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Fossil Energy Research Meeting

June 28, 29, 1977

Sponsored by
Energy Research and Development Administration*
Division of Physical Research Publication

Publication Date — December 1977

*Under P.L. 95-91, the Functions of the ERDA were transferred to the Department of Energy on October 1, 1977.

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Richard H. Kropschot
Gerald C. Phillips

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Division of Physical Research
Washington, DC 20545

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PREFACE

On June 28 and 29, 1977, at the Quality Inn in Washington, D. C., the United States Energy Research and Development Administration held a public meeting to review the basic and applied research programs having impact on future fossil energy technologies. The goal of the meeting was to solicit public input to aid the Agency in long-range planning. The meeting consisted of two parts:

- presentations of the various research programs by ERDA personnel; and,
- four discussion groups intent on obtaining feedback relative to the material presented.

The MITRE Corporation/METREK Division (under Contract No. EX-77-C-01-6110) provided analytical, evaluative resources and prepared materials for presentation at this meeting. They also provided timely assessment of responses from the public meeting participants.

The proceedings of the presentations by ERDA personnel are contained in this one volume.

ACKNOWLEDGEMENT

The authors of this report wish to express their thanks to Dr. James S. Kane for his support of this project. We also wish to acknowledge the able assistance of Charles Bliss, Dr. Jim Lang, and Roy Peterson of the MITRE Corporation/METREK Division, who acted as leaders in the group discussions, and Dr. F. Dee Stevenson, Dr. E. Karl Bastress, Paul Scott, and Frank Ferrell, the ERDA representatives who also assisted in the group discussions. We wish to thank Ruth Gilliam for her assistance during the meeting. And finally, to those two untiring people, without whose assistance neither the meeting nor the report could have been accomplished successfully, Donna Stein of ERDA, and Marie Benford of the MITRE Corporation/METREK Division.

THE MITRE CORPORATION/
METREK DIVISION

and the

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

PUBLIC MEETING

on

FOSSIL ENERGY RESEARCH

Quality Inn
415 New Jersey Avenue, N.W.
Federal Ballroom South
Washington, D. C.

Tuesday, 28 June 1977

The meeting in the above-entitled matter was convened pursuant to notice, at 8:30 AM. Messrs. J. S. Kane and G. C. Phillips, chairmen, presiding.

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PROCEEDINGS

DR. KANE: My name is Jim Kane. I'm going to chair this morning's session.

The meeting is an open public hearing, and we are going to have question and answer sessions after each speaker. I'll ask each of you, to go to one of the microphones and identify yourselves before you ask your questions.

The entire proceedings are being taped. You should know that ahead of time.

We're very fortunate to have our welcome introduction speaker here this morning, because his presence was requested rather preemptorily by the Senate, and he's been up on the Hill since 7:00 o'clock this morning. He has expressed to me privately that it was a great, great pleasure indeed to be here to give you these welcoming remarks.

Excuse me, I thought you all knew him. I didn't even introduce him. He is my boss: Bob Fri, Acting Administrator of ERDA.

MR. FRI: Thank you, Jim. It is indeed a great pleasure to be here. We are conducting this hearing in the usual Washington fashion. We have virtually everybody that ought to be talking to you testifying before the Senate instead of being here; but we are trying to run a little relay race back and forth. It is only a few blocks. The hearing should be over by 10:00, so I think, we have ourselves reasonably covered.

First of all, let me just thank you all for coming. This project that we are embarked on is terribly important to us, and we can use all the help we can get, both from inside and outside the agency.

I might give you a little background on it. You should know that although ERDA may be well known for getting into controversies, such as whether or not to build high Btu gas plants and breeder reactors it also has basic research responsibility in energy. Indeed, the basic research responsibility for all energy sources rests here.

We inherited a substantial basic research program from the constituent agencies, but primarily from the Atomic Energy Commission. Our people have worked over the last two years to reshape that program in a way that provides the fundamental science underpinnings of our entire range of projects.

A little over a year ago, we set forth a series of management goals for the agency.

One of those was to make sure that our basic energy sciences program was in fact, a sound one. Not only in the organization that Jim Kane runs, which conducts much of that operation and has that title, but also in the supporting research functions of a variety of our other program offices, all of whom virtually have some basic research responsibilities and sponsor research in those areas.

Jim approached this very difficult problem of shaping a basic research program in, I think, a very good way and set up a project with a couple of distinguished people from outside the agency to spend a year with us and help us understand how we could do better. They have in fact done that.

One of the results of that project was to point out that fossil energy research was one of our most important products, and one in which the fundamental research base requires--in a kind of program that we ought to be running--some clarification. It's important because, you know at least as well as I, that fossil energy is terribly important to the United States, and it's important because the research base for that program was not one of the big things that was brought over to the agency. A significant program was brought from the Department of Interior, but it had never been at the AEC. The confluence of those two observations early led us to say, we need to do the best job we can; and to take a hard look at the fossil energy research base.

We thought one good way to get a fix on the kind of research that needs to be done and the kind of role a federal agency could play was to bring together, in a public meeting, a group that could help us out. As I see from the agenda we'll try to give you some background this morning; then turn around later on in the afternoon and look to those of you who have come to give the advice and help that we frankly seek in this matter.

So you're very kind to have come. It's going to be a great help to us. We are doing this for a selfish reason, to help put together our research program; but we hope you find some interest in it, too.

Unfortunately, I have to go back to the Hill, but again, thank you, and I hope you have a successful meeting.

(Applause.)

DR. KANE:

We are going to try to keep this on schedule, so we have a couple of people with a clock down here to keep us all on time.

I'm going to repeat a lot of the things Bob said. He took a lot of my opening talk, but I think it's probably important that I repeat some of the things he said because in my few minutes of opening here, I would like to tell you, again, why you're here precisely; and what this meeting is expected to cover and what, by implication, it is not expected to cover. So, some of this will be repetitive of what Bob just said, but I think it's worth it that I go over it again.

This is a mandate given to me by the Administrator of ERDA to assess the--I will have to be careful to explain some of these words--the quality of the Basic Energy Sciences Program. And now I have to explain very carefully what I mean by "quality" and "Basic Energy Sciences Program," because that's really why we're here.

Subsequent discussions with Mr. Fri and Dr. Seamans, when he was here, defined this in the following way. By "basic energy sciences," I mean the basic relevant sciences, the applied sciences, and the kind of broadly applicable generic sciences that pertain to energy technologies.

Today we are going to limit this to fossil energy but the charter they gave me wasn't limited to just fossil energy. So it's the very basic work, the applied science work and the broadly relevant generic type work, which is not specific to one particular technology.

Let me describe what Dr. Seamans and Mr. Fri meant by "adequacy." They didn't mean by "adequacy," the usual idea; Is this individual piece of work of high scientific quality? They meant by "adequacy" that, from the viewpoint of the agency; Was the research across the agency integrated? Remember, it's done by different players sometimes. Were these people talking to each other? Was the research program balanced? This is a question you will hear again and again today. Do we have a balanced program? Are there parts that, in your opinion, are receiving far less emphasis than they should? Are we doing too many things in one area and not enough in others? Is the program comprehensive? Are we overlooking great opportunities for research? That's really what they meant by "adequacy." So that's the thing I'll ask you to concentrate on today. The balance, the comprehensiveness, the integration, as well as, of course, suggestions on subject matter.

Now, to do this for the agency, of course, would be an enormous job and I decided that it was highly improper to do it with our own people, and our own resources. To ask an organization to look at itself critically is kind of a risky business. So I thought it best to use outsiders, who Mr. Fri told you about. They're not full-time ERDA employees, and they are the two gentlemen you will see more of during this meeting, Dr. Gerald Phillips, who's on leave from Rice University, where he's a professor of physics, a longtime head of the Bonner Laboratory there and a man who has at least a passing acquaintance with the oil patch.

The other participant is Dr. Richard Kropschot, who is a commerce science fellow. He's Chief of the Cryogenic Technology Section of the National Bureau of Standards at Boulder, Colorado.

I gave these two people very broad guidance, just what I'd been told by Mr. Fri and asked them to come back and tell me what they thought needed doing.

This was their three months progress report: they found much they liked about ERDA. They had two principal observations relevant to this area I'm talking about.

One, they sensed there was an unevenness in emphasis on applied sciences.

Secondly, because of the unique organization of ERDA, the vertical organization of ERDA, in which one assistant administrator is given responsiblity for a specific technology they found what they thought was a neglect of crosscutting technologies. Ones that were of interest to many people across the agency, and yet no one administrator felt his career rose or fell on their success. And these had a tendency to drop through the cracks.

That was their preliminary report to me. As I say, they found much they liked; they found some things that concerned them.

My guidance to them at that time was to concentrate their efforts on fossil energy rather than the entire agency. For two people to try to do the entire agency, of course, would be folly. The reason we chose fossil energy was because the agency has given such enormous--well, the country for that matter--such enormously high priority to coal, in the nation's future, and particularly, the critical shortage of liquid fuels that may occur. So fossil energy was chosen because, in our opinion, it was a high priority topic, particularly the aspect of utilizing coal. And, again, I'm narrowing down here--I've told you already we're narrowing into one end of this broad continuum what ERDA's responsible for in research. Remember, ERDA's responsible for everything from basic research to commercialization. I've told you we're going to concentrate on one end of that spectrum today. And I'm saying we're going to concentate on fossil energy and, specifically, we'll try to keep it highly focused on coal, coal to liquids and coal to gas.

Now, I realize with an audience of this quality, I don't want to focus you too narrowly. We appreciate your comments on any subject, but the general purpose of this meeting is to focus as narrowly as possible on the topics I've mentioned.

All right. The two of them came back in the spring and reported the following: they had concern about the balance of the overall fossil energy program. Particularly, they were concerned about a gap between the basic research program, which is under my jurisdiction, and the applied science programs. Let me explain a little bit about responsibilities in the agency. My organization is responsible for the basic research for the entire agency. In other words, basic research related to solar, fission, and fusion sources, and fossil energy, the whole gamut.

I am not responsible for the applied science. The applied science is left to each of the assistant administrators, and it's his decision on the emphasis he gives to the applied science, that leads to the goals that he has defined for his particular cut of technology. So they perceived what they thought to be a gap in between the basic work and the applied science.

They also perceived what they thought and, again, I will put this in qualitative terms because this is a supposition on their part, but they at least expressed concern over what they perceived to be a lack of novel applied science directed toward concepts that would appreciably lower the cost of converting coal to liquid and gas. I guess kind of a slang way of saying that would be--well, maybe you'd want to call them high risk, high pay out approaches.

I don't know what you'd prefer to call it, but at least I'm trying to put in words the opinions they gave to me. They reported these opinions to me and of course, the first thing we did was talk to the people in fossil energy about this. And I want to emphasize this again. This is not in any way an adversary hearing today in which we are saying one approach is right, and another one is not right.

We have had the total cooperation of the fossil energy people in this. Rather than an adversary hearing, this is a constructive session in which we hope to solicit opinions on how we can make our programs better.

Dr. Kropschot and Phillips reported their opinions to me. We explained them to Dr. White, who is head of the fossil energy program, and I've been--by the way, let me digress a minute here--while we're waiting --three of the participants on this morning's program are up at the Hill right now. Dr. White is one of them, and we're going--because he is so important to this program, we're going to work him in as he comes and delay his part of the program. So our agenda this morning is apt to be a little out of order because there are three absent participants; Chris Knudsen, Dr. White, and Harry Johnson. I think we have a substitute for Harry Johnson because he is so early on the program, but the other two, we'll try to work around them.

All right. We told our opinion to Dr. White, and this meeting resulted. It's an honest seeking of diversity of opinions and viewpoints. We ask your help.

Now, let me tell you what it is not. I have said this twice, but I want to make it very clear. It is not a review of the entire fossil energy program. As I said, a group like this is going to make their opinions felt on any subject they wish to. It's an open hearing. But we'll try to keep it away from specific discussions of the technology, commercialization, and demonstration program, and the advanced technology. This is not meant to be a review. On the other hand, in order for you to give us your opinion, you have to understand the program. So you're going to hear a lot this morning about the entire program, more as background material, so that the format is a presentation of the fossil energy program. Then, after that, a report on the research program, and a time for a discussion and criticism.

Now, although I'm going to be on the stand this morning, I want to make one final comment and that is, from now on, I'm really a participant in this; my program is as much under scrutiny as any other program here today, and I invite your comments. I'm really more of a Mr. Interlocutor than I am running this thing from now on.

I'd like to, before I go any further, introduce Dr. Phillips and Dr. Kropschot, who have been responsible for this review. They're sitting in the front row here. Dr. Phillips is in the brown suit, and Dr. Kropschot in the blue.

Our first speaker then on this morning's session will be a pinch hitter for Harry Johnson, of ERDA's Planning Office. Let me explain a little bit about what Harry does. Harry is a planner, the one who outlines the missions, the programs, and advises on the budget for the agency's energy programs. His place is being taken by Bruce Robinson, who will give you the first presentation of the morning.

DR. HILL: Dr. Kane?

DR. KANE: Yes.

DR. HILL: While he is setting up, would you describe for us the functions that NSF RANN, and NSF used to carry that are no longer carried by them and must be by ERDA?

DR. KANE: I don't believe I can really do that. I'm not well enough acquainted.

Bruce, do you know any of those fuctions that were transferred in from NSF or terminated over in NSF and RANN, which have been picked up by ERDA?

DR. ROBINSON: The programs that come to mind are solar, geothermal, biomass.

DR. HILL: There was a lot of coal research.

DR. KANE: -- there was a lot of coal. Alex Mills then could perhaps address that one.

DR. MILLS: We had 23 projects from RANN, which were transferred to ERDA. I'd like to say, in all frankness, they were transferred with no money, no personnel, and they are now coming in for renewal.

DR. HILL: So it is expected that your shop will pick up everything NSF was doing?

DR. MILLS: Coal; right.

DR. ROBINSON: Well, my task, as I understand it this morning, is to give you a brief overview of ERDA's programs and budget, to give you some context for the more focused discussion you are going to have during the course of the day. So what I intend to do is give you a very abbreviated indication of how ERDA's programs are consistent with a strategy which derives logically from consideration of national energy problems. In the course of that, to hit on some of the highlights of the programs; and then to give you a quick overview of ERDA and the ERDA budget that was submitted to the Congress recently for fiscal year 1978.

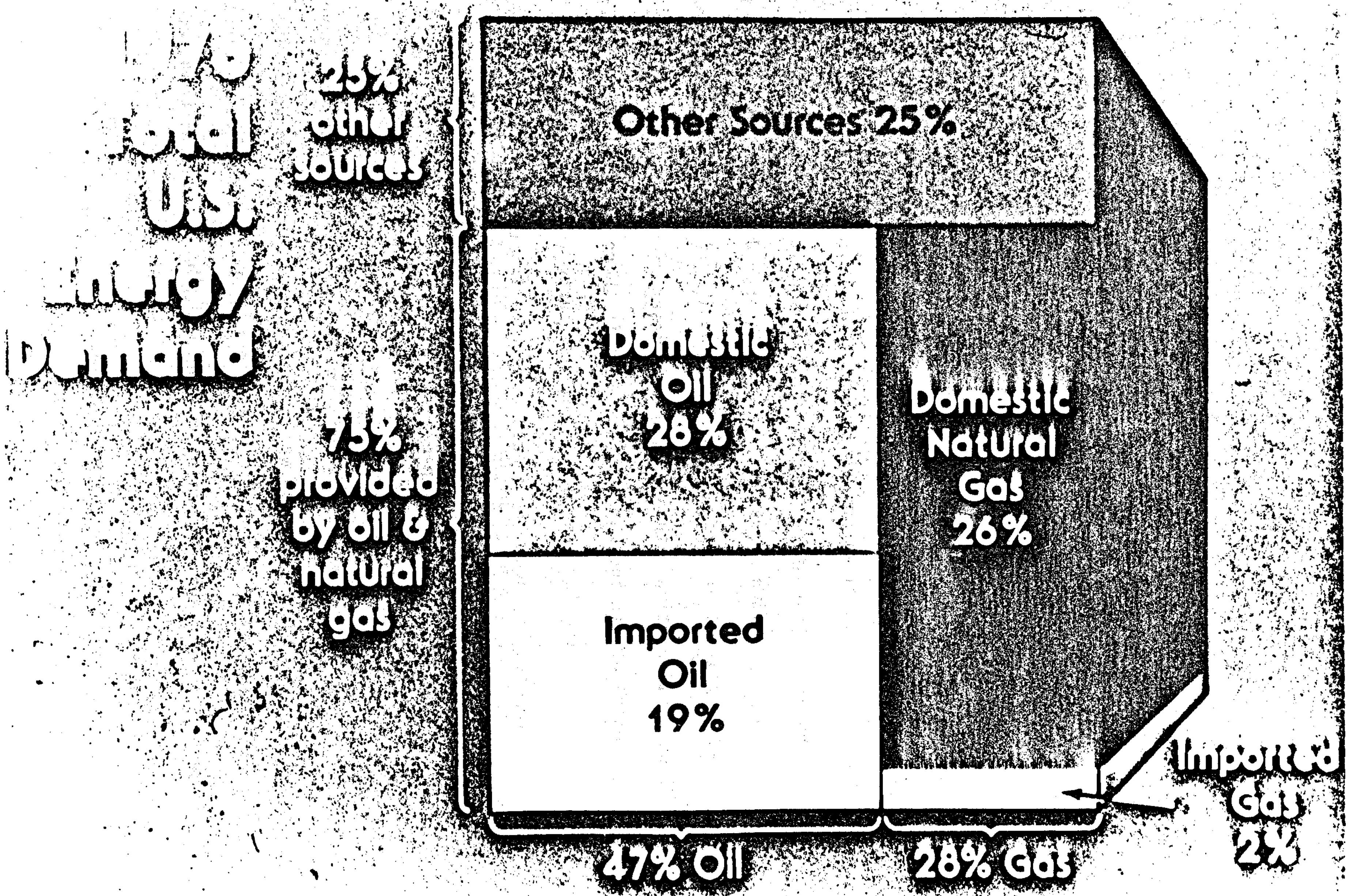
I might say that a more detailed discussion of the kind of topics I will be covering and related topics will be included in the ERDA Annual Plan, which is due to come out in about two weeks and will be available from the Technical Information Service in Oak Ridge at that time.

Can I have the first slide, please.

(Slide 1)

Of course, the major component of the national energy problem is the fact that our entire economic infrastructure is dependent on oil and gas. As this slide indicates, about 75 percent of the consumption in 1976 was in oil and natural gas.

As you know, and as we'll see in a subsequent slide these are our least plentiful resources, and our fix to date has been importing. As indicated, in 1976, we imported something like 40 percent of our oil.


U.S.
Demand
25% other sources
75% provided by oil & natural gas
Other Sources 25%
Domestic Oil 28%
Imported Oil 19%
Domestic Natural Gas 26%
Imported Gas 2%
47% Oil
28% Gas

Our domestic resources simply cannot support the kind of production required to meet our demands, and we cannot depend on the temporary import fix because there is a similar worldwide oil problem not too far down the road.

Can I see the next vugraph.

(Slide 2)

This slide projects a cumulative consumption worldwide. The upper band indicates estimates of world oil resources. The yellow bar is the halfway mark; a typical bell-shaped production curve. You begin to level off production at the halfway mark. As you can see, if the world continues this present 8 percent growth, production will be leveling off in the late 1990s. Even if there is no growth at all, we will reach the leveling off point very early in the next century. So the import fix, even if we are willing to ignore problems of national security and balance of payments, is at best a temporary fix.

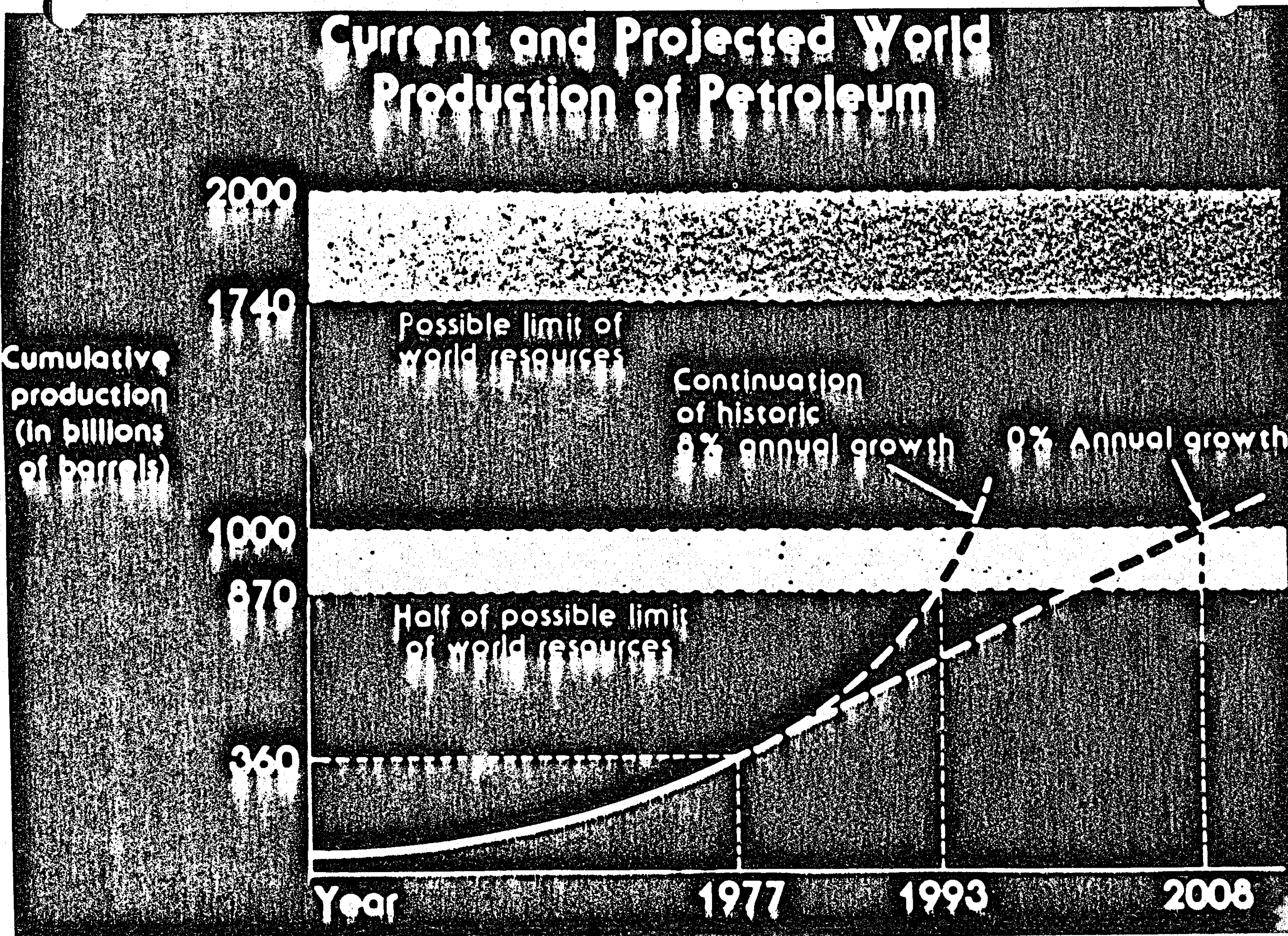
The next slide, please.

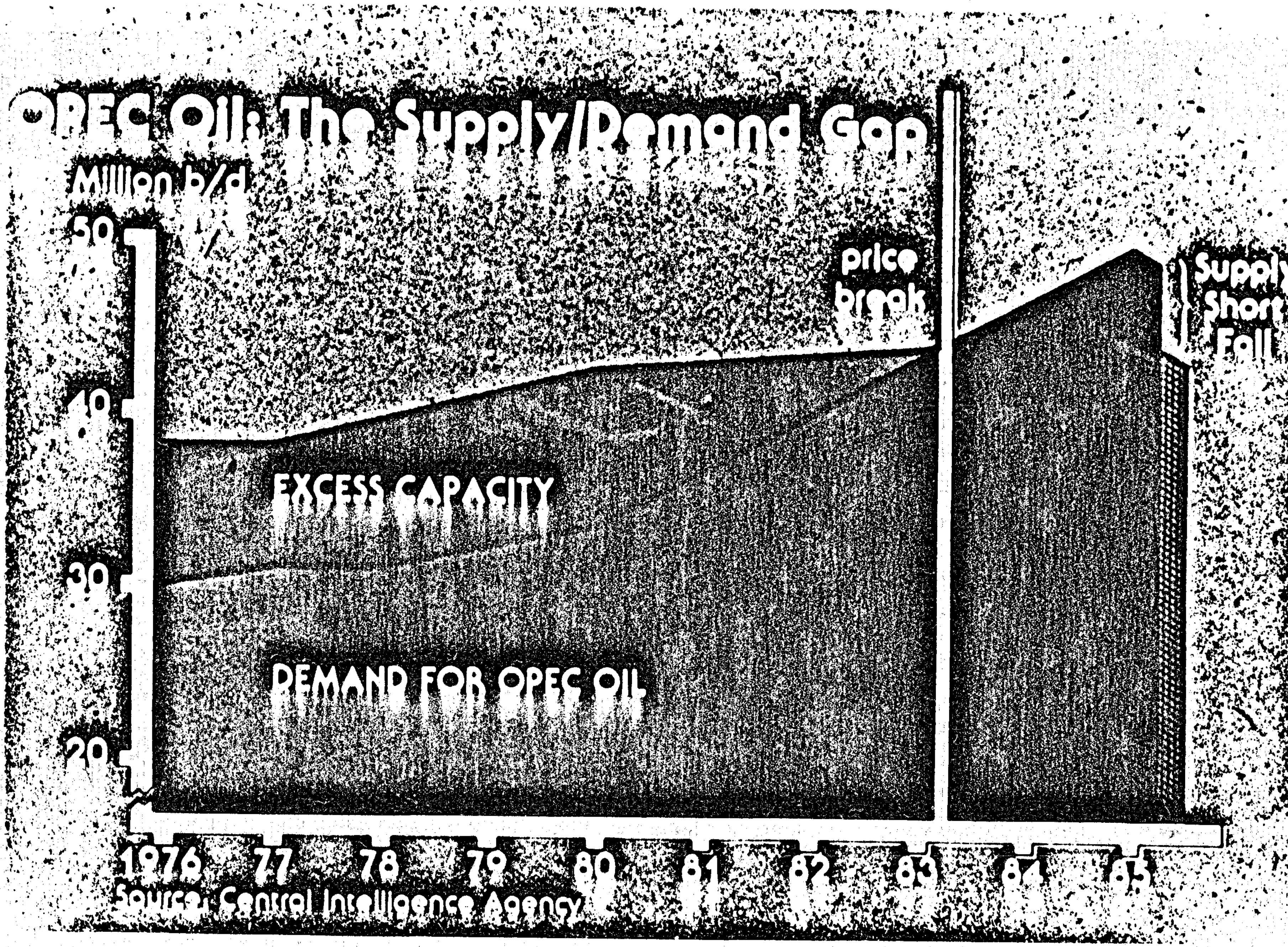
(Slide 3)

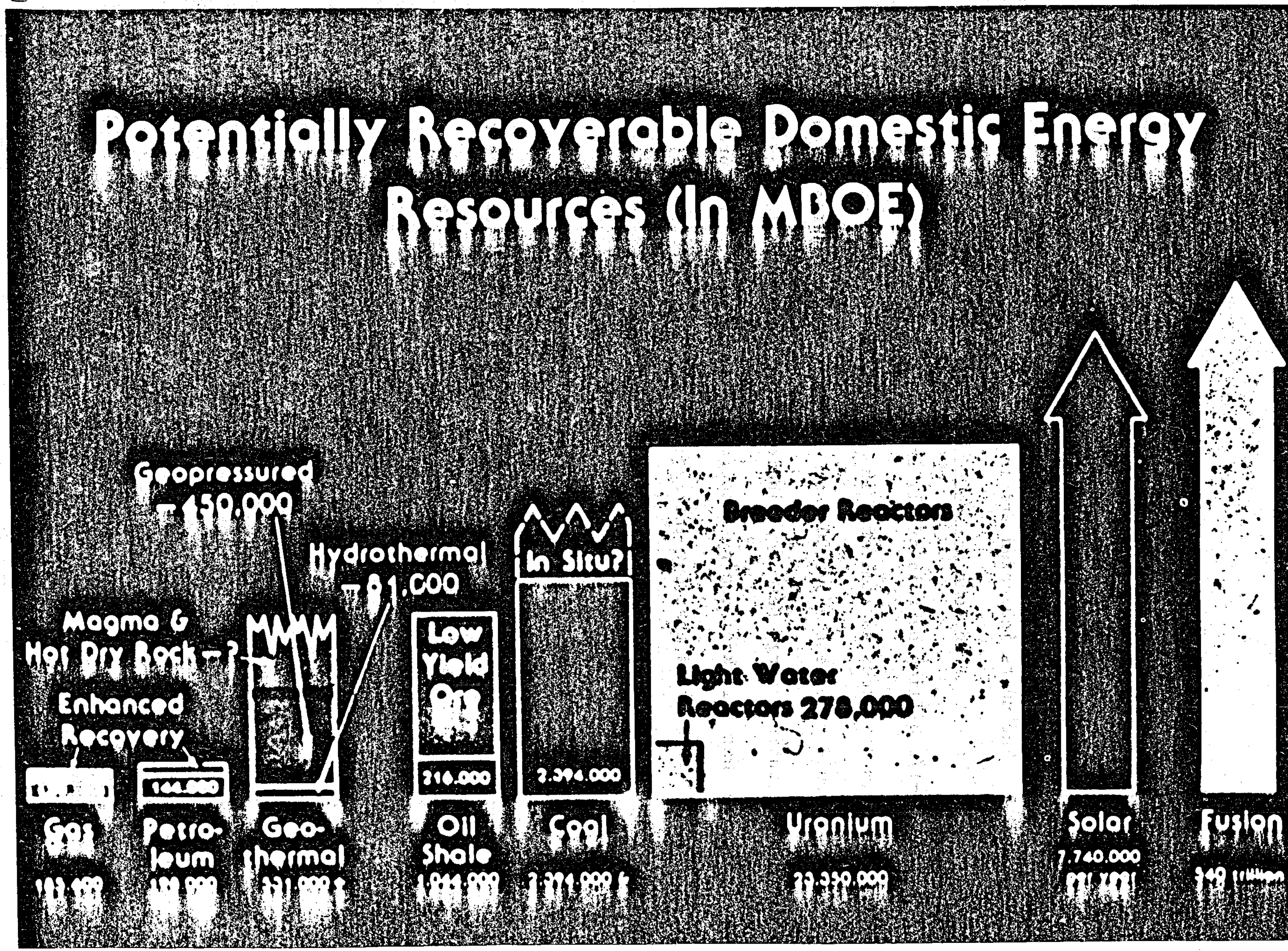
This is the result of a recent CIA report where they have projected that the problem we are projecting in the '90s would actually occur in the '80s. There is some disagreement as to exactly when it will occur, but there's no doubt that imports, at best, are a temporary fix.

Could I have the next slide.

(Slide 4)


Current and Projected World Production of Petroleum
Cumulative production (in billions of barrels)
2000
1740
1000
870
360
Possible limit of world resources
Half of possible limit of world resources
Continuation of historic 8% annual growth
0% Annual growth
Year
1977
1993
2008


OPEC Oil: The Supply/Demand Gap
Million b/d
50
40
30
20
price break
Supply Short Fall
EXCESS CAPACITY
DEMAND FOR OPEC OIL
1976
77
78
79
80
81
82
83
84
85
Source: Central Intelligence Agency



Potentially Recoverable Domestic Energy Resources (In MBOE)
Geopressured
Hydrothermal
Magma &
Hot Dry Rock – ?
Enhanced Recovery
144,000
Low Yield Ore
216,000
In Situ?
2,394,000
Breeder Reactors
Light Water Reactors 278,000
Gas
Petroleum
Geothermal
Oil Shale
Coal
Uranium
Solar
7,740,000
Fusion

This is a slide which shows the various energy resources available to the United States domestically. The first thing to conclude is, we don't have a lack of energy resources.

