	Develop 1 - 5 MWe wellhead generators
6.	Determine economics and reliability of a commercial size binary plant (50 MWe)
7.	Improve capability of downhole instruments and log interpretation
8.	Control scaling
9.	Develop 10 - 20 MWe power systems
10.	Improve injection capability
11.	Improve capability for determining reservoir recharge
12.	Increase electrical power cycle efficiency
13.	Reduce effluent pollution (H_2S, mercury, radium, arsenic)
14.	Improve reliability of downhole pumps
14.	Reduce corrosion and erosion
16.	Establish confidence in the economics and reliability of direct heat systems
17.	Improve the technology for power plant cooling systems
18.	Improve understanding of reservoir chemistry
19.	Improve system modeling capability
20.	Improve non-metallic materials (seals, coatings, tools, cables)
21.	Reduce cost of heat exchangers
22.	Develop low temperature refrigeration and air conditioning equipment
23.	Improve capability to predict or control induced seismicity and subsidence
24.	Improve the availability of existing geoscience and resource data
25.	Reduce cost of component testing in hydrothermal environment
26.	Reduce cost of hardware for direct heat applications

UTILITIES

A large majority of this group is very high on the 50 MWe binary demonstration plant. There were nine utilities included in the survey. The utilities were in good agreement with the consensus of the combined groups or summary. They agreed with 4 out of 5 of the top five technical requirements and 8 out of 10 of the top 10. The four technical requirements that ranked in the top five are: "Increase Reservoir Confidence," "Determine Economics and Reliablity of a Commercial Size Binary Plant (50 MWe)," "Reduce Hydrothermal Field Development Costs and Improve Well Flow Rates," and "Control Scaling." The additional four elements that were in the overall top 10 requirements are: "Reduce Cost of and Improve Technology for Drilling," "Improve Injection Capability," "Reduce the Risk and Cost of Exploration," and "Develop 10-20 MWe Power Systems." Those elements with the same ranking had identical numerical scores. Additional charts summarizing these results are given in the Appendix.

UTILITIES

Ranking	Technology Requirements to Accelerate Commercialization
1.	Increase reservoir confidence (reservoir engineering & assessment techniques)
2.	Determine economics and reliability of a commercial size binary plant (50 MWe)
3.	Reduce hydrothermal field development costs and improve well flow rates
4.	Control scaling
5.	Reduce cost of and improve technology for drilling
6.	Improve injection capability
7.	Reduce the risk and cost of exploration
8.	Improve reliability of downhole pumps
9.	Reduce corrosion and erosion
10.	Develop 10 - 20 MWe power system
11.	Increase electrical power cycle efficiency
12.	Improve system modeling capability
13.	Improve capability for determining reservoir recharge
14.	Reduce effluent pollution (H_2S, mercury, radium, arsenic)
15.	Improve capability of downhole instruments and log interpretation
16.	Improve the technology for power plant cooling systems
17.	Improve understanding of reservoir chemistry
18.	Reduce cost of heat exchangers
19.	Develop 1 - 5 MWe wellhead generators
20.	Reduce cost of component testing in hydrothermal environment
20.	Improve capability to predict or control induced seismicity and subsidence
22.	Improve non-metallic materials (seals, coatings, tools, cables)
23.	Improve the availability of existing geoscience and resource data
24.	Establish confidence in the economics and reliability of direct heat systems
25.	Reduce cost of hardware for direct heat applications
26.	Develop low temperature refrigeration and air conditioning equipment

DIRECT HEAT USERS

Ten participants responded to the survey. At the top of their list is to "Establish Confidence in the Economics and Reliability of Direct Heat Systems." It is evident from the survey, however, that they could benefit most in the area of technical assistance. There was fair agreement in the top and bottom five technical requirements; however, beyond that their opinions vary widely. This is demonstrated in graph form in the Appendix. This group agreed with 3 out of the all-industry top five and the other 2 were associated with only direct heat applications, which one would expect. The two technical requirements that are relative to only direct heat usage were "Establish Confidence in the Economics and Reliability of Direct Heat Systems," and "Reduce Cost of Hardware for Direct Heat Applications." Those elements with the same ranking had identical numerical scores. Additional information is given in the Appendix on the comparison between the different groups.