The units indicated are in millions of barrel of oil equivalent. To put it in some perspective, we are now consuming something like 13-1/2 billion barrels of oil equivalent per year, so our gas and petroluem resources as indicated in the lower left-hand part of the slide would represent about 30 years of current consumption: considering the entire energy resources indicated with that kind of scale, you can see that a lack of energy resources is not a part of the problem. The real problem is that our infrastructure is completely tied to the oil and gas, or very scarce resources, and it's going to take time to get away from that dependence.

The resources are scaled in order of increasing availability and recoverability, with gas and petroleum, the most scarce, on the left-hand side, and the virtually infinite resources, solar and fusion, on the right-hand side.

The area of the rectangles are roughly proportional to the recoverable resource available.

By looking at this slide, one can easily see what the components, of any national strategy to cope with the energy problem, are. One, of course, is conservation, to try and save energy resources, particularly the scarce oil and natural gas. Second, to attempt the enhancement of the availability of oil and natural gas, because our economic infrastructure is so tightly tied to them, and (for that reason) there is a long time constant associated with getting away from those resources.

Finally, we must develop methods to switch to the more plentiful resources. This includes using them directly, for example, direct combustion of coal, or using them to provide direct substitutes for the oil and natural gas that our system is dependent on. Again, coal provides a good example with coal liquefaction and coal gasification.

I think this slide, displaying the domestic resources, actually provides a good background for discussing the resource-related ERDA programs. So I'll put off for the moment discussing conservation. We'll pick those up on a subsequent slide.

Discussing the other points of any national strategy, first, increasing the availability of those energy resources that we're so dependent on, namely, oil and natural gas. ERDA, indeed, has enhanced gas programs and enhanced oil recovery programs. You'll be hearing more about those today so I won't bother mentioning more about them.

The second component is, of course, switching to the more plentiful fuels, and since the topic today is fossil, let me just quickly touch those. You'll be hearing more details later today.

Our most plentiful fossil fuel is coal, the fifth box in the array. As you can see, there are a couple of centuries worth of coal, measuring by current total energy consumption.

The coal program consists of development of technologies to permit direct combustion of coal, and the major problem there is being able to do it in an environmentally acceptable manner. That will be discussed in more detail today and on technologies for making direct substitutes for liquids and gas fuels from coal.

The final fossil fuel on the slide is shale oil. Again, ERDA has a program here; and again, environmental and water resource constraints are a major problem which face the development and implementation of that technology. You'll be hearing more about that today.

Moving to the nonfossil resources on the slide, the first nonfossil resource is indicated the third box in the array, namely, geothermal. It is divided into two areas. The area at the bottom of the slide is hydrothermal geothermal. It is not a huge resource, but certainly very significant and it has a great regional significance in the West and the Southeast. The larger area on the slide with the undetermined upper limit is the geopressure resource which is a vast resource, principally in the Gulf state regions.

ERDA has programs in the hydrothermal area. They include geothermal loan programs to try to remove some of the institutional barriers to the private sector picking up the state of the art technology and implementing it.

ERDA has research programs that include test facilities to advance the state of the art, examination of the environmental problems associated with geothermal, and very importantly, an attempt to assess the resource. Very little has actually been done in the past to assess just how much geothermal energy is available in the United States. These are very approximate figures.

Finally, there is a plan for design of 50 megawatt demonstration plants.

The geopressured resources cannot be tapped with state of the art technology. There is a huge resource there, as indicated. In addition to the thermal energy, it has recently become clear that there is a huge amount of methane, natural gas, dissolved in the geothermal brines. It has been estimated that energy in the methane may be about equal to that of the thermal energy in the geopressured area.

ERDA, again, has a program to assess the extent of that resource and, in fact, our first exploratory hole in the geopressured area began producing results about four weeks ago and, indeed, confirmed the fact that huge amounts of methane are dissolved in the brine, at least in the region of the test hole.

The next nonfossil resource is uranium, and the extent of the resource, of course, depends on the available technology. The small box in the left-hand corner represents the amount of energy that could be recovered with conventional light water reactors, which, of course, is an existing technology.

ERDA's program is designed to insure that light water reactors which do exist and can have a very large, reasonably near-term impact, can be implemented. This involves programs aimed at solving the safeguards and waste disposal kind of problems.

The large box, represents the energy available for uranium, if breeder technology is successfully developed. Breeder reactors are roughly 100 times more efficient than the converter reactors, and hence the same uranium resource is greatly enlarged.

I should have mentioned also that in support of the LWR program, there is, again, a resource assessment program to get a better measure of how much uranium is available in the United States.

The largest single component of the breeder program is the liquid metal fast breeder reactor. The Carter Administration recently cancelled a commercial demonstration program in that area. The program has been diversifed to consider alternatives and assess which breeder technology is most compatible with current concerns about proliferation.

The next, very large resource, is solar. The last two sources are essentially infinite resources. They're renewable, inexhaustible resources.

The solar program, of course, consists of a variety of technologies. The near-term technology in that area is solar heating and cooling. The major component of that program is a demonstration program, to have several hundred highly visible demonstrations and to publicize the results of those demonstrations to remove institutional barriers which are setting back the growth of an industry in that area; and to make the results of those demonstrations available to building owners, builders, and people in the financial community. They're already, of course, in 1977 demonstrations programs for solar heating. It's hoped by '79 to have demonstration programs in solar cooling. There are related programs for solar heating applications in industry and agriculture.

Solar energy is also potentially useful for generating electricity. There are several programs in that area. There is direct solar thermal electric generation where the sun is essentially used to produce steam to be used in conventional turbines to generate electricity.

ERDA has a test facility, testing the components of such a system. A site has been selected for a 10-megawatt facility.

There is also a photoelectric program, where the sun's energy is converted directly into electricity. That technology was developed for space applications. It is now an expensive technology. The major goal of that program is to get cost down by about a factor of about 50 to 100. The emphasis is on small applications that have some chance of being cost-effective in the relatively near future. The major emphasis is on conventional silicon technology, although there are programs in gallium arsenide and other less conventional semiconductors, where there's hope that some cost breakthrough can occur.

Those are the direct applications of solar. There are, of course, less direct applications. One would be wind. ERDA and NASA are now testing a wind facility in Ohio; a 100-kilowatt test generator with about a 125-foot blade. There are two improved versions of that underway. A 1.4-megawatt system is being designed. An initiative of the Carter Administration in the wind area is to put greater emphasis on small systems which are compatible with decentralized applications for industrial uses, small communities, and agricultural uses.

Another indirect use of solar is an ocean thermal electric application where one exploits the temperature difference between the surface and reasonably shallow waters in the Gulf region. At the present time the focus is on small scale testing of the critical components of that system, principally the heat exchangers. No heat engines have been operated in the past using such small temperature gradients. The feasiblity of doing that has to be established before any kind of large-scale program could be considered.

Finally, in the solar area there is a biomass program. There is already on the order of half a quad of biomass being used which is principally in the form of industrial waste. The ERDA program does emphasize this kind of residual application, but also is exploring biomass, which is purposely grown in aquatic and terrestrial environments for the purpose of conversion to energy.

The last resource on the slide is fusion. Deuterium is available in huge quantities in the oceans. Fusion of deuterium of course, gives off the energy which drives the sun--also the source of H-bomb energy. There are, parallel approaches being pursued by ERDA. One, inertial confinement, where the reaction is confined to the necessary densities and temperatures by impingement of high density lasers, or beams of particles. In parallel with that program, there is a magnetic confinement program where magnetic fields are used to confine charged particles to obtain the necessary densities and temperatures to get a fusion reaction with net energy.

The fusion program is a long-term program, of course, and there is a plan of sequential events to arrive at both feasibility and, hopefully, in the distant future a demonstration of that technology.

I've used the estimated resources available in the United States to give at least some of the highlights of ERDA's programs on the production side of energy.

We've demonstrated the various components of any national strategy, namely; enhancing the availability of those resources on which we are very dependent, gas and oil, providing substitutes for them from our very abundant resources, like coal; making greater direct use of the more abundant resources, like coal, shale, et cetera; and getting our economic infrastructure untied from the scarce fossil resources and linked to inexhaustible resources in the long-term.

The one component of the strategy which I didn't mention in my discussions of resources was, of course, conservation, which can have a very important near-term effect and is cost-effective in many, many areas.

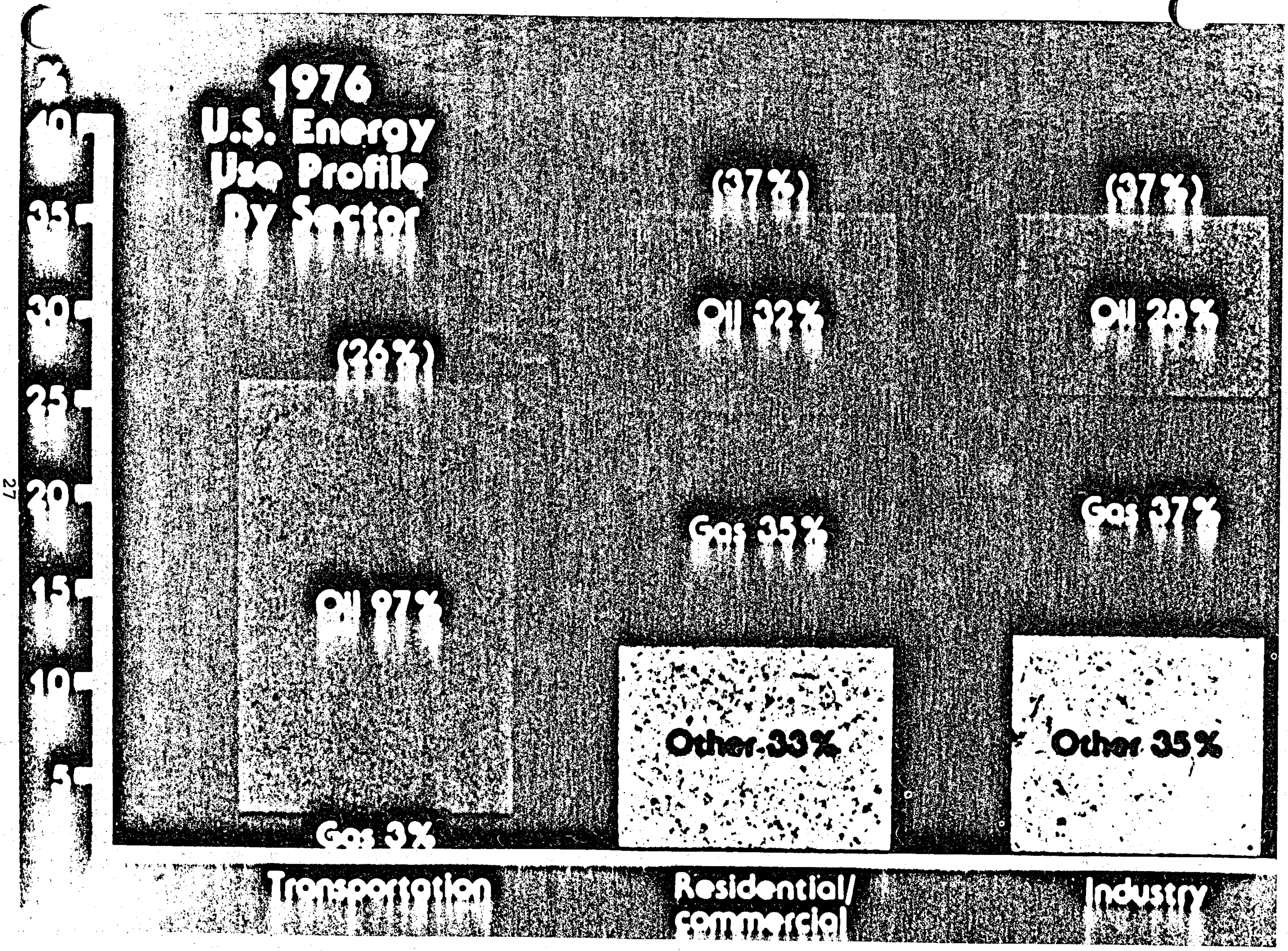
May I have the next slide, please.

(Slide 5)

This slide indicates how we now meet our energy needs in the various end-use sectors. Of course, the transportation sector is virtually all oil. There is little hope that oil will be completely displaced in this sector by the end of the century. We do have an electric vehicle program which is aimed towards demonstrating electrical vehicles in the early '80s and providing the beginning of a viable industry in that area. But it's unlikely that oil will be displaced in the transportation areas, so conservation there is very important.

The largest single component of ERDA's program, is research on heat engines; sterling cycle and gas turbine. There is related research on auxiliary systems like variable transmissions, drive train improvements, et cetera.

In the residential and commercial areas, there is some hope that by the end of the century oil and natural gas could be more or less displaced entirely. There are research programs, in building design and community systems where waste heat from electric generation plants are used to provide a lot of the residential/commercial energy.


1976
U.S. Energy
Use Profile
By Sector
%
40
35
30
25
20
15
10
5
(26%)
Oil 97%
Gas 3%
(37%)
Oil 32%
Gas 35%
Other 33%
(37%)
Oil 28%
Gas 37%
Other 35%
Transportation
Residential/
commercial
Industry

Other areas include, improvements in efficiency of consumer products and use of urban waste. These are some of the highlights of the residential/commercial building area of ERDA's program.

In industry, again, there's a great deal of opportunity for savings. There's hope that by the end of the century oil could be completely displaced except for petrochemical use. One of the major things there would be switching to coal, which is part of the fossil program. But in addition, in our conservation program, we have projects aimed towards the recovery of waste heat for low temperature applications, and cogeneration, where again, the waste heat from electrical generation plants can be used for process heat or direct heat uses in industry.

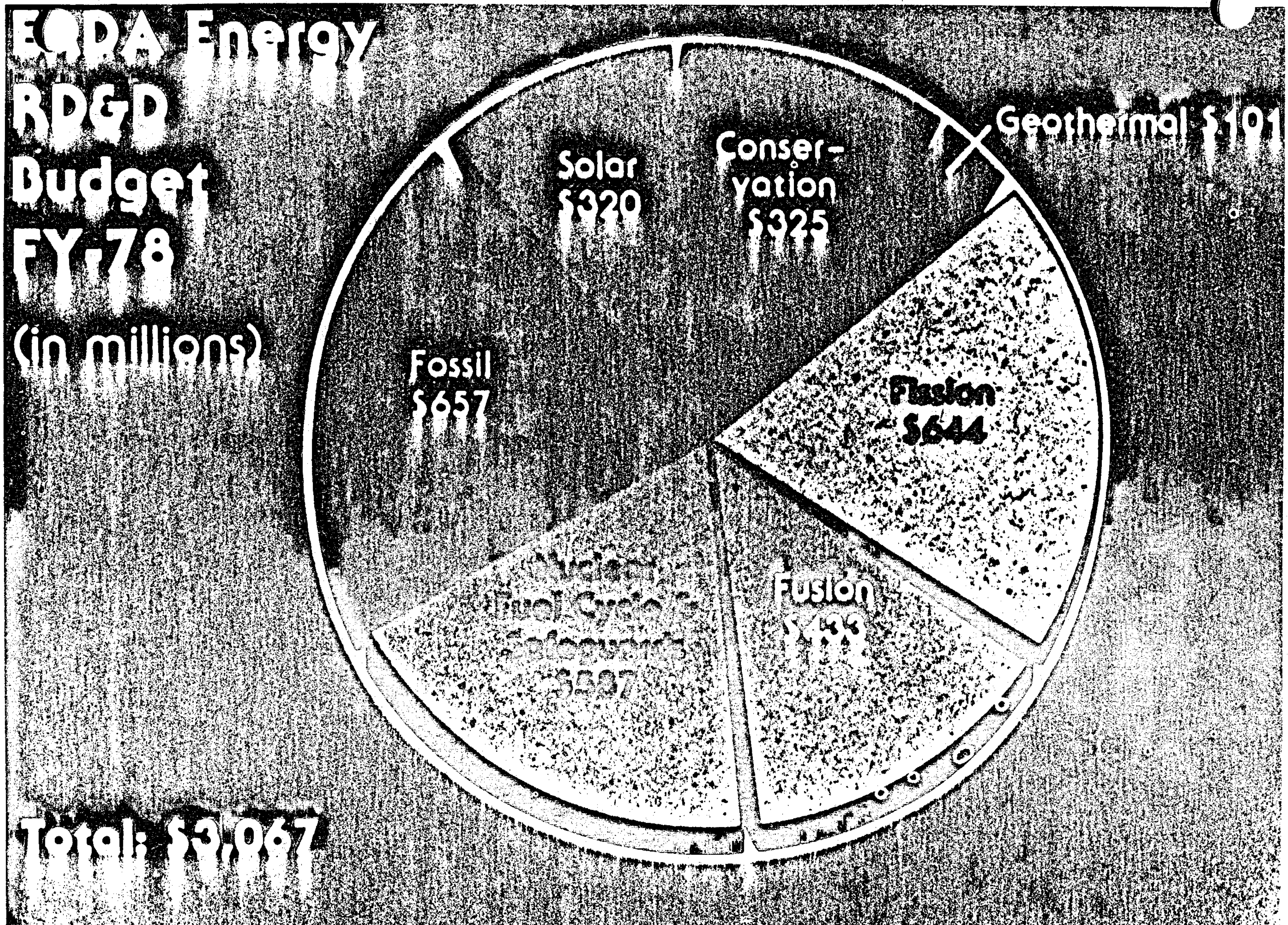
Finally, there are changes in industrial process, especially for those processes used by the most energy-intensive industries. ERDA, again, has programs in all of these areas in cooperation with industry.

Can I have the next slide, please.

(Slide 6)

By looking at the resources available, and the kind of national problem we seem to have, I've just hit some of the highlights of our programs. I'd like to now hit some of the highlights of the budget that was submitted for FY '78 to the Congress.

The total budget in the energy area is about $3 billion, and it's divided as indicated. I think the labels are pretty much self-


ERDA Energy
RD&D
Budget
FY-78
(in millions)
Solar
$320
Conser-
vation
$325
Geothermal $101
Fossil
$657
Fission
$644
Fusion
Total: $3,067

explanatory, based on what I was saying before. The nuclear fuel cycle and safeguards refers to the kind of thing, I said was needed to support the LWR, namely, the safeguards, and waste disposal problems.

The area marked "fission" is predominately breeder reactor research. And the others, I think, are pretty much self-explanatory.

I should point out this is not the entire ERDA budget. People get confused thinking when they see the total ERDA budget it's an ERDA energy budget.

The total ERDA budget is something like $6-1/2 billion, the directly energy-related RD&D, is less than half of the total budget. The remainder of it breaks out roughly as follows. About $1.9 billion is for national security research, essentially weapons development. About $600 million is associated with basic research and technology development, which is not energy related; high energy physics and nuclear physics, which isn't energy related; and biomedical research. About another half billion is related to uranium enrichment production. The latter is not research, but the actual production of enriched uranium for both domestic and international contracts. There is a remaining several hundred million that is associated with management--program management, et cetera.

The remaining 3 million is the energy budget, which is the principal topic of interest this morning.

To put this present budget into some context with the past, and to give you some feeling for how we have evolved since ERDA was formed, let's look at the 1975 budget, ERDA's first budget.

May I have the next.

(Slide 7)

Notice it is not as well balanced as our present budget. Fission breeder research certainly was a very dominant area. Fossil with a very large piece coming from the Department of Interior and is a fairly mature program. Solar, conservation, geothermal were relatively new federal R&D programs and had not really gotten off the ground at that time.

Can I have the next vugraph.

(Slide 8)

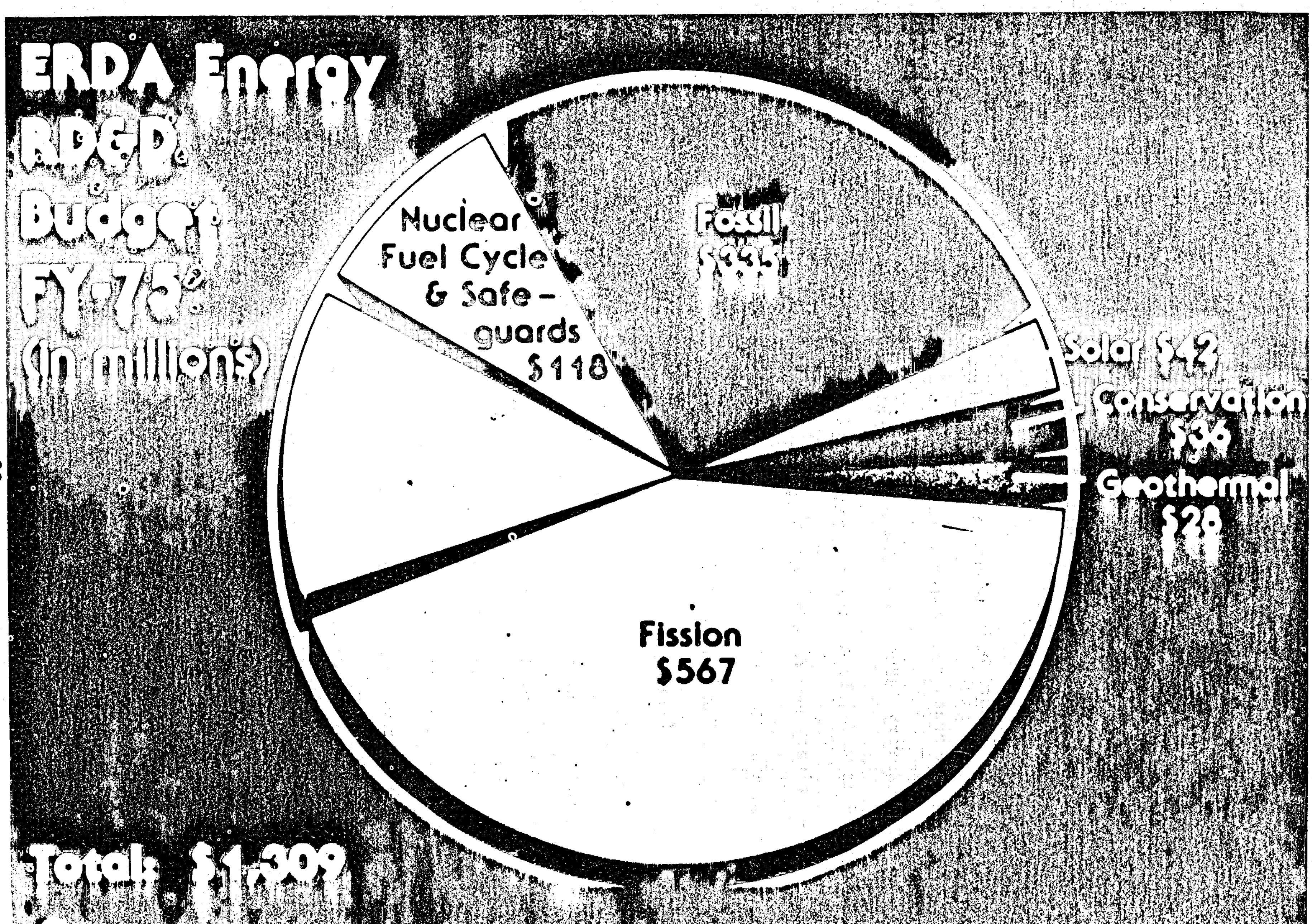
This gives you some feeling for the kind of growth that has happened in the various areas. It gives a feeling for where priorities have been, at least as far as incremental growth is concerned.

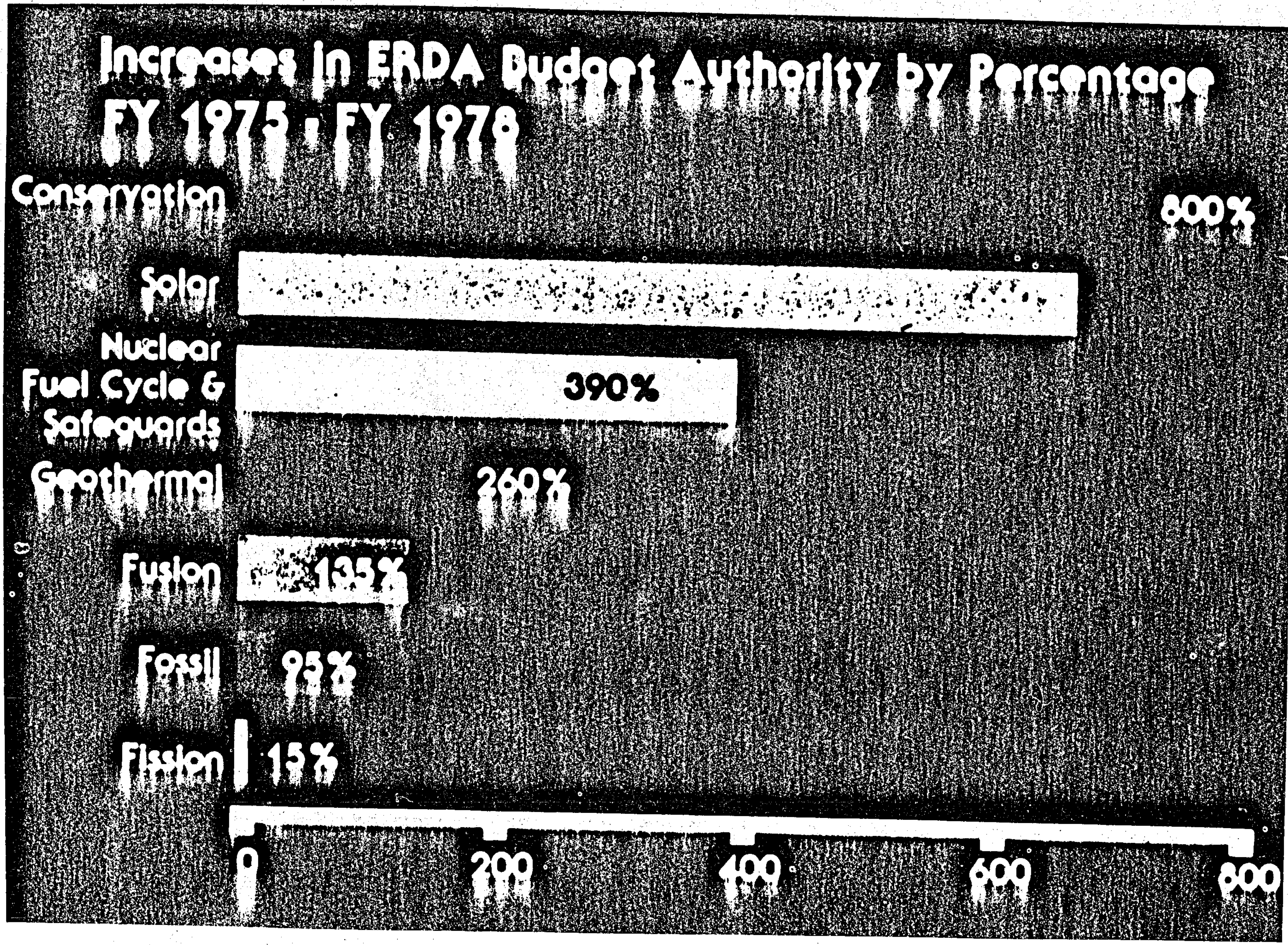
The conservation area has grown some 800 percent, consistent with the fact that it was just getting off the ground when ERDA was formed. It can have a very significant near-term impact, and it is usually cheaper to save a barrel of oil than to produce one.

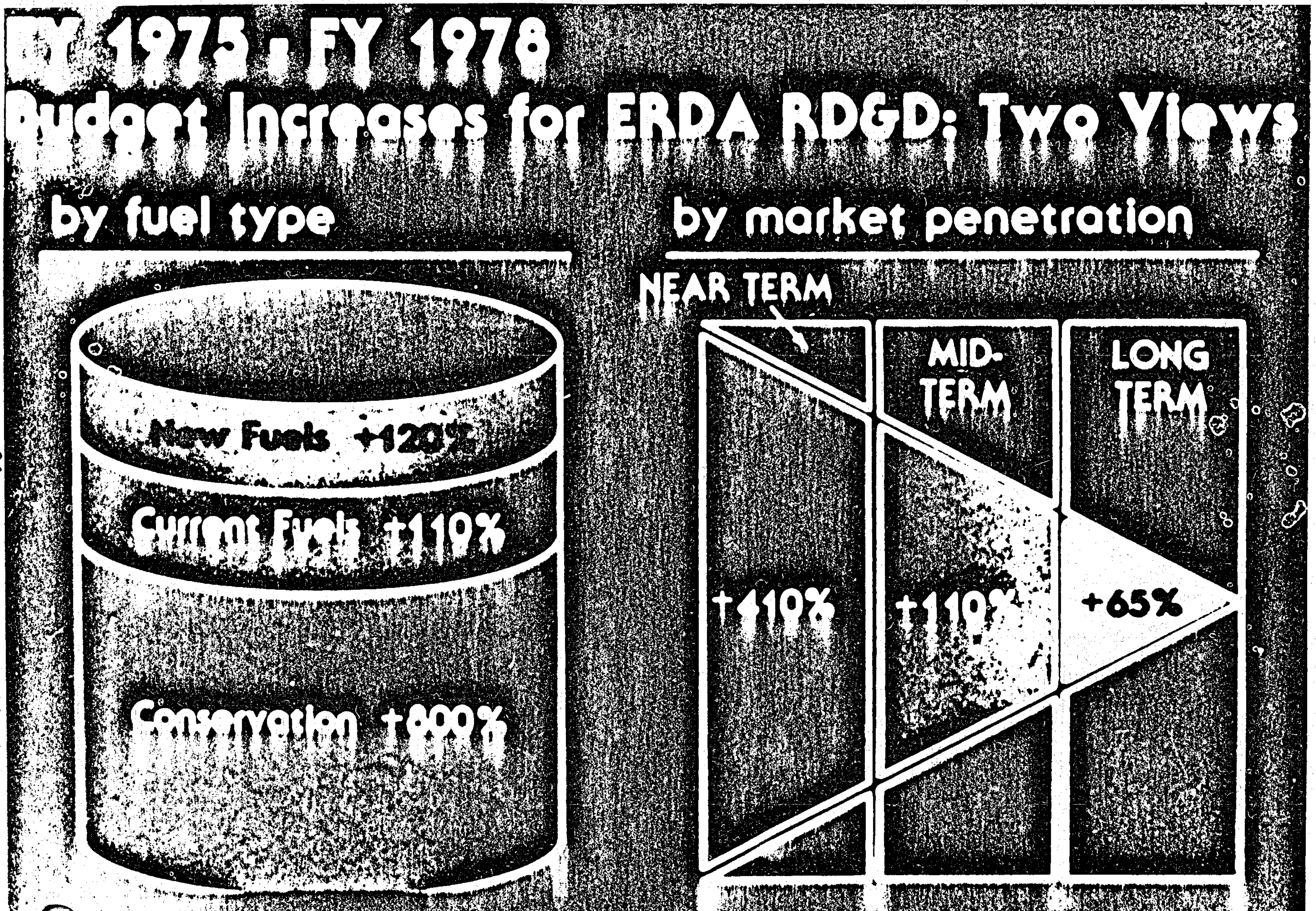
Solar, nuclear, et cetera have grown. Safeguards, supporting LWR has grown significantly. You can see the rest of the slide.

May I have the next one, please.

(Slide 9)


ERDA Energy RD&D Budget FY-75
(in millions)
Nuclear Fuel Cycle & Safe-guards $118
Fossil $335
Solar $42
Conservation $36
Geothermal $28
Fission $567
Total: $1,309


Increases in ERDA Budget Authority by Percentage
FY 1975 - FY 1978
Conservation
800%
Solar
Nuclear
Fuel Cycle &
Safeguards
390%
Geothermal
260%
Fusion
135%
Fossil
95%
Fission
15%
0
200
400
600
800


FY 1975 - FY 1978
Budget Increases for ERDA RD&D: Two Views
by fuel type
by market penetration
New Fuels +120%
Current Fuels +110%
Conservation +800%
NEAR TERM
MID-TERM
LONG TERM
+410%
+110%
+65%

This slide, breaks down the growth in a couple of other areas. I think the one of most interst is the one on the right-hand side, which does it by essentially the time frame in which a technology would have an impact. Notice that near-term technologies have grown some 410 percent since ERDA was formed. Mid-term, 110 percent; long-term, 65 percent. This represents, first of all, our recognition of our problem; it has made us realize that we need a lot more emphasis on near-term solutions. It also represents the fact that before ERDA was formed, before the Arab embargo, the federal role was considered to be principally to handle the long-term stuff that would ease our transition to the inexhaustibles. Since that time, there's been a recognition of the need for the Federal Government to make sure that the other technologies, that can get us away from our dependence on gas and oil, needs some federal support to insure that they are implemented on a timely basis.

I think I'll cut off there since I've run out of time.

DR. KANE: In my rather sloppy introduction, I don't believe I made it clear that Bruce speaks for the entire agency, not just the fossil energy. This was meant to be just an introductory, general look-see at the entire agency. So any questions should be directed in that context, rather than specifically in the fossil energy context.

Are there any questions:

DR. RAMSEY: Norman Ramsey. Harvard University.

Am I right in inferring from your comment that if you include the dissolved methane in the brine the reserves of natural gas would go up quite a bit, a factor of 5 or more on the curve. Is that correct?

DR. ROBINSON: That's with no consideration of how much it would cost to get it out, right.

DR. RAMSEY: Is there any indication of how much the cost will be to extract it?

DR. ROBINSON: It's extraordinarily uncertain at the present time. Part of the ERDA effort is to make assessment of both the amount that's there, and how much it would cost to extract it.

DR. RAMSEY: I see.

DR. ROBINSON: Yes?

DR. GREEN: Leon Green, General Atomic Company.

This is a question for Jim Kane. I notice in the final program, the item that was called "the overview of research and industry" has fallen off. Is that your decision to sponsor any research in industry?

DR. KANE: These parts are not meant to be just a review of what we are sponsoring. What we had intended was to get the viewpoint of industry, up and out, and we gave that up as a hopeless task in that we could not pick one individual who we thought would speak for all industry satisfactorily. So, let me give you a direct answer. By my division, you mean basic research. We sponsor a very small amount of basic research in industry. It is growing--it's a very rapidly growing fraction, but a small fraction of our research is in industry.

There are, of course, the usual problems of proprietary aspects the industry often wishes to avoid.

DR. GREEN: Thank you very much.

DR. KANE: If there are no further questions, now the scene shifts to the real meat of the meeting. And the first speaker of the day was meant to be Dr. Phillip White, who is in charge of the fossil energy program for ERDA. I told you already, he's at a hearing. I have every reason to believe he'll be here, so what we're going to do is invert the program, and go ahead without him, and when he gets here we will work him into the schedule, because I think it's crucial that you hear from Dr. White on this subject. It's his program that is under discussion for much of the day today.

The first speaker, then, will be Dr. Martin Neuworth, who is going to discuss one of the three major programs within the coal R&D, and that is the coal conversion aspect of it.

Is Dr. Neuworth here?

DR. NEUWORTH: Yes

DR. KANE: Oh, good.

We promised, Dr. Neuworth, to give you a little extra time since this particular topic you're talking about is of absolute and very large importance to this meeting.

DR. NEUWORTH: Thank you.

VOICE: We'll extend your time a little bit.

DR. NEUWORTH: Okay.

Good morning. I would like to attempt to answer three questions: What are the specific technical objectives in our coal conversion program (gasification and liquefaction)? Where do we stand and what are the research needs to improve our technology?

Could I have the first slide.

(Slide 1)

I am going to talk about coal liquefaction. We're actually concerned with the production of three types of fuels: solid solvent refined coal which can be burned without the use of fluegas scrubbers; syncrude, which can be substituted in a petroleum refinery for the production of gasoline and fuel oil and chemical feed stock, and heavy boiler fuel.

What I've shown are the essential chemical steps that one must perfect in converting coal to liquid fuels. Coal essentially is a hydrogen deficient substance with too much oxygen, nitrogen, and sulphur, and mineral matter, which all have to be reduced or eliminated. We show the first step as the addition of hydrogen. This can be done by adding external hydrogen, or redistributing the hydrogen in the coal in which case you produce a hydrogen deficient species, char, and a relatively limited amount of liquid.

Coal is a high molecular substance and therefore it must be hydrocracked to lower molecular species. You must remove the sulphur, oxygen, and nitrogen as hydrogen sulfide, water, and ammonia. This is in connection with environmental and stability considerations, as

Essential Steps in Coal Liquefaction

- Addition of Hydrogen
- Hydrocracking to Lower Molecular Weight Species
- Removal of Sulfur, Oxygen and Nitrogen as H_2S, H_2O and NH_3
- Separation of Unconverted Coal and Ash from Clean Liquid Fuel

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well as compatibility with petroleum fuels. Finally, you have to separate the uncoverted coal and ash to produce a clean liquid fuel.

New slide please.

(Slide 2)

I've shown a rather busy flow sheet there, but I can--do you have a pointer?

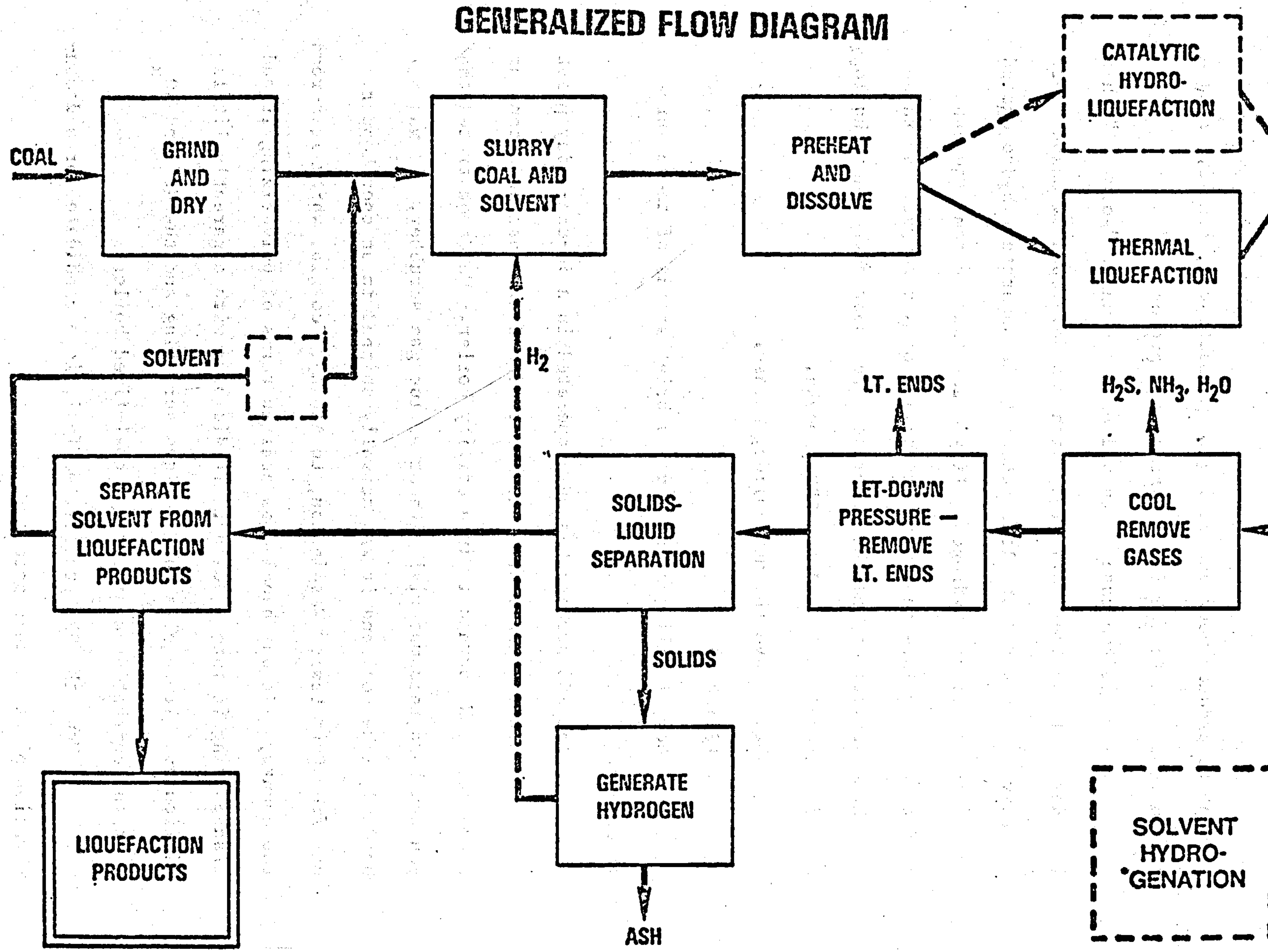
VOICE: No, sir, I don't believe so.

DR. NEUWORTH: Okay. I'll just walk you through this very quickly. In order to convert coal completely to a liquid product, you have to grind it. Looking up at that upper box there, combine it with a coal derived slurry solvent and pump the mixture into a pressure vessel where you preheat it to temperature of the order of 750 degrees F. At that point, essentially all the coal is dissolved except for a small amount of unreactive material and mineral matter.

Now, you have two alternatives. You can do the liquefaction thermally as it is shown in the lower box. This is the technology used in solvent refined coal, the so-called SRCI and SRCII versions; or you can convert it catalytically, which is the way we handle the H-coal or the synthoil technology. At that point--I guess we're missing--There's a loop around. You take the effluent from the dissolver and cool it, separate the gaseous components and then let it down to atmospheric pressure where you effect the solids-liquid separation.

The solids containing material can be a source of hydrogen by gasification, and then you separate the liquid products from the

COAL LIQUEFACTION
GENERALIZED FLOW DIAGRAM



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solvent to produce your export liquid products and, finally, return the solvent back to the first part of the process.

Now, in the case of this dotted box under "solvent," this includes still another variation which was developed by Exxon where the solvent--it's a distillate material, is separately hydrogenated to supply additional hydrogen. If you use that system, you can produce a distillate fuel without the use of a catalyst. So these are three variations and they represent our most advanced technology, that is, H-coal, SRC, and the EDS process.

May I have the next slide, please.

(Slide 3)

Now, I will just give you a brief status of these three processes.

The SRC process has been operated in a 50-ton-a-day pilot plant for about 2-1/2 years. It has produced at least 3000 tons of clean fuel. We burned it in a utility boiler. We demonstrated that you can burn this material without a flue gas scrubber. It was handled, like coal and it was actually shipped in an open hopper car from Fort Lewis, Washington, to Albany, Georgia, which is across the country. It was handled as coal in terms of pulverizing it and transporting it into a boiler. It did burn with apparently little difficulty. It requires no flue gas scrubbing and the NO_x and SO_x meet the current standards for a coal-fired boiler.

Now, the SRC process, we feel, is a candidate for a demonstration plant at this point.

Slide #3 is not available.

The H-coal and EDS processes are in earlier stages of development. We're building pilot plants to demonstrate these technologies. In the case of EDS it's a 250 tons a day unit; and in the case of H-coal, it will be 300, to 600 tons a day. The intent there is to bypass the need for a demonstration plant, and if the pilot plants operate successfully, these will be scaled up directly to commercial plants.

Now, some of the problem areas that we see in scaling up coal liquefaction are shown on the next vugraph.

(Slide 4)

Oh, you're going too fast.

VOICE: I'm sorry.

DR. NEUWORTH: I will just walk through these quickly. The preheater scale-up deals with the question of the amount of heat flux that's being used without caking the slurry. The dissolver scale-up is concerned with the question of three-phase flow.

Then we have the problem of pumping slurry, and the let-down valves. These are concerned with the handling of the abrasive mineral matter components. Then you have the distillation of dirty residues, and by "dirty", I mean residues which contain unreacted coal and mineral matter.

Finally, the question of solid-liquid separation. The uses of filters and centrifuge appear to be unattractive from a cost-scale-up point of view, and we're looking at the use of other techniques like solvent deashing on a pilot plant scale as an alternative.

LIQUEFACTION PROBLEM AREAS

Engineering Problems

- Preheater Scaleup
- Dissolver Scaleup
- Slurry Pumping
- Let Down Valves
- Distillation of "Dirty" Residue
- Solids-Liquid Separation

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(Slide 5)

In the case of the process problems, it's developing a better understanding of the primary liquefaction steps, so that you can design equipment to maximize the chemistry of the conversion. Hydrogen selectivities are concerned with the fact that hydrogen is a very expensive chemical, and if you use it, you produce varying amounts of gas, which is a high consumer of hydrogen; and optimizing this step is critical. You have to remove the oxygen compounds to produce the material which is stable and compatible with petroleum-derived fuels. The nitrogen compounds have to be reduced to a level so that on combustion the product will meet nitrogen oxide standards for fuel oil. And finally, in those processes where coal sees a catalyst, the catalysts that have been used have simply been transferred from the petroleum industry and design of catalyst which can cope with the fouling effect of coal, would permit significant improvement in the technology.

That is a quick look at liquefaction.

Now, moving on to our gasification program. The objective there, of course, is to make synthetic natural gas by the reaction of carbon monoxide with hydrogen or the direct reaction of carbon with hydrogen.

In the low Btu gas program, we're concerned with making synthesis gas as a chemical feed stock, a fuel gas diluted with nitrogen, which is a significantly cheaper fuel because air is used in place of oxygen.

PROCESS PROBLEMS

- Primary Liquefaction Step
- Hydrogen Selectivity
- Removal of Oxygen Compounds
- Removal of Nitrogen Compounds
- Catalyst Fouling in Contact with Coal

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Now, I have shown a typical flow sheet--

(Slide 6)

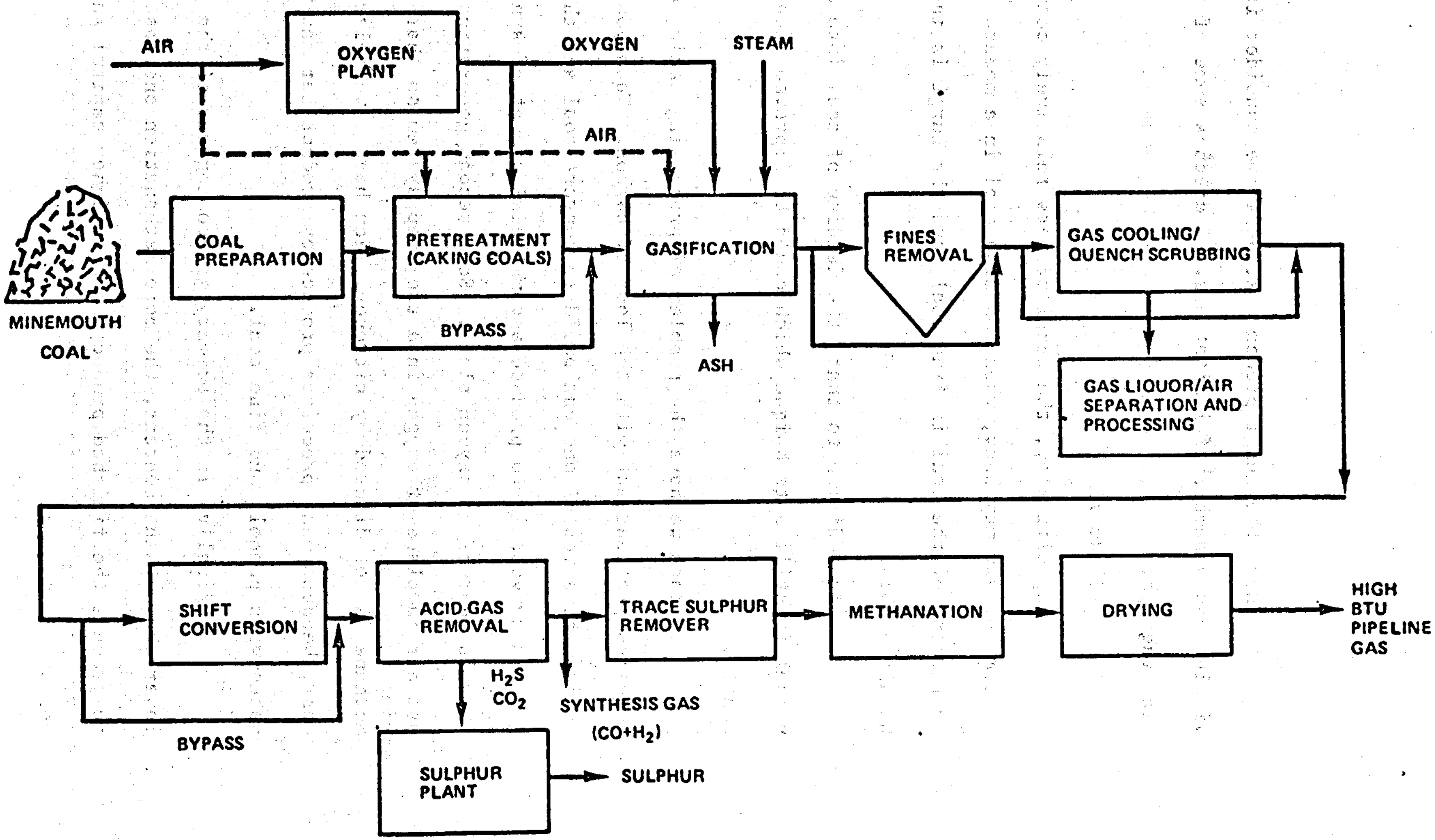
-- for a first-generation or second-generation coal gasification process.

Briefly, starting with coal, we have the coal preparations and pretreatment in the case of caking coal, and then the gasification step as you can see is a minor part of the overall flow sheet. There coal is reacted with steam and air or oxygen. The air or oxygen supplying heat to compensate for the endothermic heat of reaction of carbon with steam.

The next series of blocks concern themselves with gas cleanup and finally, going to the lower series of blocks, the shift conversion is needed to adjust the carbon monoxide hydrogen ratio. Then you have the steps of removing H_2S and CO_2, and then trace sulphur compound removal because of the sensitivity of the methanation catalyst. In the methanation step you react carbon monoxide with hydrogen to produce methane and water. Finally, you have a drying step. It's pretty apparent from looking at that flow sheet, it's quite a complex flow sheet. The capital costs accordingly are very high, and the operating costs are affected by the fact that 60 percent of your operating costs are the recovery of capital.

Now, as most of you know, there is commercially ready technology to carry out this process. The most well-known technology is that of Lurgi and this is considered to be a candidate for a commercial syngas plant.

ANATOMY OF GASIFICATION PROCESSES
HIGH BTU VERSION



Now, the Lurgi process, although we consider it technically viable, has a number of limitations. I discuss some of these in the next vugraph.

(Slide 7)

Specifically, the Lurgi prefers relatively coarse size coal. As some of you may know, when you mine coal in a modern mine, about 30 percent of the coal is fine coal, and the Lurgi is incapable of handling this.

In addition to that, the feeding of coal into a pressure vessel is still a technique which could be improved upon significantly.

Then we have the problem of processing caking coals, which requires pretreatment with the loss of carbon. Then you have the maximum size vessel one can build to convert coal and this requires a great many vessels to produce a commercial amount of syngas. Then there's cost of an oxygen plant. Some second generation processes use air in place of oxygen in a two-step system so that the resulting methane is not diluted by nitrogen. You have a very large cleanup cost, because many processes produce by-product tar and water contaminated with phenols and fine coal.

Finally, in the primary gas coming out of the gasifier, the lower the methane content, the more methanation one has to carry out to produce the finished product with a higher capital and operating cost.

Coal Gasification Problems

- Coal Feeding
- Processing Caking and Fine Coal
- Gasifier Capacity
- Substituting Air for Oxygen
- Byproduct Tar, Water and Fines
- Methane Content of Gasifier Output
- Gas Cleanup

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Finally, there is the high cost of the gas cleanup.

May I have the next slide.

(Slide 8)

Now, in our second-generation pilot plant program, what we have attempted to do is take care of all or most of the limitations of the first-generation technology. What I've shown here is a summary of the pilot plant program. We show five pilot plants. Under reactor type, we've shown the fluid bed or entrained bed, which are designed to handle fine coal, the coal types that one can use in these processes. The through-put ranges from 25 to 120 tons per day. The pressures are up to 1000 pounds. The reason for that is you'd like to deliver the methane to the pipeline at 1000 pounds pressure.

The first two processes, the CO_2 acceptor and the HYGAS process, have essentially completed their technical programs and these are considered to be candidates for either a demonstration plant or a commercial plant. The HYGAS plant is seriously being considered for a demonstration plant.

The other three programs are essentially in early stages of their operation.

Now, in order to effect a significant change in the capital cost, one has to completely change the flow sheet, and there are two programs now concerned with that, and I've shown a schematic of the first one.

(Slide 9)

DESCRIPTION AND STATUS OF HIGH BTU GASIFICATION PILOT PLANTS

	CO^2 ACCEPTOR PROCESS	Hy GAS PROCESS	ASH AGGLOMERATING PROCESS	Bi GAS	SYNTHANE
REACTOR TYPE	FLUID BED	FLUID BED	FLUID BED	ENTRAINED SLAGGING	FLUID BED
COAL TYPE	LIGNITE SUB-BITUMINOUS	NON-CAKING — WEAKLY CAKING	ALL TYPES	ALL TYPES	ALL TYPES
THROUGHPUT T/D	36	75	25	120	75
PRESSURE psi	150	1,000	100	1,000	1,000
STATUS	TECHNICAL FEASIBILITY CONFIRMED	TECHNICAL FEASIBILITY CONFIRMED	PP COMPLETE CY76	PP COMPLETE CY76	START-UP
COST (MILLIONS)	41.3	32.6	13.0	66.0	40.0

This is the so-called catalyzed gasification, which involves treating the coal with a catalyst like potassium carbonate. This increases the rate of the gasification reaction so there is no need for any oxygen or air. And since a significant amount of methane is produced in the primary step, which is an exothermic reaction, the reaction is thermally neutral and you are able to convert the coal to about 40 percent methane per pass.

Now, this eliminates the need for a great many steps in the gasification process, namely, the methanation step, and the water-gas shift. By using a catalyst like potassium carbonate, all tar and all organic materials are eliminated, so that there is a considerable reduction in the whole cleanup system. You substitute the cryogenic separation of methane for the need for an oxygen plant, and this appears to offer a sizable reduction in capital and operating costs.

There is one other process which involves the direct reaction of hydrogen and coal, but I just didn't feel there would be time enough to go into any detail.

Finally, I would just like to complete the discussion by mentioning in our low Btu gasification program we're not concerned so much with the gasification reactor system. But since low Btu gas can neither be stored nor transported for any distance, the projects were concerned with coupling the gasification step with the end user, and we're using state of the art gasifiers.

We have three programs in that area. One of them is a so-called gasifier in industry program, which involves the substitution of low Btu gas for methane in those industries which were curtailed from having a continued supply of methane; a low Btu gas combined cycle electric power production, which appears to offer one of the lowest cost options for making electricity from coal.

Finally, a hydrogen from coal project, which is concerned with producing chemical hydrogen, a very critical ingredient in both gasification and liquefaction technology.

Thank you.

DR. KANE: Are there questions for Dr. Neuworth?

DR ZUCKER: My name is Alex Zucker, from Oak Ridge.

Do you see any need for a deeper understanding of any of the phenomena involved in these processes before the engineering problems and some of the process problems can be solved?

DR. NEUWORTH: Well, I think that the solutions that are being carried out, as you know, are completely empirical and using the whole array of technologies that have been developed in the petroleum industry. Adjust it for the fact that coal has these problems, but if you are concerned about doing something in a short time frame, that's the only practical solution.

Now, I would certainly encourage an understanding of all the basic phenomena in all this technology as a guide to improving future scale-up of these technologies.

DR. ZUCKER: Do you have a priority for some as opposed to others?

DR. NEUWORTH: Well, I thought I highlighted what I considered to be some of the key problems in all this technology. I should explain that my responsibility is for pilot plant scale-up of technologies which have been brought to a level that you can justify that scale-up. I think Alex Mills is more concerned with the phenomena that you are speaking to.

MR. SHANNON: My name is Robert Shannon.

You do not address the SRC facility operations which is currently in operation on coal. Do you intend to cover that; and if so, will this be part of the demo plant?

DR. NEUWORTH: Well, I tried to explain that I had originally thought I have seven minutes on liquefaction. The SRC-2 process which you are referring to is essentially a thermal liquefaction involving recycle of the slurry effluent from the dissolvers. So, in effect, you have increased the mineral matter level, and you've increased the residence time. The relationship of that process, which is now a distillate fuel producer to the H-coal and Exxon process, will determine whether there is any interest in pursuing that. I think the fact that the process operates is not enough. As you might have mentioned if you are familiar with the technology, you pay quite a price for practicing this process, namely, in reducing the through-put by a factor of 3 through the liquefaction unit. Its an area, that I didn't intend to exclude, I just felt that there wasn't enough time to go into detail about all the technology.

MR. SHANNON: You mentioned distillate as primarily to produce a No. 4 to No. 6 fuel for power.

DR. NEUWORTH: I feel it's a distillate fuel producer and, therefore, it must compete with the EDS process and H-coal process, all of which are distillate fuel producers. It must stand or fall in how it compares with those, and until it's run for a few months, we just can't make that comparison. We have no bias in ERDA. We have no in-house technology to speak of. We're just technical bankers, I think, is a good way of describing us.

DR. BARON: I'm Tom Baron, Shell Oil Company.

Would you care to quote your latest estimate on the cost of synthetic natural gas?

DR. NEUWORTH: Methane?

DR. BARON: --methane.

DR. NEUWORTH: I think we have a speaker who is going to cover this topic. It's a big number.

DR. KANE: There will be a speech on that very topic, Dr. Baron.

DR. BARON: Thank you very much.

DR. KANE: Dr. White has not yet arrived; is that correct? It's been suggested that we take a break and have some coffee, and await Dr. White's arrival.

(Short recess.)

DR. KANE: Before we get on to the next speaker who will discuss the research needs in another aspect of coal utilization, I would like to have Dr. Phillips come up and give you a brief discussion of a subject that I know you are all interested in. Bluntly, you know, this is a great meeting. We're hearing lots of talks; but we asked you to come here, and how are we going to get your reaction factored into this meeting.

Dr. Phillips is going to discuss that for a minute.

DR. PHILLIPS: Jim Kane says the purpose of this meeting is to get the feedback from you, the attendees, representing the American public.

Our purpose in having the meeting is to get your feedback, and to provide for that we want to break you up into a set of smaller groups that would meet tomorrow afternoon, for those of you that want to do that. The reason for breaking up into small groups, as you know, is that with a group of this size, only one of us can speak at a time and get a message across. While on the other hand, if we can breakup into groups, like 10 to 20, then each member of that group perhaps can say something and get some of his ideas across.

To provide for that, we're doing two things so that we can sort of organize you a little bit and try to get some balance within the sub-discussion groups. The MITRE Corporation (the monitor of this meeting) has handed out a form and if you would please check that off it will help us in forming up some discussion groups tomorrow afternoon.

If you turn one of those in, that means to me that you want to attend tomorrow afternoon's informal discussion groups.

To arrange for the administration of those groups, there will be at least one ERDA person with each group and at least one person from The MITRE Corporation, our contractor, for each of these groups.

You're probably also concerned about what will be the format of anything that comes out of this meeting. ERDA wants a summary report from this meeting, anything that we can come up with in the way of a consensus or a spirit, a set of recommendations that you might believe in. We want that by early August in such a way as hopefully to possibly influence the budget cycle that will be under study at that time.

There will be a formal report including all of the papers that you're hearing at this meeting, and all of our discussions, and including the output from tomorrow afternoon's discussion groups. That will be a report available to the public and should be out sometime in September.

Thank you.

DR. KANE: The next speaker is Dr. Steve Freedman. He is going to talk about the direct combustion aspects of the program.

DR. FREEDMAN: Welcome.

My responsibilities as the Assistant Director for Combustion and Advanced Power Development within the Coal Conversion and Utilization Division of Fossil Energy include administering the fluidized-bed combustion boiler program, the coal-oil slurry program, several other direct coal combustion programs, and the advanced power program which consists of gas turbine projects designated to indirectly utilize the products from coal combustion via closed-cycle turbines or designed for direct utilization of low Btu gas and liquids made from coal via the open-cycle turbine.

(Slide 1)

During preparation of this meeting, since audience needs were left undefined, it seemed desirable to me to provide a little introductory background information.

There is an interest in coal primarily because of its abundance and the diversity of applications to which it may be put. Coal is not a new energy source such as nuclear was 30 years ago when that program began. For those people doing research in the field of development, it should be remembered that coal has been used as a fuel for centuries. Our principal goal is to use it more efficiently and in a manner that is environmentally acceptable.

I tell people that . . .

. . . In contrast our division is concerned with engines that burn coal-based fuel. I am referring to the gas turbines of

COAL UTILIZATION
BACKGROUND

- COAL USED AS FUEL FOR CENTURIES
- NEEDS OF 1980'S THRU 21ST CENTURY
  - REDUCE EMISSIONS, SO_2, NO_X, PARTICULATE
  - REDUCE COST
- REFERENCE SYSTEM
  - CONVENTIONAL FIRING + SCRUBBER
- ENGINES TO USE COAL BASED FUELS
  - PERFORMANCE & COST IMPROVEMENT

today which, when modified with low-Btu combustors, meet present utility requirements.

A primary question is: Can we make improved engines (turbines) so that the entire system from coal pile to busbar is more attractive than that would exist without the development?

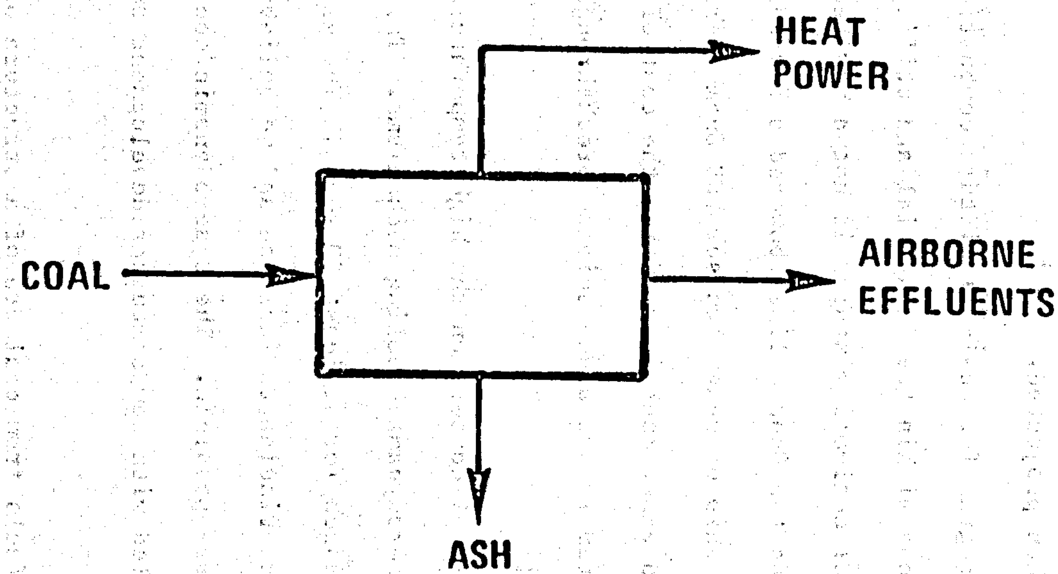
(Slide 2)

Here is a rough sketch that depicts utilization of coal in an energy conversion process for production of clean and economical heat or power. We have coal to be used as a resource. We are concerned with utilization of heat and power and the minimization of airborne effluents while making the ash and solid waste products as environmentally benign as is practical.