DIRECT HEAT USERS

Ranking	Technology Requirements to Accelerate Commercialization
1.	Establish confidence in the economics and reliability of direct heat systems
2.	Increase reservoir confidence (reservoir engineering & assessment techniques)
3.	Reduce hydrothermal field development costs and improve well flow rates
4.	Reduce the risk and cost of exploration
5.	Reduce cost of hardware for direct heat applications
6.	Improve capability to predict or control induced seismicity and subsidence
7.	Increase electrical power cycle efficiency
8.	Improve capability for determining reservoir recharge
9.	Develop 10 - 20 MWe power systems
10.	Determine economics and reliability of a commercial size binary plant (50 MWe)
11.	Improve the availability of existing geoscience and resource data
11.	Develop 1 - 5 MWe wellhead generators
13.	Control scaling
14.	Reduce cost of and improve technology for drilling
15.	Improve reliability of downhole pumps
15.	Improve injection capability
17.	Improve understanding of reservoir chemistry
18.	Reduce corrosion and erosion
19.	Improve capability of downhole instruments and log interpretation
20.	Develop low temperature refrigeration and air conditioning equipment
21.	Improve system modeling capability
22.	Improve the technology for power plant cooling systems
23.	Reduce effluent pollution (H_2S, mercury, radium, arsenic)
24.	Improve non-metallic materials (seals, coatings, tools, cables)
25.	Reduce cost of heat exchangers
26.	Reduce cost of component testing in hydrothermal environment

A&E FIRMS

Nine A&E firms supplied survey input. Their responses were in good agreement with the consortium. This group agreed with 4 out of 5 in the overall top five and 9 out of 10 in the top 10 contenders. The top four technical requirements were included in the overall top five and the top eight and tenth ranking elements were in the overall top 10 requirements. Those elements that have the same ranking had identical numerical scores. Additional information on the relative ranking comparisons for the different groups is given in the Appendix.

A&E FIRMS

Ranking	Technology Requirements to Accelerate Commercialization
1.	Reduce the risk and cost of exploration
1.	Reduce hydrothermal field development costs and improve well flow rates
1.	Increase reservoir confidence (reservoir engineering & assessment techniques)
4.	Control scaling
5.	Improve injection capability
6.	Reduce effluent pollution (H_2S, mercury, radium, arsenic)
7.	Determine economics and reliability of a commercial size binary plant (50 MWe)
8.	Improve capability for determining reservoir recharge
9.	Establish confidence in the economics and reliability of direct heat systems
10.	Reduce cost of and improve technology for drilling
11.	Reduce corrosion and erosion
12.	Improve capability of downhole instruments and log interpretation
13.	Improve the availability of existing geoscience and resource data
14.	Improve reliability of downhole pumps
15.	Improve understanding of reservoir chemistry
16.	Improve system modeling capability
17.	Reduce cost of heat exchangers
17.	Develop 10 - 20 MWe power systems
19.	Improve capability to predict or control induced seismicity and subsidence
20.	Increase electrical power cycle efficiency
21.	Reduce cost of hardware for direct heat applications
22.	Develop low temperature refrigeration and air conditioning equipment
23.	Improve non-metallic materials (seals, coatings, tools, cables)
24.	Improve the technology for power plant cooling systems
25.	Reduce cost of component testing in hydrothermal environment
26.	Develop 1 - 5 MWe wellhead generators

FINANCIAL FIRMS

Four financial firms were surveyed, and in general, there was not as good agreement between this group and the other groups. They only agreed on one of the overall top five requirements and on five of the top 10. This was the smallest group sampled, which may be the cause of this variation. However, they were high on demonstration projects and elements that will bring earlier returns on investments such as: "Develop 1-5 MWe Wellhead Generators," and "Develop 10-20 MWe Power Systems." This might indicate that they will require demonstration of the technology and earlier return on their money before they are very interested in investing in hydrothermal resources. They are also high on "Increase Reservoir Confidence." Those elements with the same ranking had identical numerical scores. Additional information is given in the Appendix on the comparison between groups.

FINANCIAL FIRMS

Ranking	Technology Requirements to Accelerate Commercialization
1.	Increase reservoir confidence (reservoir engineering & assessment techniques)
2.	Improve system modeling capability
3.	Develop 1 - 5 MWe wellhead generators
4.	Establish confidence in the economics and reliability of direct heat systems
5.	Improve capability for determining reservoir recharge
6.	Develop 10 - 20 MWe power systems
7.	Improve understanding of reservoir chemistry
8.	Reduce corrosion and erosion
8.	Determine economics and reliability of a commercial size binary plant (50 MWe)
10.	Control scaling
11.	Reduce effluent pollution (H_2S, mercury, radium, arsenic)
12.	Improve injection capability
13.	Increase electrical power cycle efficiency
14.	Improve the availability of existing geoscience and resource data
15.	Reduce cost of heat exchangers
16.	Improve reliability of downhole pumps
16.	Improve capability to predict or control induced seismicity and subsidence
18.	Improve non-metallic materials (seals, coatings, tools, cables)
19.	Reduce hydrothermal field development costs and improve well flow rates
20.	Improve capability of downhole instruments and log interpretation
21.	Reduce the risk and cost of exploration
22.	Reduce cost of hardware for direct heat applications
23.	Reduce cost of and improve technology for drilling
24.	Improve the technology for power plant cooling systems
25.	Develop low temperature refrigeration and air conditioning equipment
26.	Reduce cost of component testing in hydrothermal environment

COMPARISON OF PRIORITIZATION RESULTS
WITH
MAJOR ENERGY TECHNOLOGY PROGRAM CATEGORIES

The listing on the facing page shows the results of the prioritization when compared with the major DOE-sponsored Hydrothermal Energy Technology (ET) Programs. It is important to note that the listing shows only the top 1/2 of the ranking of the "All Industries Sampled" list.

Because of the need to keep the prioritization matrix list as short as possible, some of the technology requirements had been combined. The priority number 2 requirement: "Reduce Hydrothermal Field Development Costs and Improve Well Flow Rates" - therefore embraced two of the major program categories and is listed under both Hydrothermal Technology and Well Drilling and Stimulation.

COMPARISON OF PRIORITIZATION RESULTS WITH MAJOR ET PROGRAM CATEGORIES

Reservoir Assessment

#1 - Increase Reservoir Confidence (Reservoir Engineering & Assessment Techniques)

#3 - Reduce the Risk and Cost of Exploration

#8 - Improve Capability for Determining Reservoir Recharge

Hydrothermal Technology

* #2 - Reduce Hydrothermal Field Development Costs and Improve Well Flow Rates

#5 - Control Scaling

#10 - Reduce Effluent Pollution (H_2S, mercury, radium, arsenic)

#11 - Increase Electrical Power Cycle Efficiency

#12 - Reduce Corrosion and Erosion

Direct Heat Technology

#13 - Establish Confidence in the Economics and Reliability of Direct Heat Systems

Well Drilling and Stimulation

* #2 - Reduce Hydrothermal Field Development Costs & Improve Well Flow Rates

#6 - Reduce Cost of and Improve Technology for Drilling (Fluids, Motors, Bits, Cements, and Packers)

#7 - Improve Injection Capability

Hydrothermal Projects

#4 - Determine Economics and Reliability of a Commercial Size Binary Plant (50 MWe)

#9 - Develop 10-20 MWe Power Systems

* This item is included in two categories.