Fluidized-beds are of real interest as coal combustors both from an economical and environmental viewpoint: the inert material in the combustor bed can be an SO_2 sorbent, such as limestone or dolomite, which calcines from the heat of combustion, picks up SO_2 in a sulfate form, and thereby reduces the SO_2 emissions obviating the need for a scrubber. Consequently, the economic incentive and the operational advantages are achieved.

The gas turbines within the Advanced Power Program, which are operating on low Btu gas to provide utility power, are of interest because of relatively attractive economics and the ease of meeting emission standards through the utilization of the low Btu gas. This

COAL UTILIZATION
ERDA R&D



- FLUIDIZED BED COMBUSTORS–CLEAN COMBUSTION
  - BOILERS, HEATERS
  - TURBINE COMBUSTORS
- COAL–OIL MIXTURES
  - OIL EXTENDERS
- HIGH TEMPERATURE GAS TURBINES
  - LOW–BTU GAS FUEL
  - HIGH AROMATIC COAL–LIQUID FUEL
- MHD & OTHER NEW TECHNOLOGIES

may enable use to produce power with even lower SO_2, particulates, and NO_x emission levels than projected.

We have a program for coal-oil mixture combustion which is aimed at applications within the industrial and utility sectors. Historically the use of coal-oil mixtures is not a new technology. In fact, back in the 1920s the Cunard lines powered a few ships with it and later, the battle ship or heavy cruiser USS Guam operated on a coal-oil mixture as an experiment in reducing the cost of oil. The coal-oil mixture program is not a new science breakthrough; it is an economic practicality.

Primary areas of concern on the high temperature gas turbines involve the aerodynamic cooling mechanisms. This topic has been a subject of research for at least 30 years. The gas turbine performance has been continuing to increase and we believe that further advancements are possible. These aerodynamic/cooling refinements have to be coupled with new combustor development to burn low Btu gas.

The liquid fuels from coal are of a structure other than conventional petroleum based fuels. The molecules are comprised of aromatic rings rather than molecular chains with a lower hydrogen content and a correspondingly higher carbon content which contributes to the difficulty of burning these fuels in gas turbine combustors. Thus, there is concern over the utilization of these carbonaceous fuels in a practical, low emission combustor.

MHD and other new technologies will be covered by Mike Raring and other speakers immediately following me.

(Slide 3)

The history and status of the technologies that we are working on is fascinating--fluidized-bed combustors, for example, have been used as waste products incinerators for some time. Fluidized-beds were first used in the Winkler gasifier 50 to 55 years ago. Following this early effort, high octane gas was made for World War II in cat crackers using fluidized-beds as a high surface area means of contacting components to be reacted. As a consequence of this, the petrochemical industry was burning off the carbon that coked out on the surface of the catalyst and had some heat recovery; heat exchangers were built in these catalyst regeneration systems. Between the petrochemical experience and the incinerator experience using the thermal inertia of a fluidized-bed to handle difficult fuels of widely varying properties, the fluidized-bed evolved as a coal combustor able to handle the wide variation of coal qualities and it also evolved as a reactor vessel into which to introduce limestone, dolomite, or other SO_2 sorbents for SO_2 suppression. ERDA and others have proven SO_2 suppression at the laboratory scale and are presently operating pilot plants to obtain data for supporting demonstration plant operation at the industrial scale.

For fluidized-beds the heat transfer and fluid mechanics are two-phased and should be a good problem for universities to work on.

COAL UTILIZATION

RECENT HISTORY & CURRENT STATUS

- FLUIDIZED BED COMBUSTION
  - INCINERATORS
    OPEN BED, TOP FED
    COMBUSTION RELIABLE
  - SO_2 SUPPRESSION
    LAB DATA
  - HEAT TRANSFER & FLUID MECHANICS
    EMPIRICAL
  - BOILER DEVELOPMENT
    IMMATURE EQUIPMENT

- COAL-OIL MIXTURE
  - RESURRECTION OF OLD TECHNOLOGY
  - PRACTICALITY & COST

- GAS TURBINES
  - MATERIALS & ADVANCED COOLING DESIGN
  - LARGE TECHNICAL BASE

- HOT GAS CLEANUP
  - NEW TECHNICAL AREA

However, for about 25 years the fluidization research community has been working on the bubble phenomena in fluidized-beds for cat cracking and other reactor operations. Researchers tend to make the work a continuing drawn out effort in bubble formation, mixing, and fluidization dynamics.

The R&D area for gas turbines is another separate art. Existing gas turbine blade materials and blade cooling technologies have been developed mainly for military engines and then filtered down into commercial engines for the same manufacturers. From the commercial aircraft engines, they filtered further into the utility applications. The turbine work is a continuing research of materials advancement and advanced cooling.

The technology research area for hot gas cleanup is listed as a new technical area that would allow the combustion of coal at elevated pressure and temperature. We would like to feed the direct products of combustion through a turbine for power generation; however, this requires a hot gas cleanup system to remove both the particulates and the alkali metals present in coal. There has been some progress made, but more advanced technology must be developed to include suppression of alkalies by tying them up chemically and filtering of particulates to reduce the transport of particles in the order of 2 to 10 microns to the gas turbines.

Existing inertial collectors can separate the larger particles of around 10 microns and up, but this 2 to 10 or 2 to 8 micron size is a beautiful grey zone that inertial collections can hardly touch and other mechanisms for cleaning them up seem to be quite expensive.

Again, if the resulting system is too expensive or requires too much of its own energy for its own operation, then the resulting complete powerplant would not have an economic advantage over existing state of the art conventional steam plants that are used as a baseline comparison.

(Slide 4)

One of the items was a list of unsolved problems or research needs for which basic economics have to be brought into perspective. Many of the gasification/liquefaction units have little trouble feeding coal into high-pressure vessels because they dry it first using large amounts of air-in terms of power and pressure drop-for conveyance. However, in a utility operation the enormous quantities of raw material, coal, and limestone that go through mandate that the cost of conveyance be kept at a minimal value both in the cost of the equipment and energy to power that equipment.

The difficulty is that when coal is mined, it comes out of the mine with the distribution of sizes, including a lot of fines, and that plus both inherent moisture in the coal while it is in the ground as well as moisture that would naturally accumulate during transportation and storage present sizing and moisture problems in feeding the coal.

COAL UTILIZATION
UNSOLVED PROBLEMS

- FEEDING WET COAL WITH FINES
  - RELIABILITY
  - COST
- SORBENT UTILIZATION & REGENERATION
  - REDUCE MATERIAL QUANTITIES
  - COST
- COAL–OIL MIXTURE STABILIZATION
  - RELIABILITY
  - COST
- CORROSION RESISTANT HIGH TEMPERATURE MATERIALS
  - Na_2SO_4 ATTACK AT 1650° F
  - COST EFFECTIVENESS
- LOW NO_x, HIGH ζ COMBUSTION OF AROMATIC FUEL
- CLEANUP OF HOT, HIGH PRESSURE GAS
  - 1600 F, 6–10 ATM.
  - PARTICULATES, Na_2SO_4
- TWO–PHASE, SOLIDS–GAS, FLUID MECHANICS IN COMPLEX EQUIPMENT

For sorbent utilization, limestone and dolomite are used to absorb the SO_2, forming a dry granular solid that sets up with the ash and the coal as low-grade cement. A contractor to the EPA, who was conducting sorbent leaching column work, experienced a problem with the columns setting up solid thereby blocking all water throughput. So, we believe that we have a once-through disposal technique that is both economical and environmentally acceptable. However, when you look at the enormous quantities of limestone and sulfated limestone that come out of a fluidized-bed combustor operation, it appears that the amount of limestone from quarries that will be required compared to the amount of disposal area required is undesirable.

So, we are concerned as to whether or not we can practically regenerate the limestone or sulfated limestone into lime again for reuse in the process.

We have to be very much concerned as to the fuel that we use for regeneration. People have made prototype regenerators that are natural gas fired, but that is premium fuel and we would prefer having to use direct coal combustion products. There is concern also during the limestone regeneration process that the SO_2 or H_2S given off (depending whether it is an oxidizing or reducing atmosphere) may have to be passed on to another plant. This regeneration plant has to be economical and dispose of the sulfur in an environmentally acceptable manner as we have seen in that first diagram where the solid waste product had to be acceptable.

The capital cost of equipment is of concern again (as in any utility operation) where coal-oil mixtures are concerned. Coal-oil mixtures are feasible, however the only question is: What is the cost of the preparation of the mixture, and the reliability of operation with a mixture because, whenever you have coal, you have ash. That is the way it comes from the ground. That's the reason for its low price. It hasn't been de-ashed yet and the fate of this ash in the boiler is of concern. Will it compromise boiler reliability? Require a boiler down-rating? And what are the prospects of the stabilization of the mixture?

You can take coal and oil, make a mixture, put various surfactants in to stabilize it so that it will not settle out and remain in a pumpable form, but the cost of surfactants adds to the cost of the product when we are concerned with making stable mixtures.

(Slide 5)

This slide is presented to review the roles of technology development and implementation.

There are different roles. Government has to have RD&D in industry, where the big equipment is built, so that resultant projects will proceed to low-cost reliable products which can be rapidly implemented. When we look at the energy picture and the urgency to switch over to coal, we really cannot afford an extra 10 years for industry to learn from the national laboratories and research communities.

COAL UTILIZATION

TECHNOLOGY UTILIZATION

- BY INDUSTRY
  - FABRICATION, OPERATION, SERVICE
- R, D&D IN INDUSTRY
  - TODAY'S ELEC POWER GENERATION
  - HIGHLY RELIABLE, LOW COST, SERVICE
- SUPPORT OF SCIENTIFIC COMMUNITY
  - BASIC RESEARCH
    MATERIALS & PROPERTIES
    EXPLORATORY PROCESS RESEARCH
  - APPLIED RESEARCH
    SCIENTIFIC BASIS OF PROCESSES
    SYSTEM OPTIMIZATION
  - CROSS FERTILIZATION OF DISCIPLINE
  - INSTRUMENTATION
    USEFUL OUTPUT OF BASIC RESEARCH

There is a support role in the scientific communities falling between basic and applied research which includes the dissemination of information and cross-fertilization of technologies. A case in point is that of the boiler manufacturer learning about fluidized-bed combustion from the cat cracker and incinerator industries.

(Slide 6)

I assume that someone else on the Program Agenda will discuss the Energy Research Centers that were previously part of the Bureau of Mines and of the Department of the Interior. They have expertise in coal handling and processing.

As I see them, the National Labs are places for big, high-powered science - like development of synchrontrons, cyclotrons and whatever else is being made these days under what I used to refer to as "atom smashers."

Instrumentation, selected scientific problems such as sorbent regeneration, chemistry of sorbent materials, in what phases they (sorbents) exist, when, and to which phases they may go, and the nature of their pore structure--these research problem areas, for example, are appropriate for the Laboratories.

The universities have their traditional basic knowledge, new ideas, and the training of the next generation of engineers and scientists. This is an important role because we have to have new

COAL UTILIZATION

RESEARCH RESOURCES

- ERC'S
  - COAL TECHNOLOGY
  - INDUSTRIAL IMPLEMENTATION
  - FEASIBILITY DEMONSTRATIONS
- NATIONAL LABS
  - USES OF BIG, HIGH POWERED, SCIENCE
  - SELECTED PROBLEMS OF DIRECT COAL INVOLVEMENT
  - INSTRUMENTATION
- UNIVERSITIES
  - BASIC KNOWLEDGE
  - NOVEL SYSTEMS & IDEAS
  - PERSONNEL DEVELOPMENT
  - DISSEMINATION OF INFORMATION
- INDUSTRY
  - DEVELOPMENT OF COMMERCIAL EQUIPMENT END PRODUCT OF R, D&D
  - COMPONENT DEVELOPMENT
  - SYSTEM DEMONSTRATION

people coming into development areas who can identify the real problems and can utilize real elements in providing solutions to these problems.

Industry plays an important role serving an implementor. Next.

(Slide 7)

Okay. Whenever I have a meeting of this nature and identify a list of research needs, I am usually inundated in about 6 weeks with research proposals. Please be reminded at this point that Dr. Mills's group is for exploratory research--where most of the novel new ideas usually are worked out first. When or after scientific feasibility has been proven, the pilot plant group gets the projects for determination of engineering practicality at this level. Following that level is the Demonstration Plant level for demonstration of a project in an actual commercial type environment.

So we are concerned about competition for the research budget, and those are some thoughts that I had about research expanding to fill the available budget.

I did a doctor's thesis once, and it was explained to me that every thesis has to uncover more problems than it solves.

I think I had one more slide for wrap-up.

(Slide 8)

Yes. In "Researcher Horizons," in the near-term, you can't do much in five years. All you can do is improve what you have

COAL UTILIZATION

PARKINSON'S LAW
4th CORROLARY

RESEARCH EXPANDS TO FILL
ACCESSIBLE BUDGET

PH.D. THESIS RULE

DISCOVER ν NEW PROBLEMS FOR
EVERY ONE SOLVED

$\nu = 2.47$, EXPERIMENTALLY

COAL UTILIZATION
RESEARCH HORIZONS

- NEAR–TERM
  - IMPROVE PROCESSES
  - EVOLUTIONARY IMPROVEMENTS
- MID–TERM
  - NEW PROCESSES
  - APPLICATION OF RESEARCH
- LONG–TERM
  - BETTER WAYS TO UTILIZE COAL
  - REVOLUTIONARY IMPROVEMENTS

and make evolutionary improvements on existing technology. In the mid-term we can get some new processes going and apply what's already in the basic research inventory now. And then, the way I see it, in the long-term, which is after the year 2000 anyway, we have opportunities for revolutionary improvements and ideas that we haven't worked on yet.

Thank you.

DR. KANE: Are there questions? Yes, sir.

Dr. Baron.

DR. BARON: As a potential large-scale user of coal, what frightens us most is the problem of transportation; assured and reliable transportation. Where in the Government are studies being made in the technical and legal aspects of assured continuous supplies?

DR. FREEDMAN: Has anyone given the overall fossil-energy organization?

DR. KANE: No, Dr. White has not yet given it.

DR. FREEDMAN: Okay. In the Office of Fossil Energy there is an Office of Program Planning Analysis, which has an Office of Long-Range Plans -- if that's the correct name -- or Strategic Plans. I forget -- one name or the other, headed by Martin Adams. That is the group that does the overall total systems analysis.

I look at a utility plant as a system, not as a collection of components. He looks at the entire coal process, which includes mining, limitations on new equipment for mines, the five-year lead time for drag lines, how long it takes to open a deep mine, the transportation limitations and potential bottlenecks, as well as the economic advantages of newer competing modes.

You have rails, slurry pipelines, barges -- how do they compete with each other?

Then the utilization aspects, be it conversion to liquid or gas, or utilization directly, as coal; and then the interaction with the waste disposal.

So it's Martin Adams, in either strategic plans or long-range planning in the Office of Program Planning and Analysis, in Fossil Energy. I trust that answers the question.

DR. KANE: Could you come to the microphone and give your name, please.

MR. CROSS: I'm Jim Cross. I'm from ERDA also.

Would you care to say anything about possible utilization of coal in heating of private homes?

DR. FREEDMAN: Right now something like 1 percent; and whether it's .8 or 1.1, I don't know. But it's less than 1-1/2 percent. I've seen the numbers -- of coal used in domestic applications. CEQ had a study done on coal for residential/ commercial applications.

Their conclusion was that the difficulties associated with coal -- handling it, getting rid of ash -- as well as the environmental problems -- because when you burn, if you burn in a small residential combuster, you would not have a reasonably high stack for dispersion, and the sulfur emissions were serious problems and that for ordinary economic reasons they did not see the residential coal market expanding.

Now there are some people who in the last winter wanted coal because they couldn't get natural gas and they considered coal as readily available. That's more a people problem than a national energy problem; and we would be assisting those people in finding out what domestic coal furnaces are now available. The home stoker has gone up from about 25 units a year to about 300 units a year being sold.

But when you turn that in terms of quads, it's negligible. The British Solid Fuel Advisory Service have a collection of brochures showing the extremely attractive architect-designed home fireplaces that include both hot-water heating for baseboard heating and some of them also include stoves and combined heaters, to use coal.

We would make this information available to people in an information dissemination mode, but I do not see us doing anything in R&D.

DR. NEUWORTH: You should tell them about that smokeless fuel they're talking about, which doesn't have a counterpart in the U.S.

DR. FREEDMAN: We don't have the smokeless fuel here yet, and I think it might be ironic if we wound up importing coal.

(Laughter).

But using coal in a residential application is more difficult than using wood. People who used it 30 and 50 years ago put up with a lot of inconveniences and a lot of emissions that I do not think we'd put up with today.

MR. CROSS: Does that mean you don't have any programs for domestic fuel?

DR. FREEDMAN: We have no program on domestic use. We're trying to put together an information-dissemination program, so that we'll just provide information for those people who are interested.

DR. KANE: The chairman has a question.

DR. FREEDMAN: Go ahead.

DR. KANE: Dr. Neuworth pointed out that solvent-refined coal was shipped and pulverized and fed into at least large industrial boilers. Is there any luck at all in doing this in domestic-size?

DR. NEUWORTH: I don't think so.

DR. KANE: None. "None" was the answer.

DR. NEUWORTH: We'll be very happy if we can get some of the industry to use it, I think. That would be quite an accomplishment.

DR. KANE: Any further questions?

MR. BORIS: Boris, IGT.

Just to comment in this regard, getting coal into the home is a problem. You can accomplish it by shipping the coal directly, as a solid. You can also gasify the coal and burn it as a gas in the form that you're already equipped to use. I think that, in the long term, may be a more acceptable solution.

DR. FREEDMAN: I would stress: Direct combustion is used as a solid not gas from coal or a liquid from coal.

DR. KANE: Yes.

DR. REYNOLDS: Lou Reynolds, Stanford.

The programs you're working on now seem to me to be the long-term programs of an earlier era. And you are benefiting them from the basic research that was done some time ago.

With this in mind, can you tell us a little bit about how your people are guiding the basic research that's going on today? -- to be sure that it will be useful.

DR. FREEDMAN: That's a difficult question. Let's see.

The basic research really winds up being communicated to the pilot-plant and possibly the demonstration-plant people if it might affect components -- by the program managers who handle the contracts for the basic research -- and I'll call it the exploratory research -- where it may be of value to a particular program I'll have somebody from Dr. Mills's group or occasionally from Dr. Kane's group come and say, "Hey, Steve, this may be of interest to you."

It's this information broker, in the terms of the research manager within the Government, who plays a key role in making sure that the users of his product are aware of it.

And the formal reports as they get bound into overall documents are distributed. But it's usually a personal one-to-one basis of saying "Here's something that may be of interest to you -- I think it fits in -- that has a key role." I think it's always been that way.

DR. MILLS: I think you missed Dr. Reynold's question. A reservoir of basic research accomplishments, based on an earlier generation's efforts, has not been utilized.

Is there a mechanism within ERDA to guarantee a certain budget level, or whatever, to ensure the input to reflect what is being used?

DR. FREEDMAN: Well, between Dr. Mills, of Fossil Energy Research, and Dr. Kane, in Division of Physical Research, their budgets -- I really can't speak from the administrator's level as to how sacred their budgets are. But there is every indication that it's intended to continue, and the rate of growth is the only thing that's really something of concern.

We have these organizational areas, to support the research and nurture it through its infancy, so that it will be available in 10 or 15 years when we need it.

Bill, am I on the topic?

DR. REYNOLDS: What I'm curious about: for example, I think you said, "There's been 25 years of research in fluidized bubbles, and it's been on single bubbles; and it hasn't been very relevant to us." All right?

Now I'm asking you, what are you doing to tell the research community now, that you think will be relevant to you in 15 or 20 years?

What you've told us, I think, is you're listening to what's going on in research now. And if it's useful to you now, you're listening.

I'm asking you to look ahead a bit more. Looking down the road, what are you doing to tell the research people to do now that will give you some interesting results?

DR. FREEDMAN: Well, there are two kinds of areas. There's one area; it's called "new ideas," and I can't tell the research people what new ideas to come up with. Before Winkler came up with the fluidization or before the cat-cracker people decided to apply Winkler's fluidization, there was nobody around to tell them what the next thing, that we don't know about today, will be discovered in the future.

With the exception of Arthur Clarke and Herman Kahn and the futurologists who may get involved in that -- all that I can do, really, is describe the technology as I see it 15 years from now.

Then the researcher has to do his thing, because if I could really tell him what to do, I would be in that field, not in the pilot plant field.

(Laughter).

DR. KANE: There was a gentleman here that had a question. Where was it? Yes sir.

DR. HOLLOWAY: Holloway, from Exxon.

More specifically to this basic research question. What are you doing to fund basic research in universities. How does your level compare with that of other mission-oriented agencies and with the National Science Foundation?

DR. FREEDMAN: Do you want to answer that one?--because you have all the charts with the pies.

That will be gone over. And there's a whole bunch of budget breakdowns and pie charts as to how much goes where.

DR. KANE: I believe both Dr. Hill and Dr. Holloway's questions are excellent, and Alex will face them this afternoon, and I will face them tomorrow in my part of it.

VOICE: Roland.

DR. SMITH: Roland Smith, General Electric.

Let me pursue Bill Reynolds's question a little bit further, Steve, and not look to the future but today.

We have a bunch of unsolved problems here. All of the problems are divided in terms of the application you need.

Now who in ERDA, you or Kane, is responsible for saying what is the scientific research that should be undertaken to solve these problems? These things are not defined in terms of the science that underlie the problems, in the areas of research that should be supported.

Is there anyone in ERDA who has that responsibility?

DR. KANE: As far as the basic research, I have it; and as far as the more applied, Alex Mills has that. And we'll talk in our turn about how we do it and how we talk to each other about that problem. That's subsequent talks.

A good point, again. I think you're all asking different aspects of kind of the same question. We deserve to be asked those questions. So don't forget them when our time comes.

Yes?

Paul Scott.

MR. SCOTT: I just had one additional comment to help to answer Steve's question on the guidance that we get from the pilot-plant people in terms of doing research.

I think one of the most valuable things we get, both from the energy centers and from the people at headquarters, is review of the proposals that we receive from universities. And we look at how our pilot-plant people and how our field people view these proposals; and this helps us keep our course straight.

So this is another kind of guidance on an ad hoc particular-event basis.

VOICE: Jim.

DR. KANE: Go on.

Again I say this as I preface each of these talks. Dr. White has not yet arrived, so we'll go on to the final one of the three technology presentations for this morning.

Mike Raring is going to talk about the magnetohydrodynamics program.

MR. RARING: I hope you will understand I'm substituting for Bill Jackson who will return tomorrow from Moscow where he has spent the past week. He delivered a five Tesla superconducting magnet to the U-25 facility which will be used in the joint US-Soviet MHD cooperative program.

I will attempt to explain what we're doing in MHD: what the purpose is; the nature of the work that's required; how we're trying to accomplish that work logically, in accordance with priorities necessary to meet the goals we've set; and finally who's doing the work.

And I will try to include a little about what's being done, and why. Finally, I'll try to say something about where we stand.

If there is time, we have a film on the U-25 pilot plant in Moscow which I know Dr. Jackson and Mr. Licarrdi, the Deputy Director, would like you to see: it makes an excellent introduction to MHD. However, if we put that on now, there will be little or no time to outline the program. So, if anyone would like to see the film and we don't have time now, I would suggest that we may be able to show it during the lunch hour: it is interesting.

After that introduction, let me say that MHD is somewhat different from most of the programs in Fossil Energy. It has a specific power conversion mission. It's an advanced Electromagnetic turbine development project. And it has a clear purpose. As in all power systems work, development requires strict engineering and economic disciplines. We've got to identify engineering problems in the correct environment, that is, with realistic electromagnetic, fluid dynamic, electrochemical and thermal stresses. Then we've got to work to solve those problems through development of designs which get to the root of the difficulties. And we've got to avoid being sidetracked into non-productive research, no matter how well qualified the available resources or how alluring the path. Engineering goals cannot be met when efforts are fragmented in peripheral research.

The design concept we're following is different from the systems which have been considered for military applications. Our work is directed predominantly to the coal-fired, open cycle system

MHD Program Goal

Develop a Coal-Fired, Electric Power Commercial Demonstration Plant which will

- Achieve Thermal Efficiencies of at Least 50 Percent (Compared with 38 Percent for Present Day Steam Plants)
- Operate Competitively Under Central Power Station Conditions
- Meet Environmental Air Quality Standards

in which coal is burned in a combustor to produce a high temperature, potassium seeded plasma. The high conductivity fluid is passed through the channel where it interacts with a high strength magnetic field to generate electricity. The plasma is analogous to the rotor of a conventional electric generator.

The first slide (Fig. 1) summarizes the objectives of the MHD program. The essential objective is to achieve an overall efficiency of 50% or more in a combined cycle MHD-Steam commercial power plant. You are probably aware of the ECAS studies which were conducted by NASA under ERDA and National Science Foundation Sponsorship. The studies were made by both NASA and industrial analysts. Industrial developers and manufacturers of heavy electrical generating equipment were represented. These studies compared advanced power conversion systems, based upon coal firing, and found that open cycle MHD looked about the best from both efficiency and cost of electricity standpoints. Of course, coal-fired MHD plants will have to supply AC power to existing grids at competitive costs. They will need to meet applicable environmental standards. In this respect, MHD possesses an intrinsic advantage: sulfur is captured by the potassium which is used to "seed" the plasma. The potassium sulphate, which is formed, can be drained off at a downstream station in the gas path and the potassium can be converted back to carbonate for reuse. This advantage means that MHD could burn high sulphur coal with minimal capital cost penalty in stack gas scrubbing equipment.

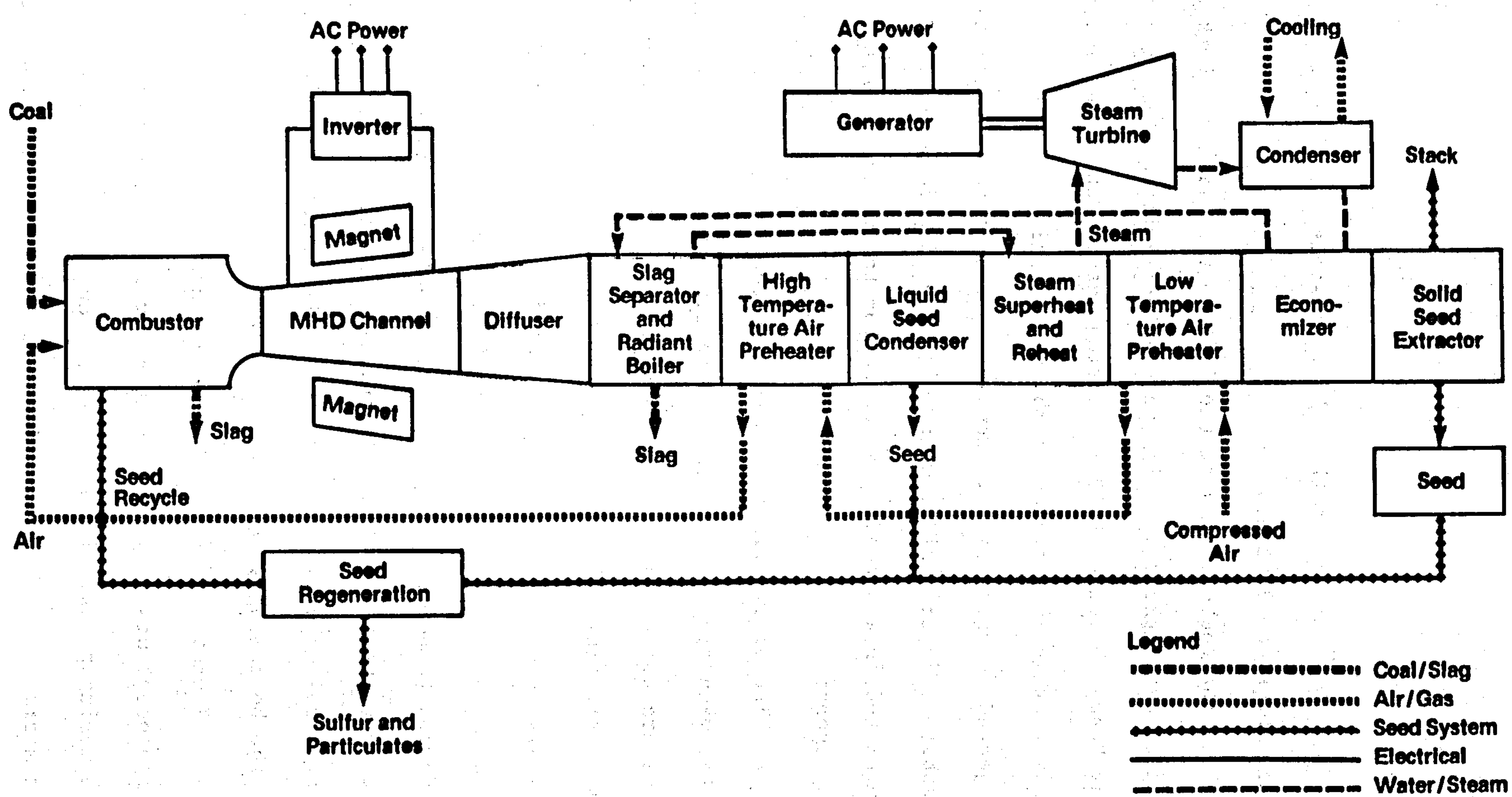
The next figure (Fig. 2) represents a schematic of a typical MHD-steam system.

The combustor is at the left in this figure. Work on combustor development is being pursued primarily at the Pittsburgh Energy Research Center (PERC). Current design envisages two stages. The first stage is a cyclone combustor in which 80 or 85% of the ash is rejected as molten slag. Combustion conditions are maintained on the substoichimetric side, which minimizes NO_x formation. Combustion is completed in a second stage combustor to produce a plasma at around 4800°F.

The plasma flows down through the channel where it interacts with the magnetic field to produce an electric field. Electric charges are collected by electrodes placed on the walls parallel to the magnetic field direction. This D.C. current is inverted to A.C. and conditioned to suit the utility grid. The hot gases then flow through the diffuser into a radiant boiler where thermal energy is transferred to boiler feed water. The cooler gases, still around 3000°F, move next into the regenerative air heater where seed and slag are drained off. Finally, the cooled gases, at around 2000°F, enter the bottoming steam plant.