TECHNICAL VS NON-TECHNICAL ISSUES AFFECTING ACCELERATED COMMERCIALIZATION

The handout that was given to the industrial participants consisted of two pages -- the matrix and an attachment. Three questions were asked on the attachment:

1) Do you believe the major barriers to accelerated commercialization are technical or non-technical?
2) If you consider the major barriers to be non-technical, please list the most important issues to be solved.
3) Are there any major technical barriers that you feel were not covered by the prioritization matrix?

A summary of the answers to these questions are given on the following page, and it is interesting to note that 75% of the knowledgeable participants indicated that the major barriers to commercialization are non-technical rather than technical in nature. Team members detected a sense of frustration on the part of some of the participants concerning the non-technical problems whereas the attitude concerning the technical problems was more positive. They felt that the technical problems could be solved by the engineering and scientific communities when given the assignment, but they were not so sure of a solution to the non-technical problems. The institutional problems in the main are going to have to be resolved through legislation whereas the technical barriers require a substantial budget for technology development.

Also, it must be mentioned that today's ranking of major barriers are very probably going to be different than a future ranking. An example of a technical barrier that will assume a more important role in the future is that of downhole pumps. Reliable downhole pumps are going to be a "must" for future binary plants, but they only rank #15 on todays list.

TECHNICAL VS NON-TECHNICAL ISSUES AFFECTING ACCELERATED COMMERCIALIZATION

1. Q - Do you believe the major barriers to accelerated commercialization are technical or non-technical?

A -

	Developers	Utilities	Direct Heat Users	A&E's	Financial	TOTAL
Technical	2	2	3	3	0	10
Non-Technical	11	4	7	4	4	30
Both Equal	2	2	0	1	0	5
No Response	1	1	0	1	0	3

2. Q - If you consider the major barriers to be non-technical, please list the most important issues to be solved.

   A - (NOTE: Only the issues mentioned most frequently were listed here. A complete listing can be found in the Appendix.)

   (1) Federal regulations and approval delays
   (2) Inadequacy of tax and rate of return incentives for a new, unproved technology
   (3) Legal/financial aspects associated with reservoir risk
   (4) Faster resolution of environmental restraints
   (5) Compliance with the myriad of federal and state regulations
   (6) Diffusion of authority for permitting
   (7) Inefficiencies and "red tape"
   (8) Broad ignorance of the economic potential by users and their lenders.

3. Q - Are there any major technical barriers that you feel were not covered by the prioritization matrix?

   A - Few relative comments - See Appendix for details.

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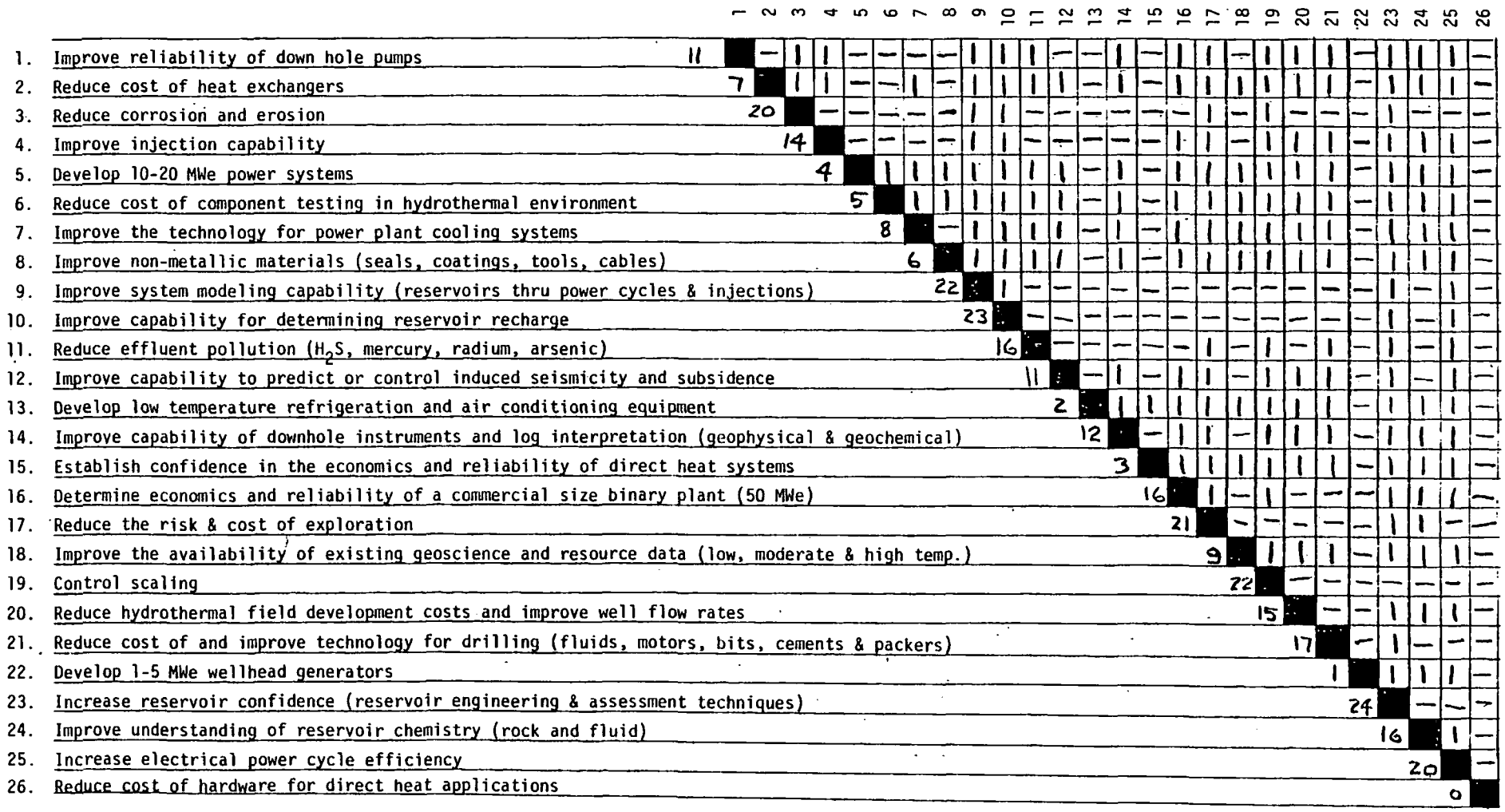
TECHNOLOGY REQUIREMENTS TO ACCELERATE COMMERCIALIZATION OF HYDROTHERMAL ENERGY



ATTACHMENT TO THE PRIORITIZATION MATRIX

1. Do you believe the major barriers to accelerated commercialization are:

Technical

Non-Technical

2. If you consider the major barriers to be non-technical, please list the most important issues to be solved.

a. _____

b. _____

c. _____

3. Are there any major technical barriers that you feel were not covered by the prioritization matrix?

Please list: _____

_____

_____

Name _____ Company _____

TECHNOLOGY REQUIREMENTS TO ACCELERATE COMMERCIALIZATION OF HYDROTHERMAL ENERGY

-Descriptions-

1. Improve reliability of downhole pumps

   The life time of downhole pumps in geothermal environment is short, which results in high replacement costs for field operations.

2. Reduce cost of heat exchangers

   Heat exchangers are major capital cost items.

3. Reduce corrosion and erosion

   Excessive materials losses in weight and thickness due to chemical reactions and to erosion by entrained liquid droplets in steam and entrained solid particles in both liquid and vapor are major problems.

4. Improve injection capability

   As a result of low permeability, plugging and scaling, fluid injections cause parasitic effects on hydrothermal systems.

5. Develop 10-20 MWe power systems

   Confidence does not exist in the use of moderate temperature hydrothermal resources for power production.

6. Reduce cost of component testing in hydrothermal environment

   The costs associated with testing are high if done on an individual basis rather than through a common component testing facility.

7. Improve the technology for power plant cooling systems

Clean groundwater for condenser coolant is typically in short supply in areas of high geothermal activity and many areas are closed to further consumptive water use.