I want to stress the unique character of the generator. This component has no precursor in power conversion machinery. There are no moving parts. The stresses are entirely different than the high temperature mechanical and corrosion conditions encountered in

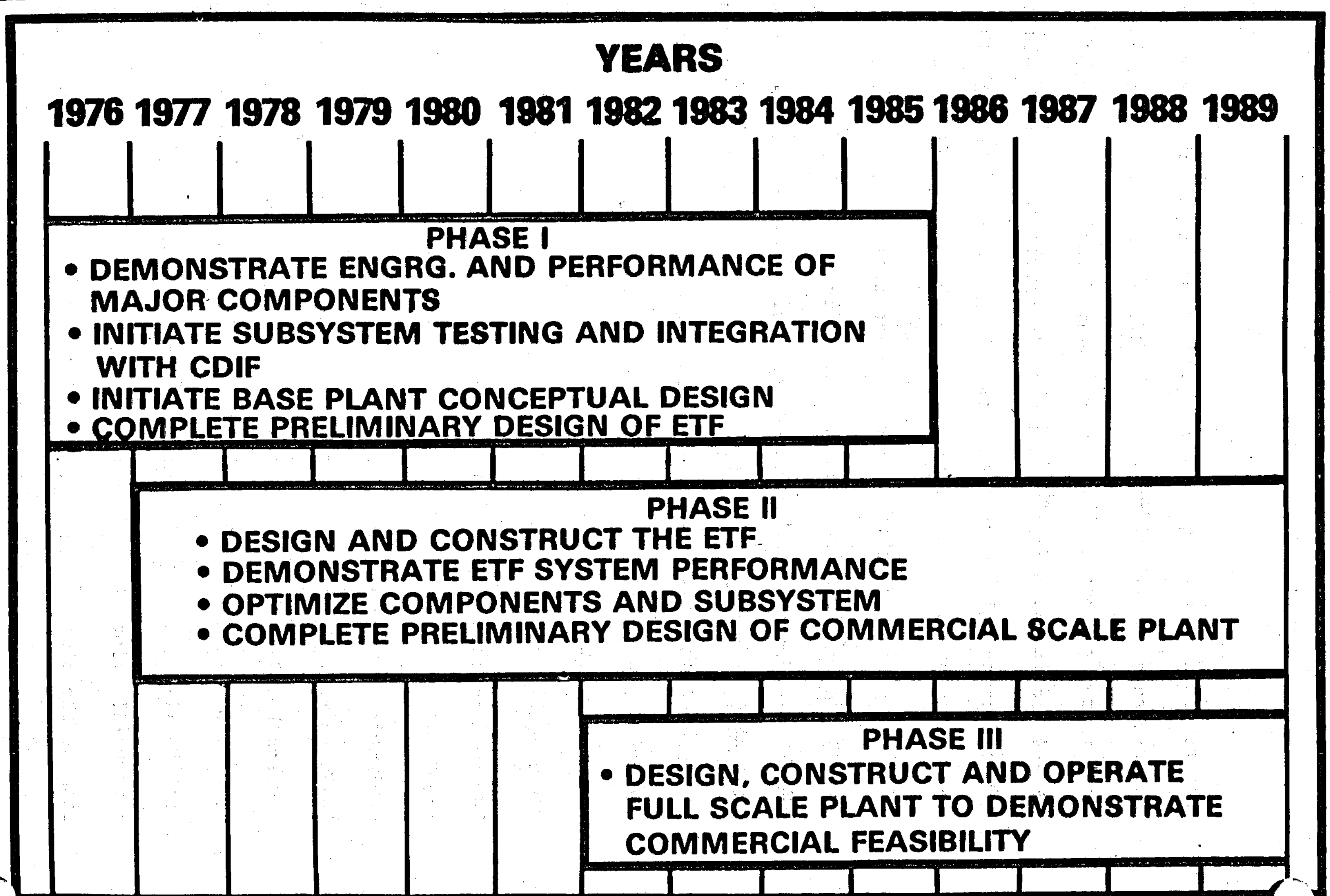
MHD Schematic — Coal-Fired/Directly-Fired Air Preheater



gas turbines or steam generators. The problems are electrochemical, electromagnetic, and thermal. Heat fluxes are high. Development work must take into account these combined environmental conditions. Stress conditions must be realistically simulated in the evaluation of design variables - whether material, geometric, thermal, or electrical.

In power equipment development like this, as the history of piston engine, steam turbine, and gas turbine development shows, work progresses through clearly marked stages. After rudimentary proof - of - principle is achieved, there is an engineering development phase to show that the concept works; then comes a commercial feasibility demonstration phase. The final phase is directed to full-fledged commercial demonstration. Our program is presently well into the first, or engineering feasibility demonstration phase as shown in this slide (Fig. 3). We are developing components for engineering feasibility testing at the 50 megawatt thermal level. A test facility, designated as the Component Development and Integration Facility, or CDIF, is being constructed in Butte, Montana. After we pass this program hurdle, we will advance to a commercial feasibility demonstration pilot plant. We have designated this project as the Engineering Test Facility, or ETF for short. This will, in effect, serve as a commercial pilot plant - about 250 megawatts thermal. Design selection of the power train will, of course, be derived from the CDIF experience.

ERDA MHD POWER DEVELOPMENT PROGRAM
MAJOR PROGRAM PHASES



The MHD program is organized in accordance with these realities. Work is classified in accordance with a Work Breakdown Structure designation to identify where it fits in the total effort. These identifications span all activities from basic design support research, analytical studies, engineering evaluations to resolve basis component design issues, then on to major engineering tests to validate the development work and finally into commercial demonstration. This slide (Fig. 4) identifies the basic development requirements and activities by Work Breakdown Structure designation. The next slide (Fig. 5) indicates the shift in program emphasis, by work breakdown structure, as work moves through the successive phases.

To illustrate the kind of Phase I support research and engineering work we are doing - it has been necessary to establish electrical, thermal, physical, and chemical properties of coal slags, electrode materials, insulators, and other materials of design interest, under conditions as closely representative of the MHD environment as possible. Seed recovery experimental work has been initiated - determination of the thermal and fluidynamic conditions under which seed and slag condensation occurs.

Stanford University has been investigating basic MHD phenomena to provide a basis for better analytical understanding of generator performance. MIT is studying combustion kinetics,

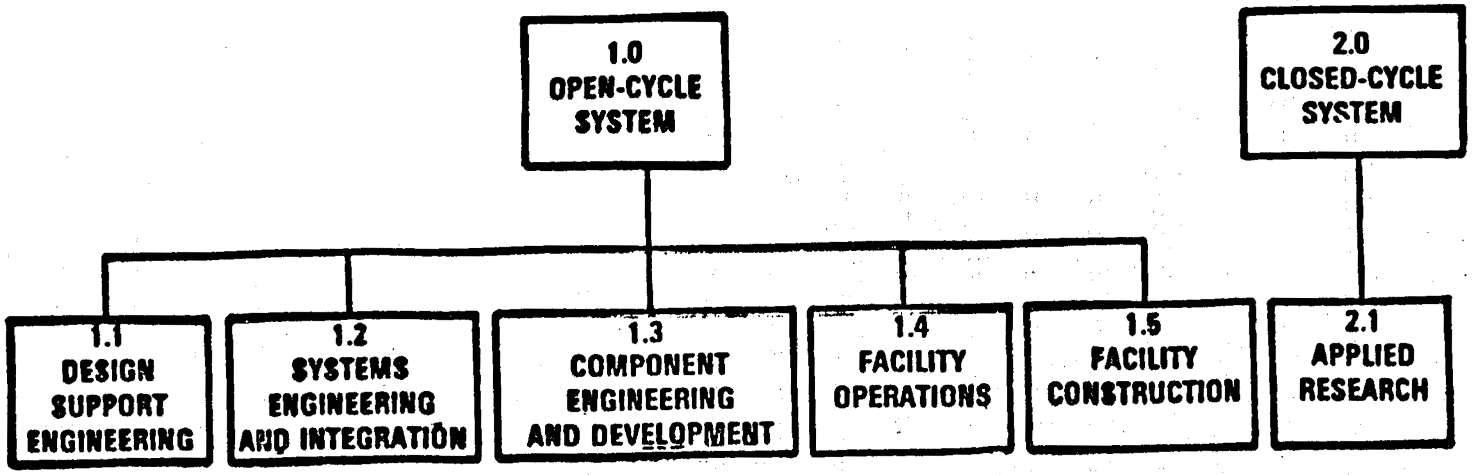

1.0
OPEN-CYCLE
SYSTEM
2.0
CLOSED-CYCLE
SYSTEM
1.1
DESIGN
SUPPORT
ENGINEERING
1.2
SYSTEMS
ENGINEERING
AND INTEGRATION
1.3
COMPONENT
ENGINEERING
AND DEVELOPMENT
1.4
FACILITY
OPERATIONS
1.5
FACILITY
CONSTRUCTION
2.1
APPLIED
RESEARCH

FIGURE (Y)

OPEN CYCLE MHD PROGRAM
WORK BREAKDOWN STRUCTURE

FUNCTION	← RESEARCH AND DEVELOPMENT →				
		← ENGINEERING DEVELOPMENT AND TEXT →			
			← PLANT DEMONSTRATION →		
WBS ACTIVITY	1.1 DESIGN SUPPORT ENGINEERING 1.1.1 DESIGN PROPERTIES 1.1.2 COMPONENTS 1.1.3 ANALYTICAL 1.1.4 1 and C	1.2 SYSTEMS ENGINEERING AND INTEGRATION 1.2.1 SYSTEMS ANALYSES 1.2.2 SYSTEMS ENGINEERING 1.2.3 ENV. & SAFETY 1.2.4 SUP. STUDY AND ENGR.	1.3 COMPONENT ENGINEERING AND DEVELOPMENT 1.3.1 POWER TRAIN 1.3.2 MAGNET 1.3.3 AIR SUBSYSTEM 1.3.4 RAD. BOILER 1.3.5 STEAM SUB.	1.4 FACILITY OPERATIONS 1.4.1 – 1.4.2 CDIF[1] 1.4.3 ETF[2] 1.4.4 CDP[3]	1.5 FACILITY CONSTRUCTION 1.5.1 CDIF[1] ETF[2] CDP[3]

(1) COMPONENT DEVELOPMENT AND INTEGRATION FACILITY – DEMONSTRATE ENGINEERING FEASIBILITY (50MW$_t$)
(2) ENGINEERING TEST FACILITY – DEMONSTRATE COMMERCIAL FEASIBILITY ($\approx$ 250 MW$_t$)
(3) COMMERCIAL DEMONSTRATION PLANT – DEMONSTRATE COMMERCIAL OPERATIONS ($\wedge$ 1000 MW$_t$)

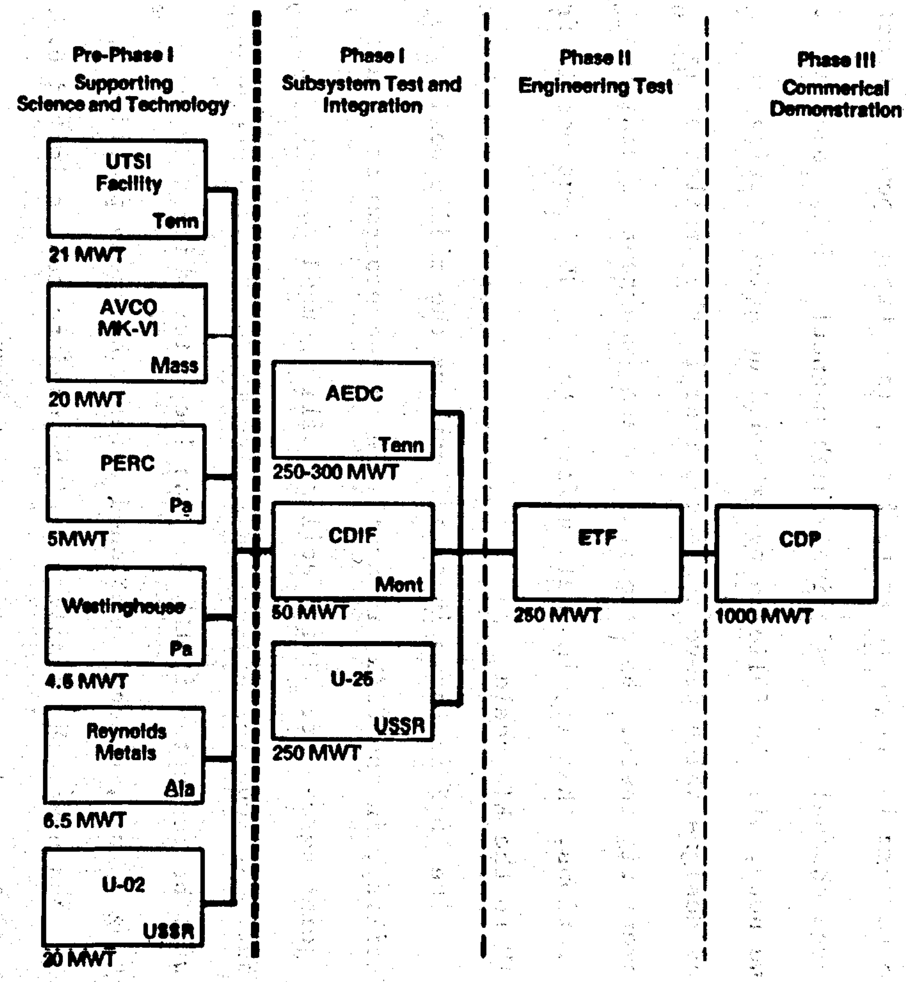
evaluating electrode and insulator materials under simulated channel design conditions, and so forth.

This slide (Fig. 6) shows the general course of component development. The left hand column of boxes represent the more significant component development efforts. The University of Tennessee Space Institute, at the top, is at present upgrading their facilities. Dr. Dicks, who directs the work for UTSI, has been active in MHD work for a number of years. The AVCO-Everett Research Laboratories, next in line in this Figure, are doing the bulk of the channel development work which will determine the design of the first CDIF test channels. PERC is responsible for development of the first coal combustor which will be tested, in tandem with an AVCO channel, in the CDIF. They are basing their development work on a five MW thermal experimental model of the projected CDIF design. Westinghouse is using bench test facilities to evaluate electrode designs. They are also upgrading a small channel facility which can provide test environments more nearly duplicating power generating duty conditions.

The Reynolds effort has been aimed toward advanced electrode engineering development and to the evaluation testing of more conventional designs. The USSR U-02 facility has provided valuable test experience on ceramic electrode designs under channel operating conditions.

The next column in Fig. 6 represents major test facilities, where designs developed by the first column activities, can be tested

MHD Development Sequence

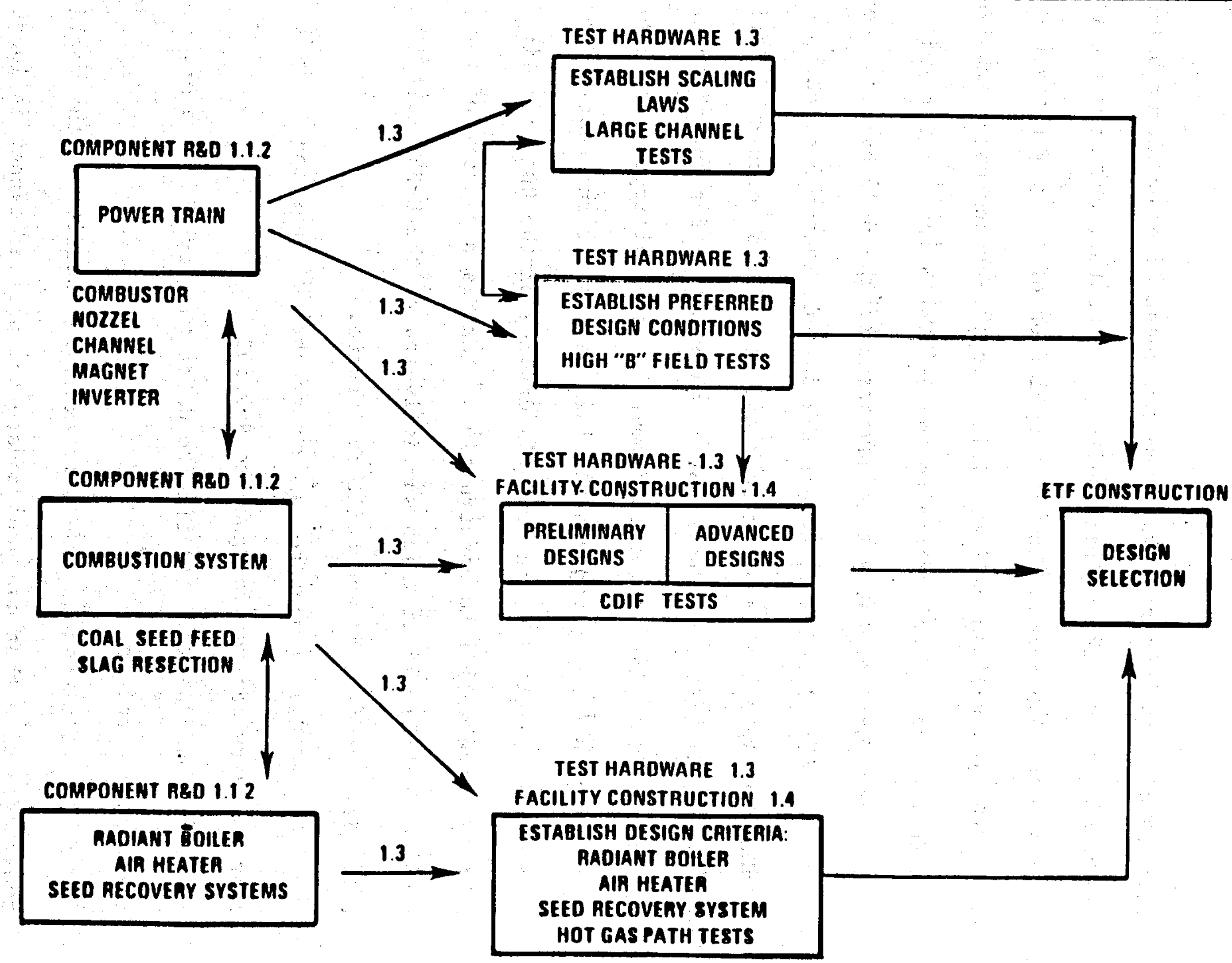


at a larger scale and under more stringent engineering conditions. The first box here is the Arnold Engineering and Development Center in Tallahoma, Tennessee. They have a 250MWt facility in which we plan to perform important tests to first, investigate power extraction in a large channel under relatively high magnetic field conditions. This, we hope, will be followed by extended duration testing of selected designs which prove to be superior in the smaller scale development rig tests. Both activities are important to scale-up considerations, that is, in scaling first to the CDIF but mostly from the CDIF to the ETF scale.

The CDIF is shown in this figure as the middle box. The U-25 facility, in the USSR, is available to the program as a part of the joint agreement. This facility will be used to meet two important test requirements. First, high magnetic field strength tests will be conducted in the by-pass loop, for which a superconducting magnet, which I mentioned before, has been provided by the U.S. And next, the facility will be used to test selected U.S. designs in large sizes - equivalent to the ETF size.

This next slide (Fig. 7) indicates the flow of activities. The top left hand box represents MHD power trains for CDIF testing. This includes the combustor, channel, inverter, and so forth. Related combustion activity, represented by the next box, is intended to look ahead to advanced coal combustor designs which would lay the ground work for an advanced CDIF test train. These activities are

MAJOR MHD PROGRAM LOGIC



(NUMBERS REFER TO WBS ELEMENTS)

intended also to support downstream component development or balance-of-plant systems - the radiant boiler, air heater, and seed recovery systems. The chart also shows extrapolation of the power train development into high B field regime. This involves extension of experimental work from a 2 to 3 Tesla range to the 5-6 Tesla range. Our initial efforts here will probably take advantage of the U-25 by-pass loop.

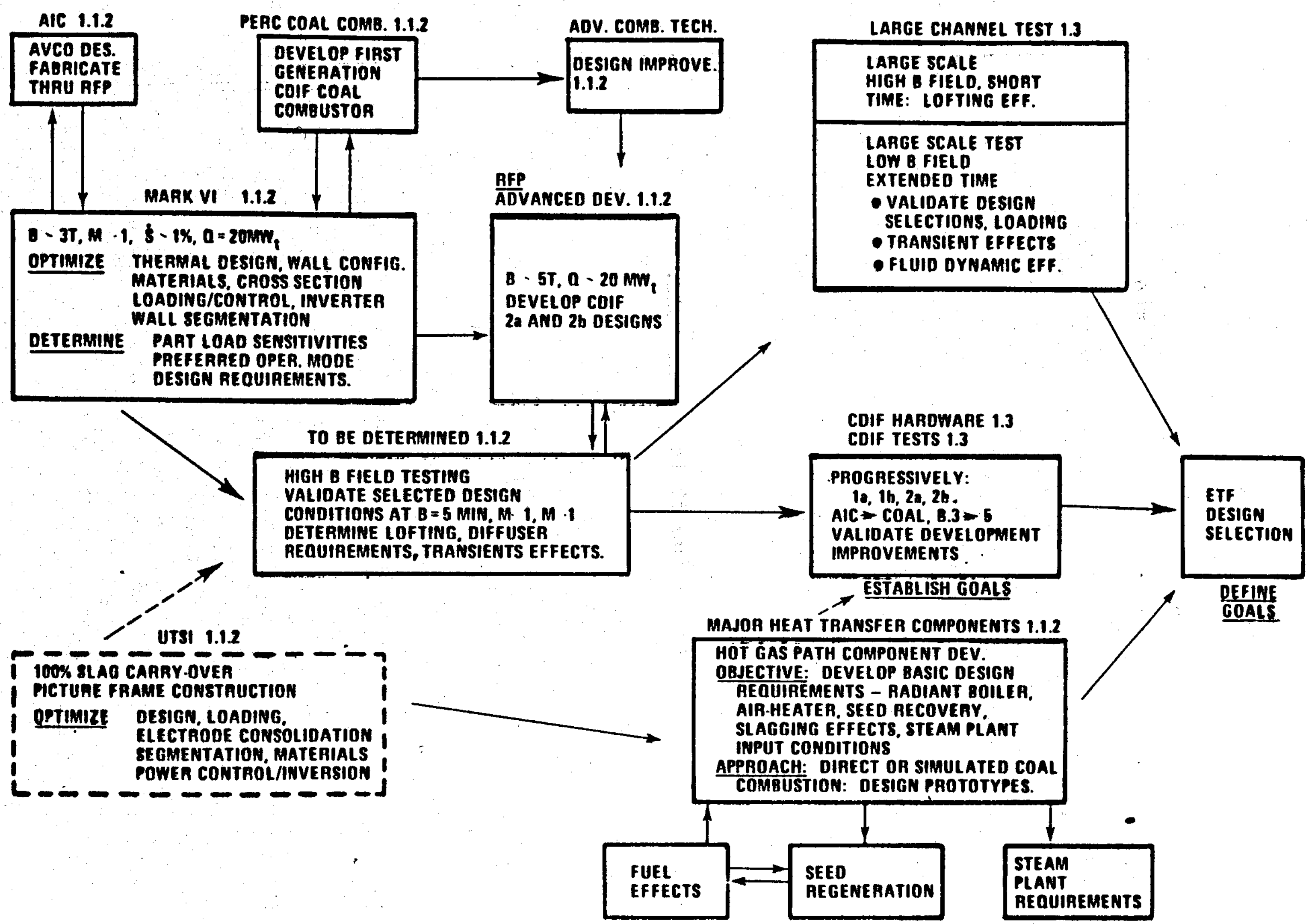
This, I believe, covers the salient features of our program. As you see, we are attempting to keep our efforts focused on a firm objective, namely, development of a sound design for the ETF combined MHD-steam pilot plant to prove commercial feasibility. The next slide (Fig. 8) simply repeats the last one except in greater detail. This figure (Fig. 9) is an artist's drawing of the CDIF facility in Butte - we're well into construction. Next is a picture of the superconducting magnet which was delivered to the U-25B site (Fig. 10). It was designed and built by Argonne.

VOICE: I want to ask a very obvious question. Why is it that our very best device goes to Russia?

MR. RARING: I'd like to defer that question to Mr. Liccardi, the Deputy Director.

MR. LICCARDI: The only existing facility in the world today of a size that can accommodate the present magnet is located in the Soviet Union. The quid pro quo that we have with the Soviets is that we will get all the data from the operation of the U-25B facility with the loan of this magnet. There is no magnet fabrication technology

MHD PROGRAM LOGIC



Slide #9 is unavailable.

Slide #10 is not available.

transfer, if that is your concern, because, as you all know, technology transfer comes primarily from the know-how in the fabrication of equipment, that is fabrication techniques. This is a scaled unit. We feel that we will not be in a position to get that data from a large scale MHD facility for about another two years. So this will help us immensely in designing our channels and future MHD power systems.

VOICE: Good answer.

DR. KANE: Dr. Green.

DR. GREEN: I have a question regarding the efficiency with which the thermal energy is converted into electrical energy in our MHD duct.

MR. RARING: The enthalpy extraction generally considered as necessary to commercial success is typically 15% minimum. Achieving this in a small channel with a high surface to volume ratio is very difficult. However, a recent test at AVCO on a disk generator under conditions which simulated combustion gas chemistry, did achieve 14% on two successive tests, shock tube tests. In the view of some plasma physicists, at least, the experiment is relatively independent of the configuration - it's a plasma experiment and the results are applicable to a large linear channel. So, there has not yet been any experimental evidence to show that 15% or more is impossible in a large linear channel.

MR. LICCARDI: We do have what we call a high-performance demonstration experiment that will be done at the Arnold Engineering

Development Center, and this will be a short duration 15 to 20 second run on a channel the size of the ETF, which is 250 megawatts thermal, and this will allow us to go to steady state conditions and validate the enthalpy extraction and turbine efficiency. That's about a year or more away.

MR. RARING: That's the purpose of that test, as I mentioned earlier. This is intended to validate enthalpy, extraction and turbine efficiency, in a large channel test.

DR. KANE: Are there other questions?

I think this meeting is a great example of the best-laid schemes. Let me tell you the nice logical order we laid it out in, so you can contrast this with what's happening here.

I was supposed to give you a focusing talk which told you the area we were specifically going to aim at for the rest of the meeting. And the remainder of the morning was to contain, first, a talk by Dr. White, in which he would give the goals, the strategy, the overall picture of the fossil energy program. Without that kind of talk, it's difficult to do what I asked you, to put the research portions in context.

After that, we were going to have, and we have had, some talks on the technologies. I told you specifically that these technologies per se were not the topic of this meeting, but nevertheless they were necessary if you were to make pertinent comments on the meeting.

Now, you still haven't had Dr. White's talk. I'm still desperately hoping that he'll make it, because I think he's an essential ingredient to this meeting.

We have one more talk that was supposed to give you the background on the meeting today, and I think it's equally essential to the technology, and that is the probable costs of synthetic fuels.

Now, you understand that the purpose of this meeting is how much research, what kind of research, ought we to have; and certainly one of the driving forces to do more or less research is the state of what you already have. So the next talk is by Dr. Chris Knudsen, and he will discuss the subject of estimates of synthetic fuel costs from fairly well-known processes. This is another talk which is supposed to put in context the question, "What research, how much, and what kind should we do?"

So, it's all backward today. I'm sorry, but we couldn't avoid it. Is Chris here, so he can go into this aspect of it. If he's not, we're in real trouble.

See, Chris too is up at the Hill today.

We do have a pinch-hitter for Dr. White, who could give his talk from the slides and so on.

Leroy Furlong. Leroy, I hate to do this to you at the last minute. I hear somewhere that you can -- if we've lost him, we're in real trouble.

Let me tell you what the topic of the Hill is today, because it really is a serious one. It has something directly to do with this meeting. Last week there was an enormous furor in the Senate over some estimates of availability of fossil energy as a function of price, existing sources--natural gas, predominantly. The subject is one in which practically everyone in fossil energy has been occupied more or less continuously, and that's the one that has, today, Dr. White, Mr. Fri, Chris Knudsen, and Harry Johnson up there. That's the reason they're not here.

I see no alternative, except to go to our first speaker of the afternoon. Alex, could we do that to you?

Let me back up just a minute and tell you the why and the reasons for this.

VOICE: Why don't you run the film?

DR. KANE: The MHD film? I would rather hold off. The subject of this meeting is really to give us advice on what we ought to do. The MHD film, we'll have it here, we'll show it during the noon hour. I haven't seen it, but I'm sure it's a good film. But the real purpose is the critique, and I think that's probably less valuable for the critique than some of the other things.

Now, the next speaker is Dr. Alex Mills.

He's director of the Division of Materials and Exploratory Research, which means that in fossil energy, he is the man in charge of the development of the intermediate, and in some cases long-range research.

Rather than describe what Alex does, I'll let him describe it. This is the talk that was to have been given this afternoon--we'll move it forward now.

Alex, sorry to do this to you on such short notice.

DR. MILLS: Thank you.

(Slide 1)

I'd like to begin with the first vugraph, which lists objectives of the division. I need to tell you, since you haven't seen the overall distribution of divisions, that we are one of the divisions, budgetarily one of the smaller divisions, but naturally we think one of the most important divisions in fossil energy. The Materials and Exploratory Research Division has these objectives. These bullets are not quite equally distributed, but the point is that we are to serve in concept as the central research management for all program areas of fossil energy.

And I hope, incidentally, Gerry, that while you stressed coal, I would believe that our discussions today should cover all fossil energy, so that oil shale is also a candidate. And a chief function that we have is to insure that we lay the foundation for innovative technology, which is an aspect we haven't heard in our discussions so much today.

To do that, we ought to develop a technology for processes we have listed; gasification, liquefaction, and also refining and chemicals. We want, on the other hand, also to improve the operational reliability and efficiency of synthetic fuel plants through materials

MATERIALS AND EXPLORATORY RESEARCH

OBJECTIVES

- SERVE AS THE CENTRAL RESEARCH MANAGEMENT ARM FOR ALL PROGRAM AREAS OF FOSSIL ENERGY
- ENSURE THE FOUNDATION FOR INNOVATIVE TECHNOLOGY THROUGH ITS PROGRAMS IN THE ERDA ENERGY RESEARCH CENTERS, NATIONAL LABORATORIES, AND OTHER GOVERNMENT AGENCIES, PRIVATE INDUSTRY, AND UNIVERSITIES.
- DEVELOP INNOVATIVE FOSSIL ENERGY TECHNOLOGY LEADING TO SIGNIFICANTLY CHEAPER SYNTHETIC FUEL PROCESSES
  - GASIFICATION
  - LIQUEFACTION
  - REFINING AND CHEMICALS
- IMPROVE THE OPERATIONAL RELIABILITY AND EFFICIENCY OF SYNTHETIC FUEL PLANTS THROUGH RESEARCH ON MORE CORROSION/EROSION RESISTANT MATERIALS AND COMPONENTS
- DEVELOP ADVANCED TECHNIQUES TO PERMIT INCREASED COMBUSTION OF COAL IN AN ENVIRONMENTALLY ACCEPTABLE MANNER

and components research. So this is a little different from the chemical kind of processing. And we want to develop advanced techniques for combustion and direct utilization.

(Slide 2)

The next slide lists some special concerns for university programs. These are listed as the objectives to locate and use the talents of university people, and I hope we use them in a constructive manner--give them the opportunity to come forward. One of the things that we've recognized of great significance is that we have a communications channel. We have had great difficulties, I think, communicating with the public at large, and also with special groups, and we think that the universities is one segment of our United States community that can communicate what the realities are.

And, of course, the last, and in some ways we would think the most important of these, is to assure an adequate manpower base. This was mentioned once before.

(Slide 3)

The next slide deals with the distribution of funds. And you see under "Advanced Research and Supporting Technology," in 1977 some 7.7 percent and 6.1 percent in the '78 budget. The Division of Materials and Exploratory Research is a major part of that, but not all. There is a planning function within that budget. So this gives a distribution of the various divisions that I mentioned earlier, and which will appear in Dr. White's talk.