8. Improve non-metallic materials (seals, coatings, tools, cables)

The life expectancy of many non-metallic materials in a hydrothermal environment is short.

9. Improve system modeling capability (reservoirs thru power cycles and injections)

Reservoir engineering and power plant system models have been developed by a number of laboratories, but none of these models are adequate to predict behavior well enough to stimulate confidence on the part of the user or the financial community.

10. Improve capability for determining reservoir recharge

Recharge is desirable to prolong reservoir life, but it must be understood and perhaps controlled to avoid cooling of the produced fluids.

11. Reduce effluent pollution (H_2S, mercury, radium, arsenic)

Some hydrothermal fluid constituents such as hydrogen sulfide, mercury, arsenic, boron, fluorine, and radium are toxic at low levels of concentration.

12. Improve capability to predict or control induced seismicity and subsidence

There is concern that fluid injection at hydrothermal fields may induce seismic events that could be damaging to plant facilities or surrounding areas. Subsidence could also have an adverse environmental affect in the area of the field development.

13. Develop low temperature refrigeration & air conditioning equipment

Current generation equipment suffers from poor efficiencies and is not available for source temperatures below 170°F.

14. Improve capability of downhole instruments and log interpretation (geophysical and geochemical)

Hydrothermal lithologies and rock properties differ greatly from those in normal oil and gas fields, but log interpretation techniques and expertise are generally restricted to oil and gas development.

15. Establish confidence in the economics and reliability of direct heat systems

High drilling costs, exploration uncertainties, and possible problems with scaling and corrosion have tended to discourage potential users of hydrothermal energy for direct heat applications.

16. Determine economics and reliability of a commercial size binary plant (50 MWe)

The economics and reliability of a commercial size binary plant has not been demonstrated.

17. Reduce the risk and cost of exploration

Exploration for geothermal resources is presently too costly because methods and techniques used are mainly those adapted from the petroleum and mining industries. Very little exploration has taken place for low temperature hydrothermal resources because large geothermal developers ignore this resource. Small developers cannot afford to finance development of better exploration techniques.

18. Improve the availability of existing geoscience and resource data (low, moderate and high temperatures)

Although a great deal of geoscience data important to geothermal exploration exists, little of it is assembled and published.

19. Control scaling

Scaling increases pumping costs and decreases the heat transfer properties of the scaled equipment.

20. Reduce hydrothermal field development costs and improve well flow rates

The hydrothermal field development costs are large and the production flow rate is an important factor in field development.

21. Reduce cost of and improve technology for drilling (fluids, motors, bits, packers, and cements)

Drilling of geothermal wells is a major cost in the development of hydrothermal resources.

22. Develop 1-5 MWe wellhead generators

Part of the problem with the development of hydrothermal resources is the uuderstanding of the reservoir, development of infrastructure between the developer, finance and utility companies and solving the environmental and institutional problems.

23. Increase reservoir confidence (reservoir engineering and assessment techniques)

Lack of confidence on the part of utilities and financial institutions in the longevity of production inhibits hydrothermal development.

24. Improve understanding of reservoir chemistry (rock and fluid)

Geothermal reservoirs are very complex chemical systems. Hot and, often reactive fluids move through pores and fractures in rocks and chemical reactions take place. New minerals are precipitated and existing ones are dissolved or altered.

25. Increase electrical power cycle efficiency

The efficiency of hydrothermal power plants using moderate temperature resources is low. This element includes the development of components or systems which will increase the overall efficiency of the power cycle or develop new higher efficient power cycles.

26. Reduce cost of hardware for direct heat applications

In many design cases for direct heat applications low cost materials of construction could be used, but the hardware is not available in these lower cost materials (e.g., plastics).