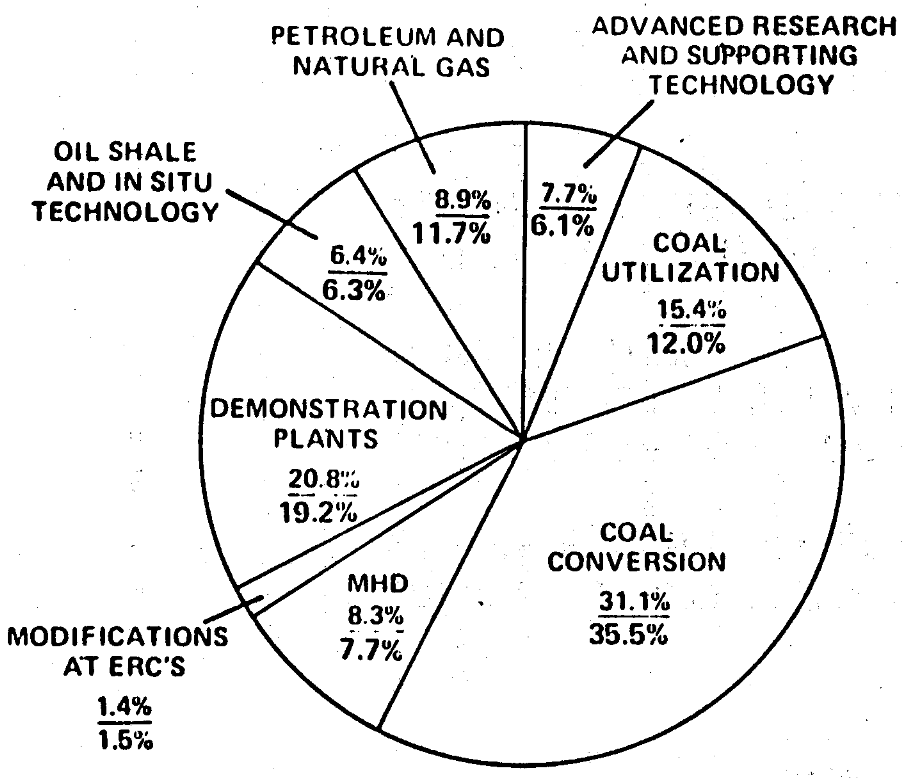
MATERIALS AND EXPLORATORY RESEARCH

UNIVERSITY PROGRAMS

OBJECTIVES

- LOCATE AND USE TALENTS OF UNIVERSITY PEOPLE TO CARRY OUT RESEARCH RELATED TO FOSSIL ENERGY
- PROVIDE COMMUNICATION CHANNEL BETWEEN ERDA–FE AND UNIVERSITIES ON RESEARCH NEEDS AND INFORMATION DISSEMINATION
- ASSURE ADEQUATE MANPOWER BASE IN SCIENCE AND TECHNOLOGY RELATED TO FOSSIL ENERGY

FOSSIL ENERGY BUDGET ESTIMATES
DISTRIBUTION OF FUNDS



PERCENTAGE DISTRIBUTION OF FOSSIL ENERGY BUDGET ESTIMATES IN FY 1977 AND FY 1978 SHOWN AS FOLLOWS:

$\frac{\text{FY 1977\%}}{\text{FY 1978\%}}$

BUDGET AUTHORITY (DOLLARS IN MILLIONS)

	FY 77	FY 78	INCREASE DECREASE
COAL CONVERSION	$150.3	$233.3	$ +83.0
COAL UTILIZATION	74.4	79.1	+ 4.7
ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY	37.1	40.3	+3.2
DEMONSTRATION PLANTS	100.3	125.9	+ 25.6
MAGNETOHYDRODYNAMICS (MHD)	40.0	50.5	+10.5
PETROLEUM AND NATURAL GAS	43.2	76.7	+33.5
OIL SHALE AND IN SITU TECHNOLOGY	31.0	41.5	+10.5
MODIFICATIONS AT ERC'S	6.9	9.6	+2.7
TOTAL	$483.2	$656.9	$+173.7

77-2656M/1-4

(Slide 4)

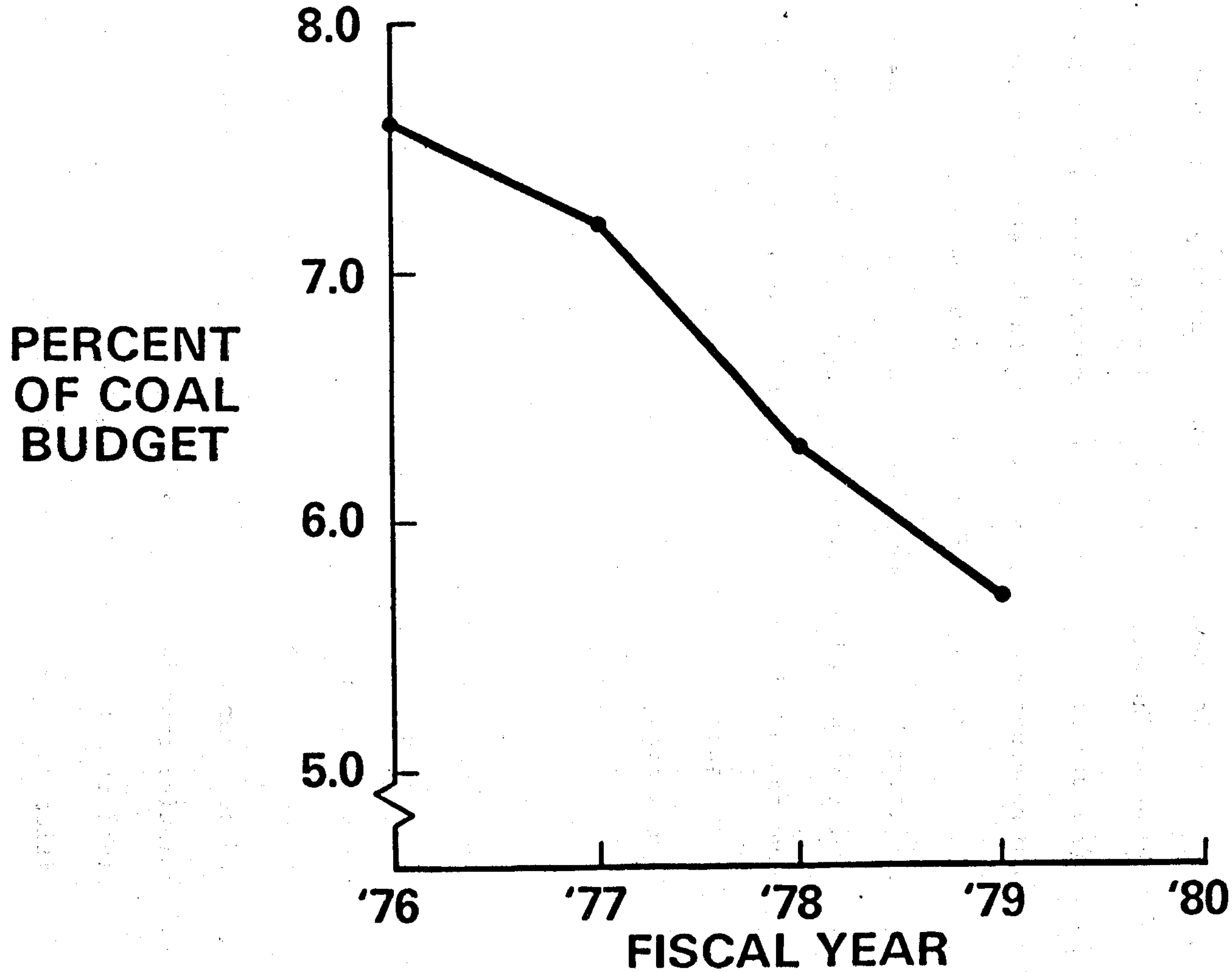
The next vugraph--and I want to go over some of these to get to the end few, which I think are more significant--related to the share of funds for this particular division in percentage, and I'm no doubt somewhat self-serving to illustrate it this way.

It shows a diminution. To bring it into focus, our budgeting has been essentially constant, constant plus 8 percent, over this period of time. The reason it has this form is that the development of power plants and large-scale activity has gone up, but at the same time I will make the point that the research activities have stayed essentially constant.

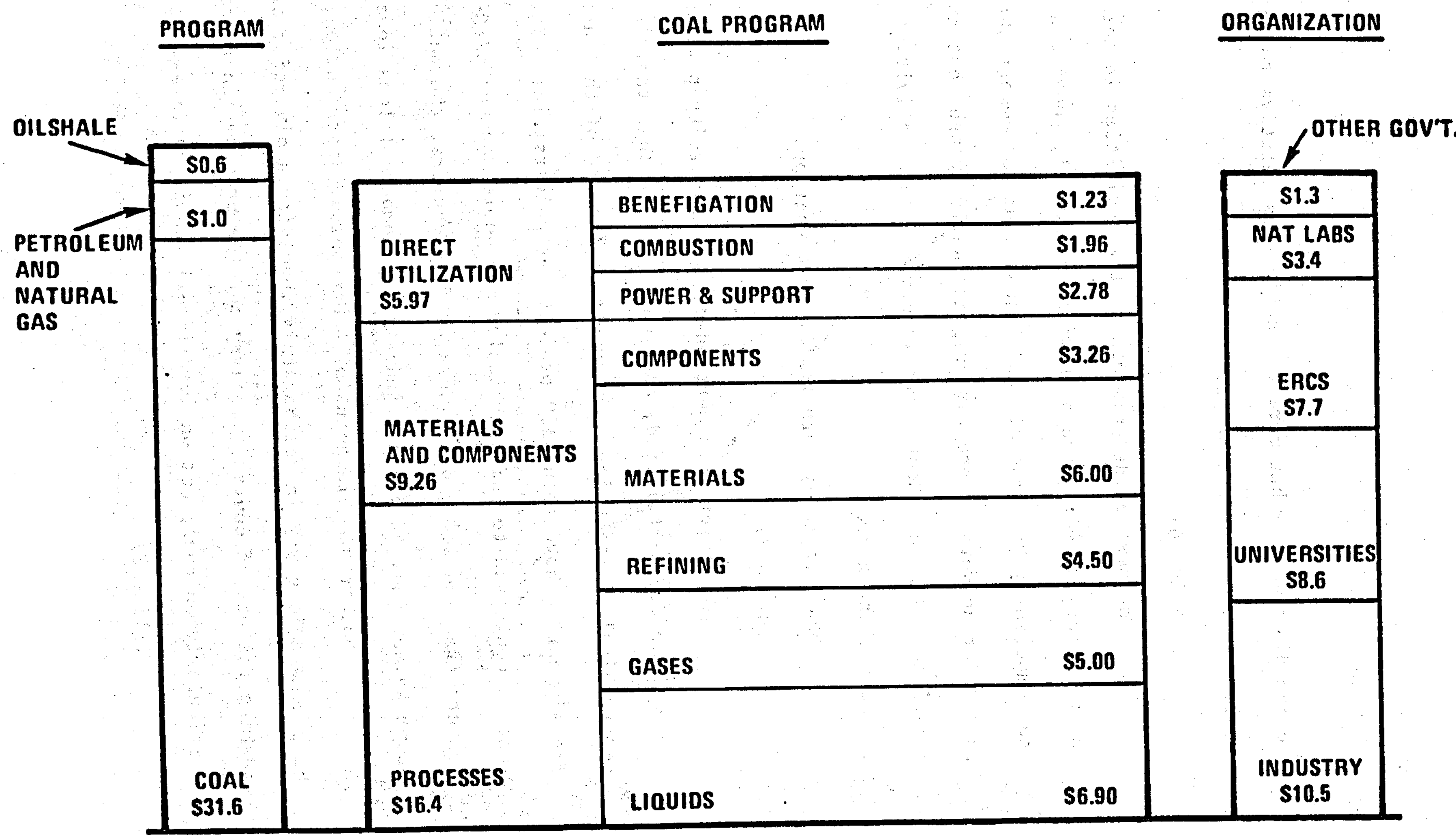
(Slide 5)

The next vugraph comments on two things, programwise and where we do work. You see that \$31.6 million for this division is in the coal area. There is some additional research activities in oil shale and petroleum. The center bar depicts the fact that our activities are divided into three parts: direct utilization, materials and components, and processes. And this bar graph represents the relative funding. And they're broken down into subgroups. At the right illustrates what organization is used to carry out the activities, and you see industry, \$10 million; universities, \$8.6; energy research centers, \$7.7, national labs, \$3.4. So, at the left is the general things we're doing, and at the right where we're doing this.

MATERIALS AND EXPLORATORY RESEARCH
SHARE OF COAL BUDGET



MATERIALS AND EXPLORATORY RESEARCH
FY78 FUNDING DISTRIBUTION (MILLIONS)



We can discuss somewhat more our activities relative to the universities or relative to industry.

(Slide 6)

The next slide comments on the activities in terms of how we're organized: processes with Dr. Podall, power and materials and components, Dr. Frankel; and I just want to comment that we regard our university programs significantly enough that these are organized under Paul Scott, who is here. Their activities actually are across the board.

Now, if I may turn to the next vugraph.

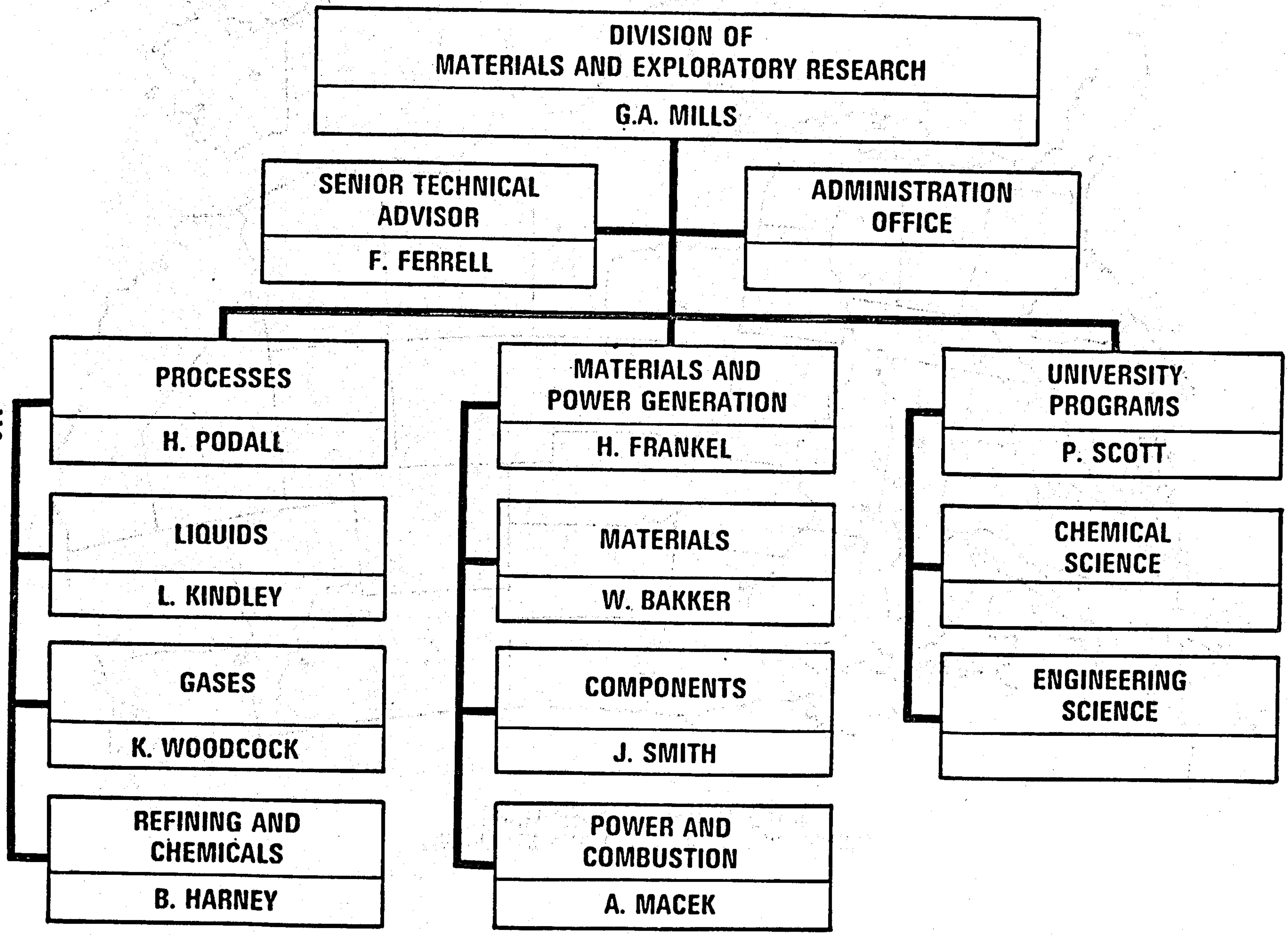
(Slide 7)

This depicts, as mentioned, the university programs where these are distributed, and you'll notice that there's wide geographical distribution. We expect at the end of the current fiscal year to have about 150 projects at universities. I thought that we could add to this particular map where the energy research centers are, and we're doing work at five centers, the national labs, about seven, and, of course, industry, a number of locations.

So, from a viewpoint of geographical distribution, we have come a long way in deliberately involving a diversity of groups, seeking talent, of course, to carry out the programs in research, particularly on coal, but on fossil--all fossil energies.

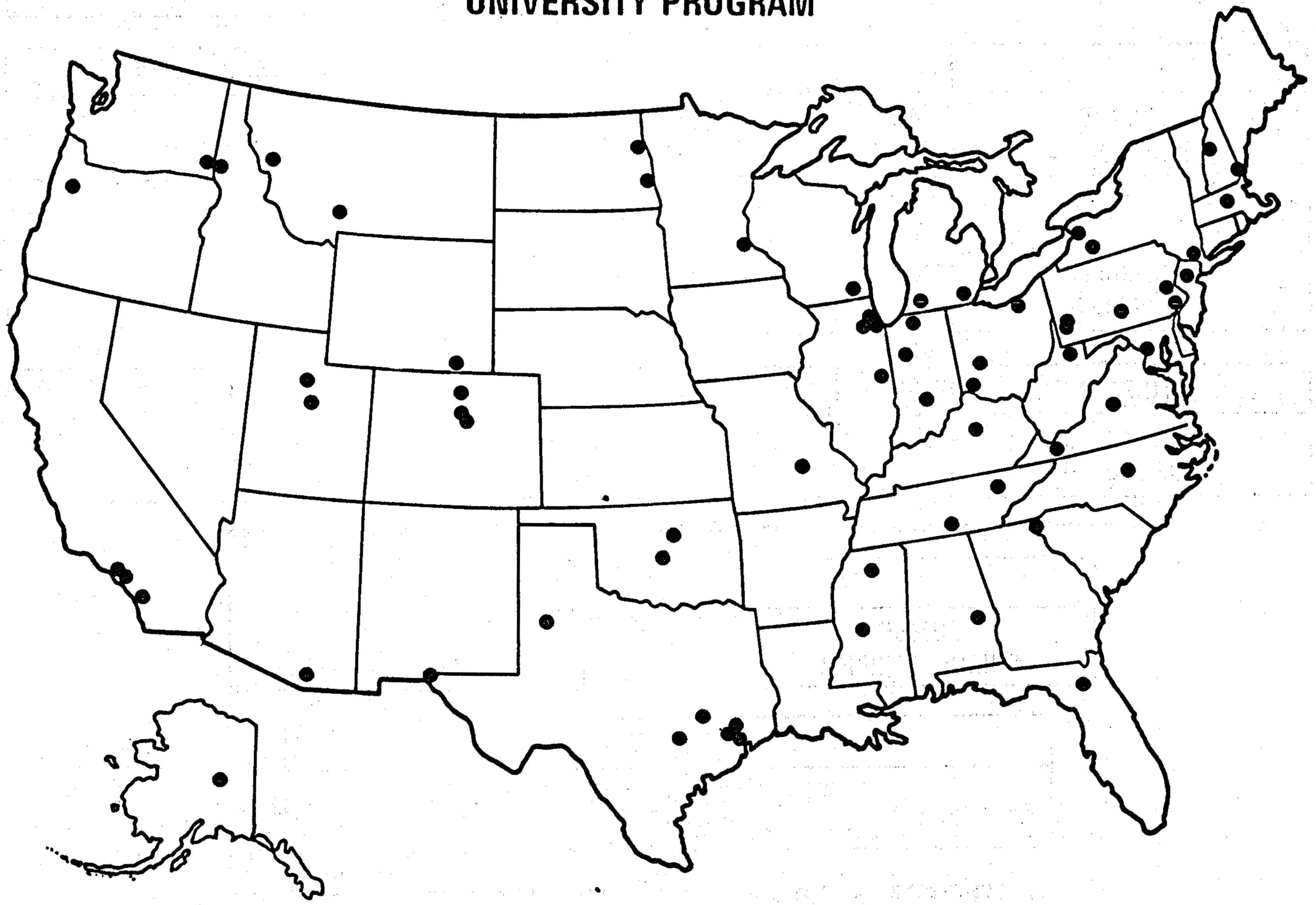
(Slide 8)

MATERIALS AND EXPLORATORY RESEARCH



MATERIALS AND EXPLORATORY RESEARCH

UNIVERSITY PROGRAM



MATERIALS AND EXPLORATORY RESEARCH

FY/76 PROPOSAL/CONTRACT SUMMARY

- **PROPOSALS**

NATIONAL LABORATORIES	123
ENERGY RESEARCH CENTERS	37
UNIVERSITIES	230
INDUSTRY AND OTHER	119
	509

- **CONTRACTS/PROJECTS**

	IND	UNIV	GOV'T	TOTAL
PROCESSES				
– GASES	15	24	11	50
– LIQUIDS	13	20	11	44
– REFINING & CHEMICALS	2	2	9	13
MATERIALS & COMPONENTS				
– MATERIALS	15	4	10	29
– COMPONENTS	3	2	2	7
DIRECT UTILIZATION				
– BENEFICATION	1	2	4	7
– COMBUSTION	2	12	4	18
– ENERGY TRANSFER	–	–	2	2
– SUPPORT STUDIES	3	7	2	12
	54	73	55	182

The next vugraph comments on how we get suggestions for research. And I must say we come to a sort of an issue as to whether we ought to be a reactive group in ERDA or one which does more positive planning. From a reactive point of view, which is described here, we took the trouble in '76, the last complete year, to list where we were getting proposals. These are unsolicited proposals from the national labs, et cetera. And, at the bottom, where the contracts or projects are. So we have, at the end of '76, some 54 with industry, 73 with universities, 55 with government labs--about 200 projects.

The plan of work which we do is then balanced in part by the projects which are proposed from various institutions--universities and others--but more importantly, I believe, our activities are fashioned on a consideration of what the needs are, and then by reacting to unsolicited proposals on the one hand, to issue either requests for proposals or so-called PERDAs, and we have three PERDAs out at the present time, one for novel, innovative research on refining, on coal gasification, on liquefaction.

So we go to the community with a discussion of needs and the PERDA has got more latitude in it than a request for proposal in the sense that it's not as well defined except as to objectives. So we have unsolicited proposals on the one hand, we have our concern for what is needed, and I'm going to come to that later. There was some discussion today, of course, on how the power plant or larger scale activities are describing their needs in terms of the problems which they have.

(Slide 9)

Next vugraph. I would say today that if you want to learn about what we're doing in the Divison of Materials and Exploratory Research, there are three sources. First is the gold book, copies of which have been available, which describes all fossil energy activities.

The second is an annual report which is available, and a new one is to come out in the middle of July.

And the third is to look at what we would call our fact sheet. We have a book that each project has a particular one-page description objective, funding, who does it, and so on, so I will give you that information to delve into. You can pick up the sheet, see what the project is, and then you can go and get progress reports and so on.

Obviously, since our projects are on the average, $200,000 per project, and we have seen that there were 182 last year, and we are going to pick up another 30 starter grants, it's impossible to discuss these individually.

So, what I'd like to do now is, in the next slide, to discuss a few particular projects with the idea of letting you see what these are like.

(Slide 10)

MATERIALS AND EXPLORATORY RESEARCH

MAJOR RESEARCH AREAS

RESEARCH AREA/MAJOR PROJECTS	CONTRACT VALUE (MILLIONS)	NUMBER OF CONTRACTORS
• MORE ECONOMICAL SYNFUEL PROCESSES – METHANOL–TO–GASOLINE (MOBIL) – CATALYTIC GASIFICATION (EXXON) – FLASH HYDROPYROLYSIS (GULF, IGT, SUNOIL, BNL) – COAL STRUCTURE/REACTION MECHANISMS – REFINING OF COAL AND SHALE OILS – NEW CATALYSTS FOR COAL LIQUIFACTION	55.4	107
• RELIABLE MATERIALS AND COMPONENTS – COAL GASIFICATION (MPC, ANL, ORNL, NBS) – FIRESIDE CORROSION (COMB. ENG., BATTELLE, G.E., EXXON, WESTINGHOUSE)	14.6	29
– VALVES FOR COAL GASIFICATION (CONSOL. CONTROLS, FAIRCHILD, MERC) – FAILURE ANALYSIS – TECHNOLOGY TRANSFER – NEWSLETTER	7.6	7
• IMPROVED DIRECT UTILIZATION OF COAL – BENEFICIATION (SRC, PERC, AMES, PERC) – COMBUSTION PROCESSES (MRI, GFERC, MERC)	5.8	39
• EXPLORATORY RESEARCH AT UNIVERSITIES	24.5 (INCLUDED ABOVE)	77 (INCLUDED ABOVE)

MATERIALS AND EXPLORATORY RESEARCH
MAJOR PROJECTS

• COAL TO METHANOL, METHANOL TO GASOLINE	– METHANOL AS A FUEL – CRUDE METHANOL TO HIGH OCTANE GASOLINE AT LOWER COST AND REDUCED POLLUTION EFFECTS
• CATALYTIC GASIFICATION	– CATALYTIC GASIFICATION OF COAL USING POTASSIUM CARBONATE AS CATALYST – ELIMINATES OXYGEN PLANT, SHIFT AND METHANATION
• FLASH HYDROPYROLYSIS	– HYDROPYROLYSIS OF COAL IN SECONDS TO MORE AROMATIC LIQUIDS AND FUEL GAS WITH SIGNIFICANT POTENTIAL TO REDUCE INVESTMENT
• BASIC APPLIED RESEARCH	– RELATIONSHIP OF COAL CHARACTERISTICS TO LIQUEFACTION BEHAVIOR; – KNOWLEDGE OF KEY STEPS AND INTERMEDIATE PRODUCTS – CRITICAL CATALYTIC EFFECTS OF COAL MINERALS; ESSENTIAL CHARACTERISTICS OF CO–MO CATALYSTS
• REFINING OIL FROM SHALE & COAL	– APPLICATION OF PETROLEUM TECHNOLOGY AND SEARCH FOR IMPROVED CATALYSTS FOR COAL AND SHALE OILS

MATERIALS AND EXPLORATORY RESEARCH
MAJOR PROJECTS (CONT'D)

• COAL BENEFICIATION	– BENCH SCALE OXYDESULFURIZATION HAS SHOWN RELATIVELY SIMPLE AND INEXPENSIVE PROCESS TO REMOVE ALL INORGANIC AND 40% OF ORGANIC SULFUR
• MATERIALS	– COAL GASIFICATION – DATA BASE ESTABLISHED FOR ALLOYS AND CERAMICS ABLE TO WITHSTAND GASIFICATION CONDITIONS
	– FAILURE ANALYSIS SYSTEM ESTABLISHED, TECHNOLOGY TRANSFER INCLUDING NEWSLETTER
	– FIRESIDE CORROSION PROGRAM FOR MATERIALS FOR COMBUSTION OF SYNTHETIC FUELS, FLUID BED COMBUSTION, HIGH TEMPERATURE COAL COMBUSTION
	– INITIATED PROGRAM FOR IMPROVED CERAMICS AND ALLOYS
• VALVES	– DEVELOPMENT OF IMPROVED VALVES FOR FEEDING COAL AND WITHDRAWING CHAR CAPABLE OF RELIABLE OPERATION, COLD OR HOT
• UNIVERSITY	– IN ADDITION TO THEIR CONTRIBUTIONS TO THE ABOVE, ABOUT 1,000 STUDENTS AND FACULTY RECEIVE TRAINING IN FOSSIL FUEL SCIENCE AND ENGINEERING

Now, I'm somewhat in the dilemma of trying to tell you what a great job we are doing, on the one hand, and then later tell you all the things that need to be done. So on the great-job activity, we would like to point out that, especially in the last couple years, with the surge of funding and interest on the part of the technical communities at various locations, that we have uncovered what we think are some promising activities for projects which we'd like to think of as kind of third-generation activities.

And, to give you some sense of reality, I've listed here the first one; coal to methanol, and then to gasoline. The point being here is that we'd like to think, first of all, that methanol is a viable product from coal, and that we should not be locked into the concern that gasoline is our only transportation fuel.

Now, I see the people from the petroleum industry see the need to bring some added costs into this, because there are great problems in distribution, the question of whether methanol is mixed with gasoline or used alone. We would feel that methanol is an option that we need to have facts about. So we're doing work on the use of methanol in terms of power output and pollution control. So there are opportunities there.

The second part relates to the fact that working with the Mobil people, it has been discovered that crude methanol can be transformed into high-octane gasoline, 95-octane research, without lead, in almost quantitative fashion. And this gives another option, from coal to high-octane gasoline, which we think, first of all, is much superior to the SASOL process--the only process in the world being used, which is in South Africa.

I would like to comment that, interestingly enough, this is achieved by a novel concept of a catalyst which acts as a molecular sieve, which only lets gasoline molecules get out. And a key feature there is that you have a very select product of high quality.

Catalytic gasification, the second item in the slide, has already been mentioned by Martin Neuworth, and the fact that it eliminates the oxygen plant, shift and methanation steps. We think that inherently this is the right direction to go, how to do gasification at a lower temperature and, of course, more rapidly.

Flash hydropyrolysis, the third activity, refers to the fact that in a second or even less, if coal is pyrolyzed you get a significantly different product distribution, and in some instances relatively high aromatic products.

The third is basic applied research, I find myself trying to use some term, such as basic applied research which refers to an investigation of an applied research, but looking somewhat more into the scientific or chemistry and engineering of it. We need to know the relationship between coal characteristics and its behavior to liquefaction. And I might mention already some very interesting things are being found.

For example, it's been discovered that, when solvent-refined coal, which you heard about earlier, is examined, after it's been processed under hydrogen pressures for long periods of time, the darned stuff has less hydrogen in it than there is in coal. So that we have a few dilemmas that we're discovering. It's been discovered that solvent-refined coal goes most of the way to dissolved liquid in the first minute or two, and then you beat it to death for the rest of the time. So that there is a belief that by understanding some of the mechanisms of the chemistry that this will provide the basis for people to have ideas to make significant improvements.

The second part, which is mentioned here, is critical catalytic effects. It is being discovered that the minerals are highly active as far as catalysts are concerned, and therefore I sort of object when this is called a thermal reaction when in fact it's been discovered that the minerals are active. And surely, it's the case that the minerals as found in coal should not be in their best catalytic form, that it ought to be possible to improve this situation by studying this in some detail.

Refining of oil from shale. I have listed here the application of petroleum technology and the search for improved catalysts, so that we begin sort of as a base case and then go on from there.

The next and last group of these major projects, to illustrate some of the interesting things that I think are happening, coal benefication turns out to be a device which is sort of not synthetic fuel, but has great opportunities. And at the Pittsburgh Energy Research Center recently it's been discovered that by a relatively simple process of heating coal under pressure with air and water that all the pyrite can be converted to sulfuric acid, and as much as 40 percent of the organic sulfur also. It's this news about the organic sulfur that's interesting. And so this looks like it might be a way to bring into compliance a very high percentage of eastern coals and is certainly, I think, an exciting possibility.

As far as materials are concerned--

DR. BARON: What is the cost of this?

DR. MILLS: We have an engineering study. It's a good question and obviously must be attractive.

We have two numbers. One is very low, and one is very high. One is $7, and the other is $27 a ton.

Materials research we regard as a very serious part of activities. If the plants don't run because they have difficulties from materials of construction, both alloys and ceramics, obviously, no matter how good the process is, it's not worthwhile. So we have a very substantial program on materials research applicable to coal gasification which we can elaborate on. We have installed a failure-analysis system, so that when failures occur these are looked into systematically. And the question of technology transfer that came up earlier, the information is disseminated in a newsletter which has wide circulation.

We have fireside corrosion activities in three parts: synthetic fuels, fluidized bed combustion, and high-temperature coal. We have a valve program. And just to add one thing about the university community, in addition to the 1000 students and faculty that we now have in active programs, faculty members can go to the energy research centers or other locations during summer months. This is a program similar to the one that AEC in past years practiced, and we have, for example, about 10 faculty members at Pittsburgh, and about the same number at Morgantown and other locations. And I think this is being received on both parts with a good deal of enthusiasm.

I hope I haven't overdone this bit about the projects we have underway. (Slide 10).

Now, I have a couple more things to say. First, I would like to turn to the next vugraph, if I may.

(Slide 11)

Issues. And perhaps this, for some, may be the most important slide, the most important consideration.

As far as criteria are concerned, I think we need to define our objectives more accurately--the objectives, I am saying, of ERDA. What are the objectives? We need to define these much more accurately than we have in the past.