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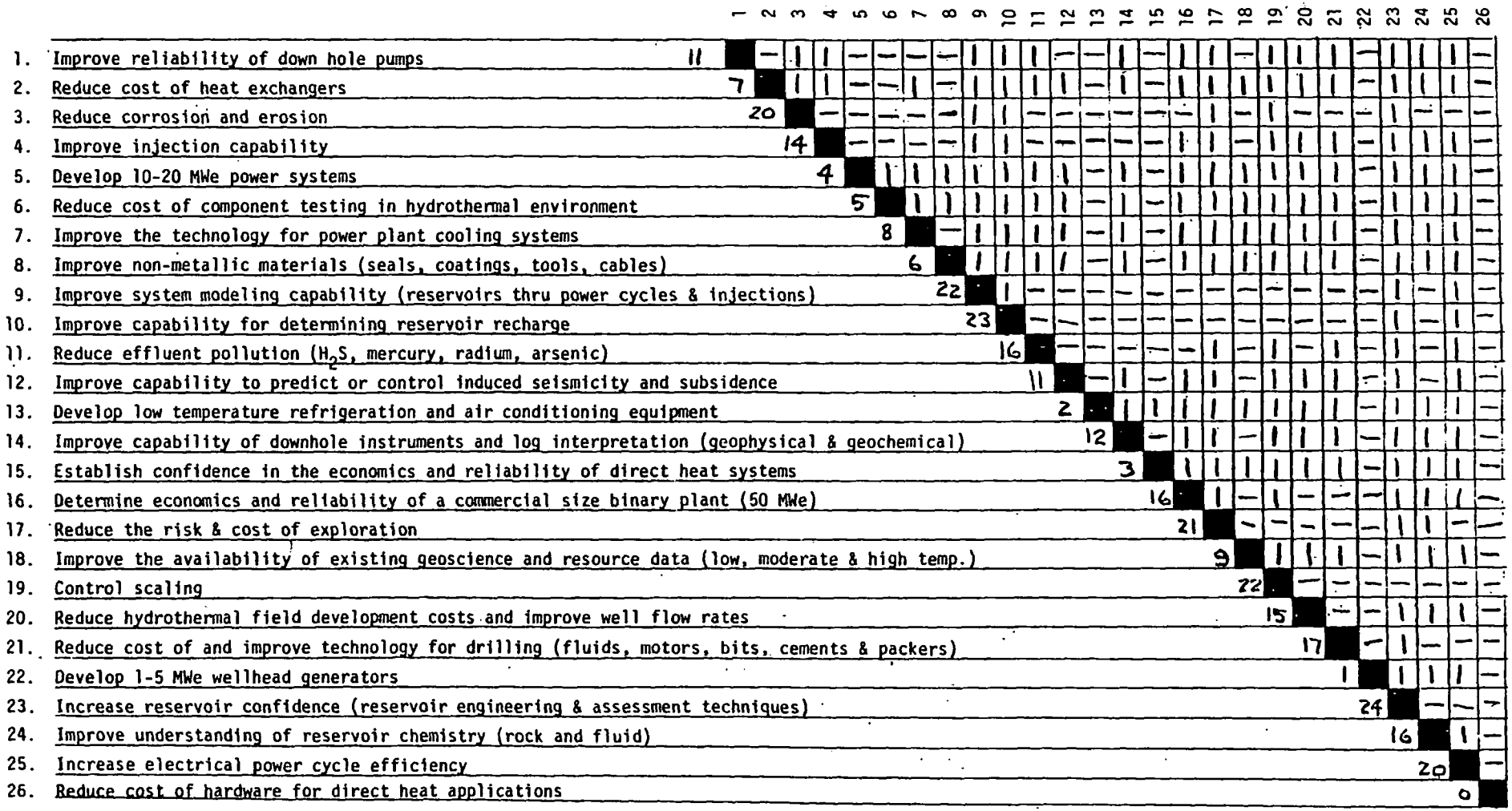
TECHNOLOGY REQUIREMENTS TO ACCELERATE COMMERCIALIZATION OF HYDROTHERMAL ENERGY



ATTACHMENT TO THE PRIORITIZATION MATRIX

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Technical

Non-Technical

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a. _____

b. _____

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Please list: _____

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Name _____ Company _____

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