MATERIALS AND EXPLORATORY RESEARCH

RESEARCH MANAGMENT ISSUES

- DEFINE OBJECTIVES
- CRITERIA FOR SELECTION
- SIZE OF BUDGET
- ORGANIZE – CENTRAL/MISSION
- INTERACTION WITH OTHER DIVISIONS/AAS PLANNING/TECHNOLOGY TRANSFER
- IMPROVE QUALITY
- WHERE – ERC/NL/UNIV./IND.
- TRAINING FUNCTION
- FUNDING SECTOR – PRIVATE/GOV'T AGENCIES

The second item there, how do we set criteria for selection of projects. Now every company or research group has that kind of a problem. In general, of course, it ought to fall from the objectives. You make your selection on criteria based on objectives.

I think something surely has to do with the fact that an assessment has to be made of the part that fossil fuels will play in the next 50 years. So that's one basis for considering what the importance of fossil energy activities are, technology and research. So what part will fossil energy play in the next 50, 75 years.

The other is an assessment of what the needs are. Obviously, if the situation is well in hand, that's different from some other kind of activity which is very much undetermined. There needs to be some sort of a priority in balance relative to short, medium, and long range, and I might object, if I may, to one of the early speakers who had a triangle that said we all know that our research must be concentrated on the near term, and if I personally can take issue with that and say he had the triangle inverted, and where the need is in the long-term for fossil energy research, I think the long-term, the long-term being what are we going to do 20 years from now.

So anyway, that's a comment on that.

The question is also, in setting criteria, how much for support and how much for advance. Our division, I might mention, was previously named Advanced Research and Supporting Technology. In some ways I liked that, because it made you think there were two objectives. You must help get the plants, the power plants and the synthetic fuels plants that are being built operating, but then the other part, you must deliberately decide what you are going to do about advanced research. And, of course, there is another concern, as to the split between basic and applied research.

What is it, if it's long-term, or basic, what gets into one particular group? Or is it the fact that the organization should choose one or the other. Well, obviously it's a concern of having both.

Another feature that is of importance in this criteria is quality; the quality of research. Jim Kane mentioned earlier that this was a key issue. I just want to touch briefly on this, and I do have a couple more things.

If I may have that back, please, Gerry. I know you have a piranha pit here.

The size of the budget, whether it's organized all in central or mission-oriented, the interaction with other divisions, the quality I just mentioned, where research should be done, the balance; obviously it's not going to be one or the other. The training function, and the last item there--training of people at universities or other locations, to what degree should that enter into judgment about funding the selection of projects.

And, finally, the question is open. What should the government do, and what is it not proper for the government to do?

The next slide says something about future research, and the question I want to raise is the need for major improvements. Is there a need? And then, can research do it? And the last is, well, okay, if you decide that, what is the strategy?

And I have the next slide.

(Slide 12)

We haven't heard from Chris Knudsen, but I have here some economics that Frank Ferrell and others have listed, and the point is that with the 50,000-barrel-a-day plant, which costs a billion dollars, that using these capital charges plus coal and the operating cost, that the selling price for 10 percent return on investment after taxes, I say its $5 a million Btu or $31 a barrel. And, Dr. Baron, you asked about prices earlier. I'd say I think that you start by saying that if you've got a billion dollars of capital charge, and we heard earlier this puts a burden on some 65 percent of the selling price, now if I have your agreement that it's $31 a barrel for the process of billion-dollar plants, my conclusion is that when these plants are operated, and the public then, the corporations, are then presented with good processes that produce, refined oil, this oil will be priced at now three times what the Arabs are

COAL CONVERSION ECONOMICS

COST *	PLANT SIZE		
	50,000 BPD		100,000 BPD
	$/MILLION BTU	$/BBL	$/BBL
• CAPITAL CHARGES – 16%	1.47	8.8	4.4
• INTEREST (4.5%)			
• DEPRECIATION (5.0%)			
• MAINTENANCE (4.0%)			
• INS. AND TAXES (2.5%)			
• COAL AT $25/TON	1.67	10.0	10.0
• OPERATING COST	0.20	1.2	1.2
• MANUFACTURING COST	3.34	20.0	15.6
• PROFIT 10% ROI AT	1.83	11.0	5.5
SELLING PRICE	5.17	31.0	21.1

*Based on 2.5 BBL Oil/Ton Coal, Net Plant Cost of $1 Billion

TABLE 2.

charging. Everyone is then going to say, "Well, why aren't we doing something about major improvements?"

So, I have a concern that this puts emphasis on new processes.

(Slide 13)

Once we decide we need to do something, the thing is, is it theoretically possible, just like thermodynamics. Can you go to that? And the first equation here says that if coal was reacted with water, you should get methane and CO_2 quantitatively with no energy loss.

And so this is what the research scientists should strive to do. Therefore, it is possible to convert coal to methane, and you should do a trade, an equal trade, with no energy loss.

(Slide 14)

The next slide which we have here says for the liquefaction situation, if you take a coal molecule of bituminous coal and would have a chemical scissors, that ought to be able to cut this apart, and it's not necessary to use, as the Germans did, 10,000 pounds pressure, or we, doing it at several thousand pounds. So it should be possible to accomplish liquefaction selectively.

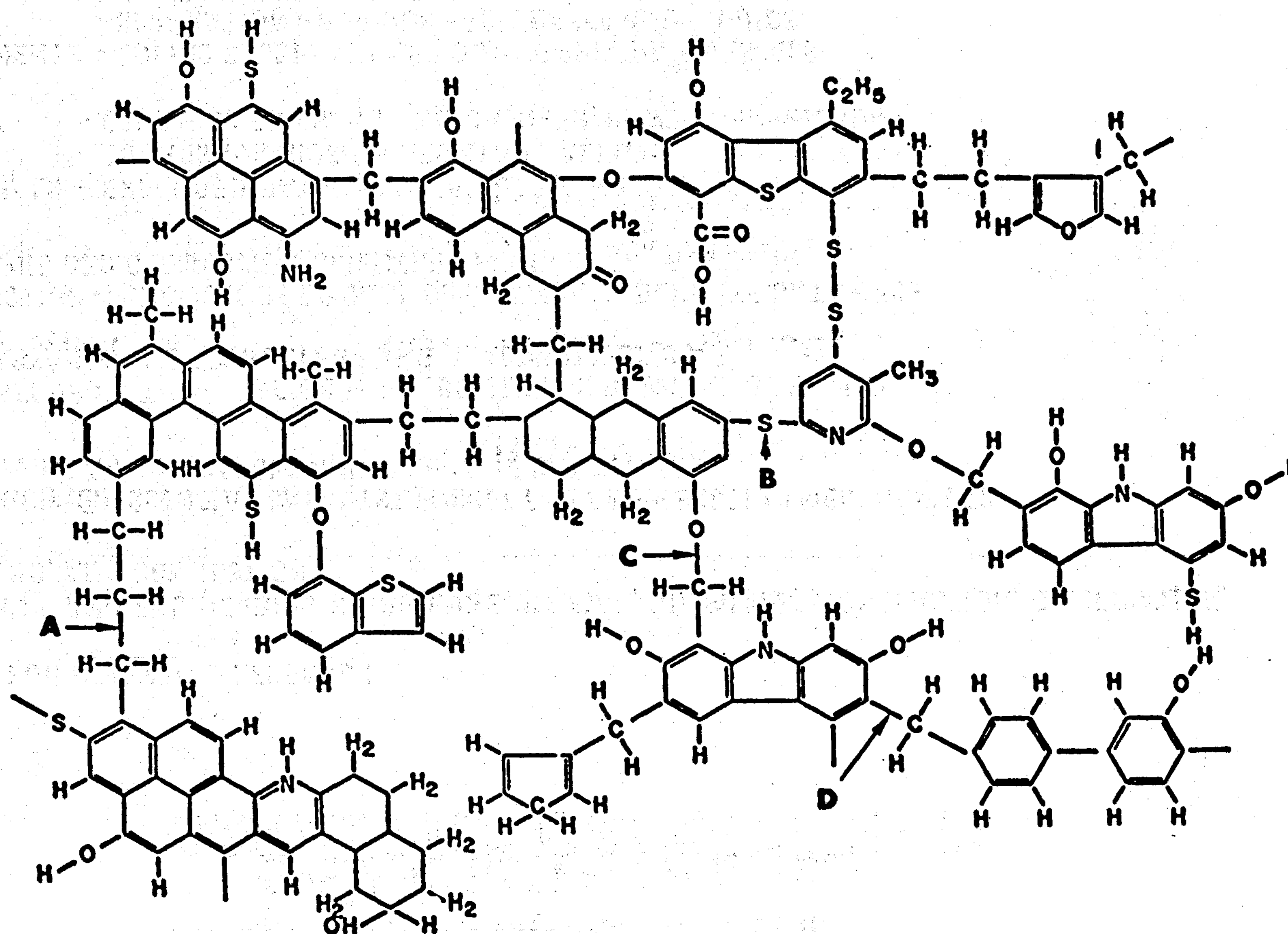
Now, the last slide which--

(Slide 15)

CATALYTIC GASIFICATION

• IDEAL:	$COAL + H_2O \longrightarrow CH_4 + CO_2$	(1)
• GASIFICATION:	$COAL + H_2O \longrightarrow CH_4 + CO_2 + H_2 + CO$ (HIGHLY ENDOTHERMIC)	(2)
• SHIFT:	$CO + H_2O \longrightarrow H_2 + CO_2$	(3)
• METHANATION:	$CO + 3H_2 \longrightarrow CH_4 + H_2O$ (HIGHLY EXOTHERMIC)	(4)

FIGURE 4



MATERIALS AND EXPLORATORY RESEARCH

SPECIFIC RESEARCH NEEDS

- IDEAS FOR INVENTIVE RESEARCH
- CHEMICAL AND ENGINEERING KNOWLEDGE OF COAL, OIL SHALE, LIQUEFACTION, GASIFICATION, REFINING, AND COMBUSTION
- RESEARCH ON ESSENTIAL CATALYST PROPERTIES AND REACTION MECHANISMS TO PROVIDE ACTIVE' STABLE AND SELECTIVE CATALYSTS
- COAL BENEFICIATION – CHEMICAL PROCESSES FOR REMOVAL OF S and N; UNDERSTANDING OF STRUCTURE AND REACTIVITY OF COAL
- COMBUSTION – KNOWLEDGE OF COAL COMBUSTION, ADEQUATE DATA BASE FOR FLUID BED COMBUSTION, SCIENTIFIC FACTS OF SO_2 REMOVAL
- MATERIALS – EXPANDED DATA BASE, FAILURE ANALYSIS
  – CORROSION/EROSION RESISTANT ALLOYS
  – CERAMICS FOR SLAGGING GASIFIER, POWER GENERATION
- COMPONENTS –SOLIDS FEEDING IN AND OUT OF PRESSURE VESSELS
  –SEPARATION OF SOLIDS FROM GASES AND LIQUIDS
  –INSTRUMENTATION OF CRITICAL PROCESS ELEMENTS
- POLLUTION CONTROL IN ALL OF ABOVE

--lists specific research needs. You can read them. I begin by emphasizing that the first need is for ideas for inventive research.

Welcome, Dr. White.

We need--and I'm repeating somewhat--chemical and engineering knowledge of coal. There's a great opportunity for better catalysts. Coal benefication we spoke of before. You've heard something from Steve Freedman about the opportunities in combustion, because after all people decide, you know, not a bad thing to do with coal is to burn it.

Materials, we need to expand our data base, to have improved materials for the known systems, components, and, of course, pollution control in all of the above.

Well, Jerry, I think I could elaborate more. As you realize, I heard the dinger go off a long time ago. So this is the last activity.

(Applause.)

DR. BROWN: Your slide went by too quickly on shale. Can you tell me what dollars those were? Are they '75 or '77 or future dollars?

DR. MILLS: Current dollars.

DR. BROWN: Current dollars.

DR. MILLS: Right.

Do you have a comment about those general prices? This is not a long economic evaluation we'll hear from Chris. I just give the simplistic viewpoint about these numbers.

DR. BARON: I'm a little astonished. Not critical. Just a little surprised. I would have thought more for coal liquefaction, $20-plus, say. And the 30 figure just shocks me a little bit. But I didn't see the breakdown, you know, what you assume for coal prices. It went too fast.

DR. MILLS: This is all equity.

DR. BARON: I certainly will agree with you that coal liquefaction is very much more costly at this point than the imported price of Arab oil or something like that.

DR. MILLS: That's the main point, I think.

Thank you.

DR. HOLLOWAY?

DR. HOLLOWAY: I wonder if you'd put that economic slide (12) back on. I'd like to ask a question or two about it.

The first question, I'll go ahead, you showed two costs, one at 50,000 barrels a day, and the other at 100,000 barrels. And the first one--

DR. MILLS: Can I comment on that? I'm sorry in a sense that I didn't cross off the 100,000 barrels or explain it. This was put on as what I would say a sensitivity analysis. It said if you would take the same plant and be able to put twice as much through it, how would this help you. And the answer is you would go from $31 down to $21 a barrel.

DR. HOLLOWAY: Well, that answers my first question, why capital charges are just half for a plant twice as big. What is this thing called "manufacturing cost" that is separate from operating cost?

DR. MILLS: That's merely a summation, and if you'd had an opportunity to examine the table you'd have realized that the first three are added up to $3.34 per million Btu or $20 per barrel.

DR. HOLLOWAY: I just had one other comment. You compared it with Arab prices. You shouldn't compare it with prices in the Persian Gulf. You should compare it with price delivered to the United States and converted into usable product, comparable to what you get from this.

DR. MILLS: Thank you.

DR. NELSON: Norton Nelson, Institute of Environmental Medicine, New York University Medical Center.

My question is a rather general one, and perhaps is as much to Dr. Kane as to you.

As the descriptions of technology and now just recently discussion of exploratory research proceeds, many issues arise which are obviously health menaces and will require control of various sorts in the plant and operational unit and source of extraction, and, finally, to consumers and to disposal problems. My question comes down to this: What mechanism is there now for following through the identification of decision points as to when health-related research or environmental research needs to be done to determine the acceptability of these various technologies?

Is that done by you? Is it done through Jim Liverman's group? And when finally the decision is made, who monitors it? Where do the funds come from?

DR. KANE: I think I will defer answering that question and let our environmental man, who is on the program later, speak to that one. Is that all right?

DR. NELSON: That's tomorrow.

DR. KANE: Yes. Because I might not be able to answer it well enough if I tried to answer it off the cuff.

DR. NELSON: I would be interested in hearing your point of view.

(Laughter.)

In other words, if you depend fully on them--

DR. KANE: I think that--I'm a proprietor of the basic research business, and my empire is exclusively defined as physical research only. So I am not concerned--the two people that would be concerned are Jim Liverman and the fossil energy people. And so let's have Alex try it first, and then--Jim Liverman is the person who can do it tomorrow.

DR. MILLS: Yes. It's a very pertinent question. First of all, Dr. White has one of the divisions specifically concerned with the environmental factor with Marvin Singer as head, so this focuses attention within fossil energy on the environmental situation. But much further than that, we have for each of the projects, to a greater or less degree, experimentation specifically designed from an environmental viewpoint.

This begins with identification of the products in detail, with special attention to those that are of environmental concern. So that each of the pilot plants, for example, has a portion of the budget and a portion of the activities specifically designed for providing information as to what products are of environmental concern. And, of course, from an overall viewpoint, each of the pilot plants has had to have an environmental impact statement and had to conform with federal laws and the state and local activities.

From a research viewpoint, we are also concerned with the ultimate importance of the environmental factor. For example, we have thought as to the relevance of high-temperature gasification, which doesn't make tars, to lower temperature, which does, as to the ultimate potential for high and low temperature processes.

But I think the main part is that we regard each of the projects as having an environmental component and examining that, and the additional part is that we have close coordination with Liverman's group as to identifying future environmental standards for gasification.

So, that's the view, at least as I see it.

DR. NELSON: What I'm really concerned about, I guess, maybe it will develop during the course of the day and tomorrow, what sort of participatory techniques one has to judge acceptability, at the same time you are judging feasibility. I think, of course, it's important that once a pilot plant is built that it comply with existing standards. But that's not my question. My question was: How do you identify, in effect, acceptability, which in some cases could be a major complement in feasibility.

DR. KANE: I understand your question perfectly, and I think any answer I would be apt to give would be dangerously wrong. I'd prefer to have the pro who is going to talk tomorrow on that precise subject answer the question.

Are there any further questions?

VOICE: From the meetings last week I heard some comments that seemed to imply that refining of shale oils and coal oils were not in the official ERDA mission, and yet this morning I've seen where you have described recently some basic research project in the area of refining.

Could you please clarify for me the official ERDA role in the area of refining of these fuels?

DR. MILLS: It is in the mission. We have projects on coal refining at Universal Oil Products, at Air Products, and Chevron. There is discussion of what we should do and what the petroleum industry should do, so that is a valid activity, and we would like to think that the things that we are supporting have to do with research aspects of unsolved problems.

VOICE: So then, would there be any applied research at the demonstration-plant level?

DR. MILLS: Ultimately, yes, but it's at the research and lab development stage at the present time, plus catalyst work which would have an implication, especially how to keep catalysts active.

DR. KANE: We'll take one more question, and Dr. White is finally here. We will put him on.

Let's take the gentleman there in the gray suit.

DR. KELLER: Bruce Keller of Oak Ridge.

In terms of research now going on, Dr. Mills, and in terms of developing new economic processes, can you look in your crystal ball and say which research areas look like they may improve the economics and give better processes for the future?

DR. MILLS: My salary doesn't provide that.

(Laughter.)

I think that we decide why do these processes cost so much from an investment viewpoint? They are too complex, too high a pressure, too low a throughput, too much hydrogen consumption. So each time we have a new activity, we look at it from the viewpoint, can it simplify the process? Can it have less hydrogen consumption, be more selective? Now obviously the ones that I listed, the catalytic gasification, on the one hand, flash hydropyrolysis, and some of the others, are ones we hope; but the research business, as you know, is that you hope you have ten good candidates and one winner.

DR. KANE: Thank you, Alex.

DR. KANE: I'm delighted to be able to introduce at this time Dr. Phillip White, who is the Assistant Administrator for Fossil Energy, and who is going to discuss the goals and other aspects, as he chooses, of the fossil-energy program.

DR. WHITE: Thank you, Jim.

Let me apologize for arriving at this hour for an 8:30 meeting, but after spending four hours in a hearing under the television lights, it's nice to get in here where it's cool and take off my jacket.

I also want to express my personal welcome, and thank you for your help in tackling this very difficult subject.

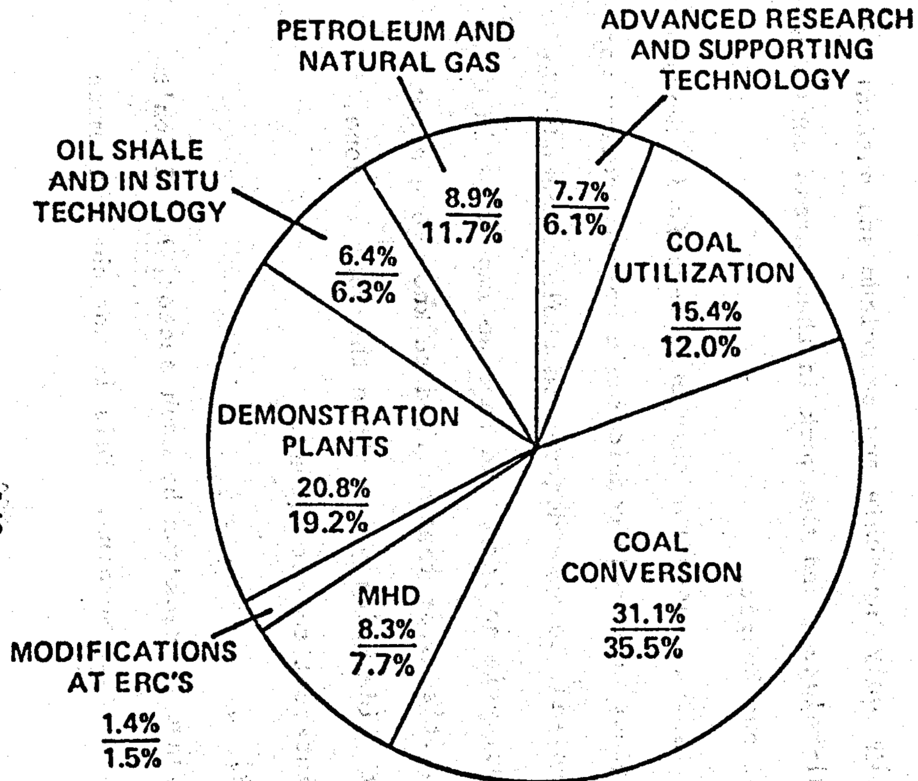
I'm going to run through the same sort of briefing that we've given our budget committees in Congress, which is as good a job as we can do of summarizing our total fossil energy program.

And if we could have the first slide--

(Slide 1)

Here is the distribution of our Fossil Energy pie, which in this Fiscal Year, totaled as you see in the first column on the

FOSSIL ENERGY BUDGET ESTIMATES
DISTRIBUTION OF FUNDS



PERCENTAGE DISTRIBUTION OF FOSSIL ENERGY BUDGET ESTIMATES IN FY 1977 AND FY 1978 SHOWN AS FOLLOWS:

FY 1977%
FY 1978%

BUDGET AUTHORITY
(DOLLARS IN MILLIONS)

	FY 77	FY 78	INCREASE DECREASE
COAL CONVERSION	$150.3	$233.3	$ +83.0
COAL UTILIZATION	74.4	79.1	+ 4.7
ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY	37.1	40.3	+3.2
DEMONSTRATION PLANTS	100.3	125.9	+ 25.6
MAGNETOHYDRODYNAMICS (MHD)	40.0	50.5	+10.5
PETROLEUM AND NATURAL GAS	43.2	76.7	+33.5
OIL SHALE AND IN SITU TECHNOLOGY	31.0	41.5	+10.5
MODIFICATIONS AT ERC'S	6.9	9.6	+2.7
TOTAL	$483.2	$656.9	$+173.7

77-2656M/1-4

left, some 483 million dollars, approved for '78. This does not count some actions by Congress this last week, this 656 million dollars. I think what they did, netted out, we hope, positive, but I am not real sure of that 'till I see all the report language. But it is of that order of magnitude.

Most of those funds are for coal because, of course, the demonstration plants are all, at this point, on coal processing.

Since MHD is also a coal process, in reality well over three-quarters of the work of fossil is directed to coal. In addition much of the advanced research and supporting technology, as previously described by Alex, is coal-related.

So really, only the shale and petroleum and natural gas parts are not coal-related, and the work in these areas constitutes some 20 percent of our budget.

Of course, the reason for this budget-split is twofold. First, it is a reflection of the considerable private sector work done in oil and gas and, to some degree, in shale. Second, our domestic coal resource is so large and thus so important in terms of national interest, it's clear that we need to know more about it.

The next slide which shows where the work is done, is a matter of some interest to this group.

(Slide 2)

--We do have a breakdown by each sector, but I don't have that detail here this morning. This is not changing much.

FOSSIL ENERGY BUDGET ESTIMATES
BREAKDOWN OF FUNDS BY R&D AGENCY
BUDGET AUTHORITY (DOLLARS IN MILLIONS)

	FY 1977	(% OF TOTAL)	FY 1978	(% OF TOTAL)
ENERGY RESEARCH CENTERS	$ 47.0	(9.7)	$ 60.9	(9.3)
NATIONAL LABORATORIES	35.2	(7.3)	34.0	(5.2)
UNIVERSITIES	18.2	(3.8)	26.1	(4.0)
INDUSTRY	375.9	(77.8)	526.3	(80.1)
GENERAL PLANT AND EQUIPMENT, CONSTRUCTION, OSHA AND ENVIRONMENT AT ENERGY RESEARCH CENTERS	6.9	(1.4)	9.6	(1.4)
TOTAL	$483.2		$656.9	

Almost all of this work is done outside with industry, reflecting very large cost-shared contracts with the pilot plants and demonstration plants particularly. But the other, the in-house work, at the energy research centers, accounts for about 50 percent more, almost twice as much a year as the national laboratories. This was, I think, an early figure on national labs. That is likely to change.

The universities, account for about 4 percent in both years. This was our estimate at the time we put the budget together. One of the things we are doing in ERDA Fossil Energy is to try to increase the work done out in the field.

We expect to do a lot more in the field as we go through the rest of the year and FY '78. Therefore, I think these numbers on how much is done in the national labs and energy research centers are quite likely to grow. Now, let's look at some of the details. We'll talk about coal conversion first.

(Slide 3)

Here are three basic subprograms: liquefaction of coal, gasification to produce high Btu or pipeline quality gas, and the gasification to produce low Btu or fuel gas for use in industry, the sort of gas we got out of the old coal town gasifiers many, many years ago.

Funding for each type of gasification is about the same and the total for gasification exceeds that for liquefaction.

COAL CONVERSION
BUDGET AUTHORITY (DOLLARS IN MILLIONS)

	FY 1977	FY 1978	CHANGE (%)
LIQUEFACTION	$73.0	$107.4	+ 47.1
HIGH BTU GASIFICATION	$44.2	$ 51.5	+ 16.5
LOW BTU GASIFICATION	$33.1	$ 74.4	+124.8

1977 ACCOMPLISHMENTS

- H-COAL PILOT PLANT CONSTRUCTION UNDERWAY
- COMPLETE CONSTRUCTION 10 TON PER DAY SYNTHOIL PDU
- SUCCESSFULLY START UP BIGAS, SYNTHANE AND STEAM IRON PILOT PLANTS
- COMPLETE REFIT OF CRESAP TEST FACILITY FOR ADVANCED TECHNOLOGY TESTING

1978 CHANGES

- CONTINUOUS OPERATION OF PRESSURIZED FLUID-BED GASIFIER (Westinghouse)
- MAJOR CONSTRUCTION OF HYDROGEN FROM COAL FACILITY Start
- INITIATE DONOR SOLVENT PROCESS PILOT PLANT DESIGN AND LONG LEAD ITEM PROCUREMENT
- INITIATE PILOT PLANT PHASE OF CATALYZED GASIFICATION PROCESS
- MAJOR CONSTRUCTION OF LOW BTU GASIFICATION COMBINED CYCLE PILOT PLANT (POWERTON)

ISSUES/PROBLEMS

- CONTINUED UTILIZATION OF EXISTING PILOT PLANT FACILITIES
- EXTENT OF FUTURE DEVELOPMENT WORK IN HIGH BTU GASIFICATION

There are some pertinent accomplishments. For example, the H-coal pilot plant is under construction.

H-coal is a process developed by the Hydrocarbon Research Corporation, who teamed up with a number of companies to help support that contract, which is cost-shared with us.

The other pilot plants, which a year ago were in the construction stage, have all started up this last year, Bi-Gas at Homer City, Pennsylvania; Synthane also at Bruceton; and Steam Iron, a process which IGT is developing in Chicago.

We are still struggling to finish retrofitting the Cresap facility for advanced technology testing in liquids.

What do we see for '78? We see a continuation of some of these projects--and the operation of the fluidized bed gasifier, under development at Westinghouse. With respect to the hydrogen-from-coal facility, we will probably choose a contractor shortly. This plant will aim at the production of hydrogen for industrial use.

We expect to start the Donor Solvent process developed by Exxon Company. The pilot plant design and long lead item procurements will certainly take place in '78.

We also expect to build the low Btu gasification plant at Powerton, in Illinois, in which low Btu gas will be fed to a gas/steam combined cycle. This gives promise of an increased efficiency for electricity power generation.

What are our problems? The two listed here probably give us the most concern. One is the utilizing of our existing pilot facility. We've been criticized for having more facilities in parallel than we really need, and spending too much of the taxpayer's money this way. I think it's a somewhat valid criticism, although each of those pilot plants was justified for somewhat different purposes, and at the time seemed to be the correct thing to do.

But as we bring in new processes we want to use the old facilities, shut them down when appropriate and put in something new. It may be just a change of the gasifier, t much of the supporting system can be used and s.ve a great deal of money and a great deal of time.

Then, there is the whole question of how much more ERDA/FE work to do on high Btu gasification. At what point should we say, all right, we now have a process on-line, maybe a commercial plant, demonstrating it can be done? Second generation processes, there are pilot plants being piloted. There is laboratory work on third generation processes. Is it now time to end the Federal Government's role and say, private industry, you take it from here? If there are process improvements to be made by further research, that is your logical job, and you do that. This is a philosophical question which we haven't really resolved.

The other part of the coal program is utilization, as you see in the next slide.

(Slide 4)

Here is a much smaller program. There are two major parts: advanced power systems and direct combustion.

Coal utilization involves hooking up either a gasifier or a fluidized bed combustor to a turbine combination. In either case, the two major problems are (1) the control of the system, because it is a system that has to be very carefully integrated, and (2) the cleanup of the gas after it leaves the gasification or combustion zone, because turbine blades and vanes are very sensitive to corrosion and erosion.

The question then is how far do you clean up the gas and how much can you improve the blade technology in order to make them more resistent? And that is the thrust of the matter.

Now as far as the accomplishments, we did issue a coal-oil slurry PON. This is a sort of quick and dirty way to conserve petroleum by replacing part of it with coal in the form of a coal/oil slurry. The point now is to see if these slurries can be fired in industrial installations with minimal retrofitting and, if so, will they meet air pollution standards.

It is a way to use coal without much retrofitting.

We have awarded a number of contracts for small atmospheric fluidized bed combustors to burn high sulfur coal mixed with limestone so that the sulfur oxides are absorbed in the bed rather than by scrubbing stack gas. Some of these units are available in the

COAL UTILIZATION
BUDGET AUTHORITY (DOLLARS IN MILLIONS)

	FY 1977	FY 1978	CHANGE (%)
ADVANCED POWER SYSTEMS	$22.5	$25.7	+14.2
DIRECT COMBUSTION	$51.9	$53.4	+ 2.9

3×10^3 lbs/hr steam

1977 ACCOMPLISHMENTS

- COMPLETED 1000 HR COMBUSTION TEST OF COAL-OIL SLURRY IN A 100 HP BOILER (PERC)
- MULTIPLE CONTRACTS AWARDED ON INDUSTRIAL AND INSTITUTIONAL APPLICATIONS OF AFB COMBUSTION
- OPEN CYCLE GAS TURBINE EFFORTS UNDERWAY ON VANE AND BLADE COOLING, CERAMIC COMPONENT AND MATERIAL TESTING
- BEGIN OPERATION OF 30 MWe FLUIDIZED-BED BOILER PROJECT IN RIVESVILLE, W. VA.
- MULTIPLE CONTRACTS AWARDED TO DEMONSTRATE COMBUSTION OF COAL-OIL MIXTURES IN EXISTING BOILERS

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1978 CHANGES

deferred until FY 79 ANL

- BEGIN CONSTRUCTION OF ATMOSPHERIC ~~AND PRESSURIZED~~ FLUIDIZED-BED COMBUSTION CTIU
- ~~BEGIN CONSTRUCTION~~ OF THE 13 MWe PRESSURIZED, FLUIDIZED-BED COMBINED CYCLE PILOT PLANT
- FABRICATION OF PROTOTYPE AFB COMBUSTION SYSTEMS FOR INDUSTRIAL APPLICATIONS
- ~~LONG-LEAD PROCUREMENT FOR OPEN CYCLE GAS TURBINE TO PERMIT VERIFICATION TESTING~~

ISSUES/CHANGES

- FEASIBILITY OF COMBINED CYCLE
- FLUIDIZED BED COMBUSTION, STACK GAS SCRUBBING, COAL BENEFICATION TRADE-OFFS

country today, and we're trying to simply push them and demonstrate them because they can be applied to different industries. We have had a number of joint contracts to introduce these.

To get higher thermal efficiency, the temperature at the inlet to the turbine must be raised several hundred degrees. This necessitates developing techniques to cool those blades and vanes. The efficiency of a gas turbine combination is much better if you can raise the temperature. By raising it from 1600 to 2400, one can achieve more efficiency. So, there is a good deal of work going on, and much of that advanced power system budget for '78 is going to be devoted to that sort of work on turbines.

We have a big fluidized bed unit in Rivesville operating in an actual utility. We have not only that test we mentioned in the first line, but a number of awards on coal-oil mixtures in existing boilers.

We plan next year to build what we call a CTIU, a component test and integration unit, designed to be able to change things back and forth, to be the sort of workhouse for developing both pressurized and atmospheric fluidized bed work. One of these will be at the atmospheric one at Morgantown, and the other will be a pressurized one at Argonne.

Flexibility must be built into a study of atmospheric fluidized bed combustion. Flexibility was the main thrust behind creation of CTIU at Argonne. A similar kind of work for pressurized fluidized bed combustion is ongoing at combustion engineering in Windsor, Connecticut. And we're doing the same thing on taking data on the small fluidized bed as I mentioned for this year. Next year we hope to actually start some fabrication of a full, larger sized fluidized bed combustion system, and even the long lead procurements of a prototype turbine.

An issue in this case is the feasibility of this combined cycle. The combined cycle is not being practiced on coal today anywhere in the world except London and Germany, and that one doesn't work very well.

There is a real problem of feasibility. There's also the question of where do you clean up sulphur? If you clean the coal, do you use a fluidized bed or do you put it on a scrubber? That's the last line there. And this problem is complicated by the fact that we are working on fluidized beds; EPA has stack gas scrubbing, and the Bureau of Mines has coal cleaning. Maybe if we got a Department of Energy starting next week, or the week after, we could quickly resolve that ambiguity.

Advanced research and supporting technology is the next slide--

(Slide 5)

ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY
MATERIALS AND EXPLORATORY RESEARCH
BUDGET AUTHORITY (DOLLARS IN MILLIONS)

FY 1977	FY 1978	CHANGES (%)
$29.3	$31.9	+8.9

1977 ACCOMPLISHMENTS

- DEVELOPED SIGNIFICANTLY LOWER COST, ENVIRONMENTALLY ACCEPTABLE PROCESS TO MAKE GASOLINE FROM COAL
- COMPLETED PROCESS RESEARCH ON NOVEL, SIGNIFICANTLY CHEAPER CATALYTIC COAL GASIFICATION PROCESS
- CORROSION STUDY ON CONSTRUCTION ALLOYS UNDER COAL GASIFICATION CONDITIONS
- MADE SIGNIFICANT PROGRESS IN DETERMINING RELIABLE MATERIALS AND VALVES FOR COAL CONVERSION PLANTS
- INITIATED STARTER GRANT PROGRAM TO STIMULATE FOSSIL ENERGY RESEARCH AT UNIVERSITIES

1978 CHANGES

- NEW EMPHASIS ON EXPLORATORY RESEARCH TO REDUCE COST OF PRODUCING SYNTHETIC FUELS FROM COAL
- COMPLETE LAB DEVELOPMENT OF PROMISING PROCESSES FOR SCALE UP OF FOSSIL TECHNOLOGIES

ISSUES/PROBLEMS

- RELIABLE MATERIALS AND COMPONENTS FOR COAL CONVERSION
- ACHIEVEMENT OF MAJOR PROCESS IMPROVEMENTS

--The budget here is about $31 million for '78, not enough to keep pace with inflation. We are trying to get them a little more money, and I think we'll make it go. I think he's probably covered that pretty well because it is really a subject of this meeting. I don't think it is necessary for me to spend any more time on it other than to give a picture of where it is in the total size of the budget.

The next one--

(Slide 6)

--is quite the contrary, a much bigger one. We have demonstration plants. And here we've had a sort of a rough go in trying to get going on this whole area. We started with a clean boiler fuel plant. This year we took another look at it, and decided there were some pretty serious weaknesses in the basic data, and we essentially stopped work on that plant except for small-scale studies. But there is no work now other than paper studies on the building of a demonstration plant for the so-called Coalcon project.

We did, however, sign the contracts just the other day on the synthetic pipeline gas demonstration plants, two of them. One with Conoco and the other with the Illinois group. We have two others under negotiation for a fuel (low Btu) gas, and we're starting much smaller ones on an intermediate level. We're aiming to have a spectrum of plant sizes for fuel gas demonstrations and applications.

DEMONSTRATION PLANTS
BUDGET AUTHORITY (DOLLARS IN MILLIONS)

	FY 1977	FY 1978	CHANGE (%)
OPERATING EXPENSES	$53.0	$50.9	− 4.0
PLANT AND CAPITAL EQUIPMENT	47.3	75.0	+ 58.6
	$100.3	$125.9	+ 25.5

1977 ACCOMPLISHMENTS

- RE-EVALUATED CLEAN BOILER FUEL PROGRAM
- INITIATED CONCEPTUAL DESIGN OF HIGH-BTU SYNTHETIC PIPELINE GAS DEMONSTRATION PLANT
- INITIATED CONCEPTUAL DESIGN OF INDUSTRIAL LOW-BTU FUEL GAS DEMONSTRATION PLANT
- INITIATED CONCEPTUAL DESIGNS FOR SMALL INDUSTRIAL LOW-BTU FUEL GAS DEMONSTRATION PLANT

1978 CHANGES

- BEGIN CONSTRUCTION OF HIGH-BTU SYNTHETIC PIPELINE GAS DEMONSTRATION PLANT AND LOW-BTU FUEL GAS DEMONSTRATION PLANT
- START DESIGN FOR DIRECT COMBUSTION DEMONSTRATION PLANT
- START DESIGN FOR SOLVENT REFINED COAL DEMONSTRATION PLANT

ISSUES/PROBLEMS

- COST SHARING FOR MAXIMUM INDUSTRY PARTICIPATION
- OPTIMUM PROJECT MIX TO MAXIMIZE PROGRAM BENEFITS
- RELATIONSHIP TO ALTERNATIVE FUELS DEMONSTRATION PROGRAM

In '78 we'll certainly begin the first stages of construction on both these plants, and we will start design on a demonstration plant for the fluidized bed direct combustion and, we hope, on solvent refined coal.

I didn't mention, liquefaction. We have a major pilot plant on solvent refined coal at Takoma, Washington, which has run for several years. Last year we made 3000 tons of solvent refined coal. And just a couple of weeks ago, we started burning it in a utility in Albany, Georgia, which I am happy to say, provides the power for Plains. It is working beautifully. This is the first time we've taken a solvent refined coal, which is like coal except it is very firable. It melts at about 400°F--it gets very sticky. It has very little sulfur, very little ash, so, it is nice if it will burn right, but it is a problem of how you handle it, and we seem to be able to handle it.

Magnetohydrodynamics, the next slide--

(Slide 7)

We see three competing ways to burn coal for power generation with improved efficiency. I previously mentioned advanced power systems. MHD is another advanced power system. Here one takes coal, burns it at a very high temperature; passes it through a channel which has electrodes under a very high magnetic field; and uses potassium carbonate seed to raise the electrical conductivity. The high velocity conducting gas passing through the magnetic field

MAGNETOHYDRODYNAMICS (MHD)
BUDGET AUTHORITY (DOLLARS IN MILLIONS)

FY 1977	FY 1978	CHANGES (%)
$40.0	$50.5	+26.2

1977 ACCOMPLISHMENTS

- INITIATED CONSTRUCTION OF CDIF TEST BUILDING
- INITIATED DEVELOPMENT OF FIRST CDIF GENERATOR CHANNEL
- DELIVERED BY-PASS SUPERCONDUCTING MAGNET FOR SOVIET U-25 FACILITY
- INITIATED MHD SUPERCONDUCTING MAGNET FOR CDIF
- INITIATED ETF SYSTEMS ENGINEERING AND CONCEPTUAL DESIGN

1978 CHANGES

- INITIATE DEVELOPMENT OF 2ND CDIF POWER TRAIN
- INITIATE HIGH PERFORMANCE GENERATOR CHANNEL TESTING AT AEDC
- INCREASE SYSTEMS AND DESIGN ANALYSIS TO SUPPORT AND GUIDE COMPONENTS DEVELOPMENT AND INTEGRATION
- DELIVER MHD GENERATOR FOR TESTING IN SOVIET U-25 FACILITY

ISSUES/PROBLEMS

- COMBUSTOR AND CHANNEL PERFORMANCE
- SEED/SLAG MANAGEMENT

surrounding part of the channel produces a current in the electrodes. The overall efficiency will probably be somewhat over 50 percent with a possibility of attaining 60 percent.

The Russians are doing a lot of MHD work. You may have seen an announcement in the paper in the last few days about our shipping them a super-conducting magnet. That magnet was just flown to Moscow in the first C5A ever to go to Moscow. It refueled in the air twice on the way over. That made a great story, and we hope that our joint project produced some useful results.

We have started to build the buildings at Butte, Montana, on this and we're building a generator channel for it. We see all this coming along next year in a program which I believe Congress has now raised, and it's for '78, from 50 million up to about 65 or 70, if my advanced information is correct.

There is a lot of MHD work going on in a number of places, not only at Butte, but also at Avco Laboratories at Everett, Massachusetts, at the University of Tennessee, and Stanford, and elsewhere around the country. Eventually, we'll not only have that channel, that magnet over in Moscow but also a generator working on a slip stream of the U25 magnet.

The problems here are still very much technical ones. MHD is a very tough technology to develop, requiring very high temperatures. Materials problems are troublesome. Other difficulties include air preheating; seed recovery/regeneration developing optimum combustion to minimize nitrogen oxides, and components problems.

The Soviets were delighted when they got the channel to run for 250 hours; but in the case of a utility, that is not very long. One must recover the seed and recycle it out of the slag if there is going to be success.

Petroleum and natural gas--the next slide--

(Slide 8)

--is about a $75 million program, as we saw earlier. Here we work almost entirely in the oil side of what we refer to as enhanced oil recovery, getting at the oil which is left in the ground by conventional production and water flooding through one of three major techniques--warming it up, either with fire or with steam; lowering its viscosity with carbon dioxide, and finally, washing it out with a detergent just like you wash a dirty greasy spot out of clothes.

Managing this 5,000 or 10,000 feet underground though, is a little tricky, and we have a lot of pilot tests going on with industry. The number is steadily increasing; and just yesterday we talked about adding another one.

We have had some criticism from the Office of Management and Budget on this because of the large private sector activity in this area. Sometimes we've gotten into these programs, we just sort

PETROLEUM AND NATURAL GAS
BUDGET AUTHORITY (DOLLARS IN MILLIONS)

FY 1977	FY 1978	CHANGE (%)
$43.2	$76.7	+77.5

1977 ACCOMPLISHMENTS

- INITIATED THREE COST-SHARED FIELD TESTS FOR ENHANCED OIL RECOVERY
- DETERMINED CHEMICAL SUPPLY AND DEMAND FOR MICELLAR-POLYMER AND CO_2 PROCESSES
- COMPLETED PROJECT PLAN FOR CHARACTERIZATION AND STIMULATION OF EASTERN GAS SHALE (DEVONIAN SHALE PROJECT)
- INITIATED TWO PROJECTS TO INCREASE DRILLING SPEED AND REDUCE DOWN TIME
- IMPLEMENTED IMPROVED MANAGEMENT PLAN FOR ENHANCED OIL RECOVERY
- COMPLETED PROJECT PLAN FOR CHARACTERIZATION AND STIMULATION OF WESTERN TIGHT GAS SANDS

1978 CHANGES

- PILOT TESTING TO DETERMINE ECONOMICS OF MICELLAR-POLYMER PROCESS
- EMPHASIZE STEAM FLOODING EXPERIMENTS AT VARIOUS LOCATIONS
- NEW START, IN THERMAL RECOVERY OF OIL - TECHNOLOGY EMPHASIZED IN MANAGEMENT PLAN
- IMPLEMENT IMPROVED MANAGEMENT PLAN FOR ENHANCED GAS RECOVERY
- ACCELERATE EASTERN GAS (DEVONIAN) SHALE PROJECT

ISSUES/PROBLEMS

- KNOWLEDGE BASE VS IMPLEMENTATION FOR ENHANCED OIL RECOVERY
- DEVELOPING VIABLE TECHNOLOGY FOR ENHANCED GAS RECOVERY

of respond to targets of opportunity. Some company makes a proposal, and if we think it looks good, we go ahead.

OMB asked us if we had a systematic plan. For the first time, we sat down and tried to work out exactly what the total program should be, and just what types of formations should be tested, and how many tests should be involved. That is what we did last year. We found all of us more comfortable with a whole program and now we have that in-house, now we're doing the same thing for gas.

In the case of gas, we're looking at not what is left in the ground, but at some gas reserves that normally aren't considered gas reserves when one hears about 10 years or 20 years of natural gas. In that case they're talking about conventional gas that flows out by itself. But in the Devonian shale, the western tight sands of the Mesa Verde formation in Colorado, and in the coal seams in the East, there is a lot of natural gas. It has usually just been stripped out and wasted for a safety measure, and now we're going after it as a resource. Using those unconventional resources gives us about 50 years of gas, and if you believe Wall Street Journal headlines about 1000 years of gas. There's only one place that could be, and that is in that geopressured zone in the Gulf where there is a lot of salty water saturated with methane. Maybe it is there and maybe we can get it out. We don't know what it will cost, but it potentially could be a very large resource of great importance.

So we are working on that.

I think you probably had a chance to read what we did pretty much as far as nominal improvements. We are doing a little bit of drilling research here as well, trying to improve drilling speed, and reduce some of the instrumentation to reduce the so-called down-hole time. Some of this work is cooperative with industry and some is work leaning very heavily on Sandia and other national labs where there is this type of technology developed as an offshoot of the nuclear program and its need to drill for nuclear shots in Nevada. For that reason, they have developed a lot of drilling technology.

We expect to just continue much the same way for '78. We are particularly pointing at that last bullet under '78, the acceleration of Eastern gas, where we are trying to beef up testing of Devonian Shale. The wells are shallow, and not very productive, but there are a lot of them. We think if we can find a way to fracture them, and if we can improve their productivity, they can be valuable. They have the attraction of being close to the market in the East where we need the gas.

Our problems here are the knowledge base and implementation. We don't have good resource data for gas, and for oil, we need to increase our general knowledge of that field.

Another one in this same division is--on the slide--

(Slide 9)

--the oil shale and the underground coal gasification. These two may not seem to fit together, but in oil shale we're working exclusively on what is referred to as in situ retorting, where we retort underground rather than mining of shale, bringing it up and retorting it. And because they both involve the same sort of technology, we've handled them in the same organization. But it's a rather modest area. They are increasing significantly for next year, but are still, a minor part of the program.

We have had a number of contracts under negotiation now for in situ retorting of shale--shared contracts with industry. For the first time we completed a test at Rock Springs, Wyoming of what we call true in situ. We didn't do any mining. We just stuck a shaft down, set in some explosives, did some rubblizing that way and then set off a fire, and collected oil out of an adjacent well. It worked, but not very well.

The Antrim shale in Michigan is a different sort of project. Here's an odd type of shale, which doesn't produce oil, but which we can gasify. Dow Chemical has done a lot of work in this field. We have now joined them to try to improve that technology.

Moving to in situ coal gasification to the so-called linked-vertical well, in which several wells are first linked by combustion and then by gasification. We burn some of the coal with a lot of

OIL SHALE AND IN SITU TECHNOLOGY
BUDGET AUTHORITY (DOLLARS IN MILLIONS)

	FY 1977	FY 1978	CHANGES (%)
OIL SHALE	$22.8	$28.9	26.8
IN SITU COAL GASIFICATION	$ 8.2	$12.6	53.7

1977 ACCOMPLISHMENTS

- COMPLETED COST-SHARING CONTRACTS FOR SEVERAL IN SITU RETORTING EXPERIMENTS
- COMPLETED DIRECT-COMBUSTION SHALE-OIL PRODUCTION TEST AT ROCK SPRINGS, WYOMING
- INITIATED MICHIGAN ANTRIM SHALE GASIFICATION PROJECT
- COMPLETED LINKED VERTICAL-WELLS PROCESS (LVW) TEST
- INITIATED FIELD GASIFICATION TESTS ON PACKED-BED PROCESS
- STARTED FIELDING FIRST COMBUSTION TEST ON DIRECTIONAL WELLS
- DESIGNED STEEPLY-DIPPING-BED (SDB) PROJECT WITH INDUSTRY

1978 CHANGES

- COMPLETE DESIGN OF A MULTI-TON OIL SHALE GASIFICATION FACILITY
- BEGIN HANNA IV LVW FIELD TEST
- CONDUCT THE FIRST STEAM/OXYGEN IN SITU GASIFICATION TEST AT HOE CREEK 2
- START SDB FIELD TEST PROGRAM

ISSUES/PROBLEMS

- ENVIRONMENTAL IMPACTS AND ACCEPTABILITY
- FUTURE OF IN SITU VS ABOVE GROUND SHALE OIL PRODUCTION
- DEVELOPING ACCEPTABLE ECONOMIC INCENTIVES FOR OIL SHALE
- MARKETS FOR IN SITU COAL GASIFICATION PRODUCTS

steam present and have a typical water gasification reaction of that coal and can take a good 175 Btu gas out of the other wells. We did this in Wyoming very successfully last year producing a good quality gas, a very even composition, which is one of the tricks.

We have some other approaches to drilling the wells and to fitting other formations a little better, and that is one of the things we hope to look at, including steeply dipping beds. We expect to keep on doing this same sort of thing next year.

Now both of these projects have tricky environmental problems, which we are trying to address. We know that they are potentially there, but in cases like this where you've got to do the work in the field, there's no way to know the extent of the problem, until you get out there and try it.

Groundwater is one problem. If there are underground aquifers, you retort the shale which is leachable, and that leaching can get into the aquifer.

If you do either of these, and a lot of it, you obviously have a subsidence problem, and the ground level begins to drop above your retorted formation, and that is not acceptable in most locations. How bad is it? What we can do to control it? These are the things we still have to learn. I'm sure in the discussions this afternoon and tomorrow, we'll have a chance to explore what some of those areas are.

This gives you a sort of general picture of the total program; where the emphases are; and some problems, as I see them. I'm not sure I could answer that question that Alex said he didn't get a high enough salary to answer and I guess I don't either, but I might offer -- toss in a few things as we get through.

Thank you very much.

(Applause).

DR. KANE: He has a car waiting, but he will answer a few questions.

MR. LODEL: In the demonstration plants program ERDA had been considering three categories for low Btu fuel gas. The industrial category, I believe, is going ahead. I wasn't able to sort out from your plans whether in fact you plan to go ahead with the utility category?

DR. WHITE: I'm waiting until I get the language of the conference report on the appropriations to be able to answer that question. I asked it myself yesterday, and I couldn't get an answer. I think we have -- I know we have authorization, maybe we've got money, but maybe we've got language that says, don't do it, or maybe we've got language that says, do it. I don't know. It is just hanging in that balance right now. And if we are told not to do it, we will have to drop that project. It is too early to answer, I'm sorry. Within a few days, we should know. I just haven't been informed.

DR. KANE: Thank you very much, Bill.

DR. WHITE: Okay. I'll be back right after lunch.

DR. KANE: Very good. He's been on the grill since 7:00 this morning, enjoy your lunch.

DR. KANE: I've decided to, with your forbearance, juggle the program one more time. And we have another gentleman here who is going to talk to you about synthetic fuel pricing. He, too, has been on the grill for a long time this morning, and he'd like to get out of here so, I think I'll impose on you, and we'll have a talk now by Chris Knudsen.

DR. KNUDSEN: Thank you very much.

I have been asked to talk about the cost of various processes that we are doing research and development on in ERDA. Copies of my slides are here on the table.

I'll try to make this a short talk so that you can get on with your luncheon plans.

My wife has been with me all morning, and I asked permission to go ahead and give it now because she has been sweating it out with me, and I promised to take her to lunch and that's the most important thing to me at this moment.

(Laughter.)

(Slide 1)

I want to begin with several slides about the methods used in cost estimating. The first slide illustrates different types of cost estimates of differing accuracies. Many people compare one estimate with another of differing quality, a back of the envelope estimate with one from a detailed study, and sometimes draw conclusions from this. We try not to, because an estimate is a function

CURRENT AFE ECONOMIC ESTIMATES

PROCESS COST ESTIMATES

HARDWARE DEVELOPMENT LEVEL	ORDER OF MAGNITUDE ($\$2\text{-}5 \times 10^3$)	STUDY ($\$2\text{-}5 \times 10^4$)	PRELIMINARY ($\$2\text{-}5 \times 10^5$)	DEFINITIVE ($\$2\text{-}5 \times 10^6$)	DETAILED ($\$20\text{-}50 \times 10^6$)
LABORATORY (BENCH)	MORTGAGE MODEL	USBM PEG			
PDU	MORTGAGE MODEL	USBM PEG KELLOGG	ORNL FLUOR PARSONS BRAUN		COALCON
PILOT	MORTGAGE MODEL	USBM PEG	ORNL BRAUN PARSONS AMOCO	BADGER	CONOCO ICGG
DEMON-STRATION	MORTGAGE MODEL				
COMMER-CIAL			BRAUN	SASOL	

175-1

of both the engineering effort that is put into it, and the data available.

Hardware development level is indicated vertically on the slide. As shown, data quality ranges between laboratory and commercial. Horizontally, the cost levels of various types of estimates are indicated by order of magnitude. For example, a study design might cost $20,000 to $50,000 of engineering effort, a preliminary study $200,000 to $500,000, a definitive study $2 to $5 million, and a detailed study $20 to $50 million. The detailed study is the type of estimate needed for actual construction of a project where detailed mechanical drawings are needed.

The order of magnitude type of estimate or "Mortgage Model" has been developed within ERDA based on past information. We have made correlations of gasification, liquefaction, enhanced oil recovery and other processes based on R&D experience. These correlations allow us to make a crude estimate of the cost of a proposed process development unit (PDU) or pilot plant.

(Slide 2)

Let me define the differences between three types of cost estimates on the last slide: the preliminary, definitive, and detailed cost estimates. The first thing that is done in any cost estimate, of course, is the design basis. All three estimate types require the same type of design basis information, with the exception that the site specification for the three differs. For example, a

DESIGN BASIS

PRELIMINARY ($0.2-0.5 X 10^6)	DEFINITIVE ($2-5 X 10^6)	DETAILED ($20-50 X 10^6)
• PRODUCT SPECS	• DO	• DO
• FEED SPECS	• DO	• DO
• DESIGN ASSUMPTIONS	• DO	• DO
• PROCESS DESCRIPTION	• DO	• DO
• UTILITY SPECS	• DO	• DO
• GENERAL SITE	• HYPOTHETICAL SITE	• ACTUAL SITE

176-1

detailed design, including detailed mechanical drawings, requires specification of an actual site with core drillings to determine foundation design.

(Slide 3)

The next phase of a process estimate is the design itself. Differences in estimate accuracy are most obvious from consideration of the varying efforts expanded in this step.

In a preliminary design, the effort ends with an equipment list, but in a definitive design, piping and instrumentation specifications are prepared. This additional information requires a great deal more engineering effort to develop. A detailed estimate includes the latter plus detailed engineering drawings and plans which may require hundreds of thousands on man-hours. Process plants contain piping and instrumentation that may represent 40 percent of the capital investment, so that preparation of P&I diagrams, for example, significantly improves estimate accuracy.

(Slide 4)

The last step is the estimate itself, process economics. For preliminary estimates, cost curves, experience factors, and rules of thumb are used; whereas for a definitive estimate, a more detailed estimating procedure is required. Vendor quotes, specific cost indexes, and projected financial conditions are appropriate. For a detailed study, one seeks vendor bids, finances under actual conditions, and look into actual labor and productivity.

PROCESS DESIGN

PRELIMINARY ($0.2-0.5 $\times 10^6$)	DEFINITIVE ($2-5 $\times 10^6$)	DETAILED ($20-50 $\times 10^6$)
• FLOW DIAGRAM	• DO	• DO
• MATERIAL BALANCE	• DO	• DO
• ENERGY BALANCE	• DO	• DO
• OPERATING CONDITIONS	• DO	• DO
• PLOT PLAN	• DO	• DO
• ENVIRONMENTAL ASSESSMENT	• DO	• ENVIRONMENTAL IMPACT STATEMENT
• MAJOR EQUIPMENT SIZED	• ALL EQUIPMENT SIZED	• DO
• EQUIPMENT LIST	• EQUIPMENT LIST AND DETAILED SPECS	• DO
	• P AND I DIAGRAMS	• DO
	• PIPING SPECS	• DO
	• PROCESS RELATED STRUCTURAL SPECS	• COMPLETE STRUCTURAL DRAWINGS
		• DETAILED ENGINEERING DRAWINGS
		• PLANT ELEVATION DRAWINGS
		• PROCUREMENT AND CONSTRUCTION PLAN

PROCESS ECONOMICS

177-2

PRELIMINARY ($0.2-0.5 × 10^6)

- COST CURVES
- EXPERIENCE FACTORS
- RULES OF THUMB
- GENERAL COST INDEXES
- ASSUMED FINANCIAL CONDITIONS

DEFINITIVE ($2-5 × 10^6)

- DO
- VENDOR QUOTES ON MAJOR ITEMS
- EXPERIENCE FACTORS BASED ON MORE DETAILED DRAWINGS
- SPECIFIC COST INDEXES
- PROJECTED FINANCIAL CONDITIONS

DETAILED ($20-50 × 10^6)

- VENDOR BIDS
- ACTUAL LABOR COSTS AND PRODUCTIVITY
- DETAILED ENGINEERING EVALUATION
- FINANCING UNDER ACTUAL CONDITIONS

A vendor bid is usually much more accurate than a quote and may require payment for the engineering time required to make it.

Actual labor costs and productivity are extremely important factors which are generally overlooked. The availability of skilled craftsmen and union rules vary in different parts of the country and have a large effect on the final cost of a plant.

Project contingencies and process contingencies can be assigned to account for the inaccuracies brought about by the estimating process and the uncertainty of the available data, respectively - the horizontal and vertical categories of the first slide. These contingencies require analysis of past estimating experience to determine and we have visited companies like Exxon, Gulf, and Mobil to begin developing them. Our figures are therefore a reflection of what we have learned because we are not a large construction or operating company. We are a small branch in the government, and we are relying on available industrial information.

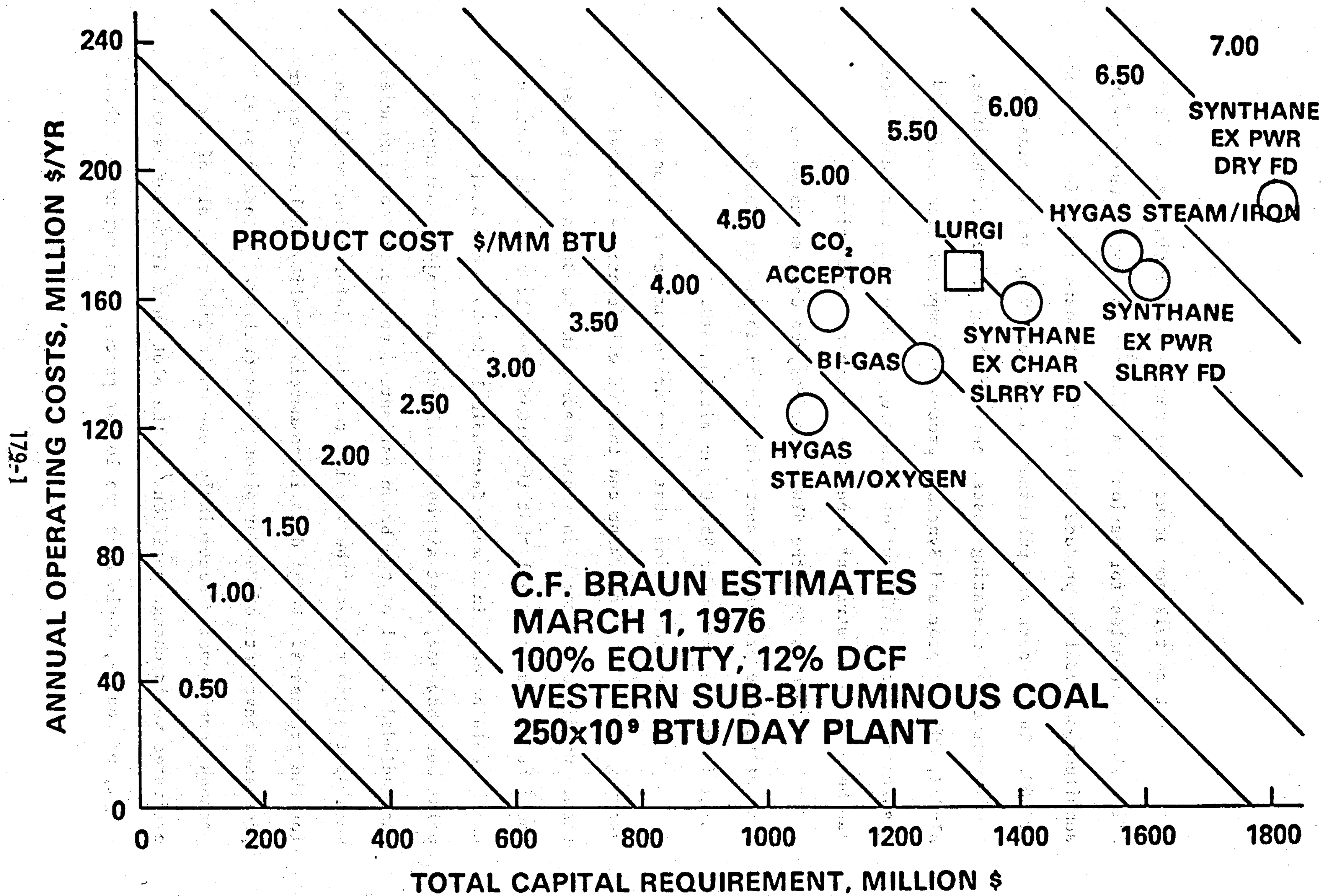
The project contingency one might assign to a study estimate would be typically greater than 20 percent. At the preliminary estimate level, a 15 to 20 percent. At the preliminary estimate level, a 15 to 20 percent project contingency might be appropriate. For the definitive estimate level, a 10 to 15 percent project contingency is indicated. Finally, for the detailed type of estimate, a 10 percent contingency would be appropriate.

Note that the project contingency reflects only the uncertainty of constructing a given design for a given cost and in effect assumes known technology. Therefore, even for a detailed estimate late in the actual construction period the project contingency is still typically about five percent to account for the bills yet to arrive, labor and material problems in completing construction, and possible start-up problems.

Turning to the process contingency, some experience indicates that an estimate based on laboratory data requires a contingency of approximately 100 percent to account for additional equipment later found to be necessary during the PDU, pilot plant and demonstration development stages leading to commercialization. Perhaps a 25 to 50 percent contingency is appropriate for the PDU stage, only a 15 to 25 percent contingency at the pilot plant stage, about 10 to 15 percent at the demonstration stage, and as little as 5 percent at the commercial state.

Application of the contingencies is made as follows. The process contingency is added as a percentage on the on-site process equipment, whereas the project contingency is applied to total investment, including off-sites and the process contingency. I would caution that these types of add-on contingencies should be used with care, as they are meant for guidance.

(Slide 5)


PRODUCT COST $/MM BTU
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00
6.50
7.00
SYNTHANE EX PWR DRY FD
HYGAS STEAM/IRON
LURGI
CO_2 ACCEPTOR
BI-GAS
SYNTHANE EX CHAR SLRRY FD
SYNTHANE EX PWR SLRRY FD
HYGAS STEAM/OXYGEN
C.F. BRAUN ESTIMATES
MARCH 1, 1976
100% EQUITY, 12% DCF
WESTERN SUB-BITUMINOUS COAL
250×10^9 BTU/DAY PLANT
ANNUAL OPERATING COSTS, MILLION $/YR
TOTAL CAPITAL REQUIREMENT, MILLION $
0
40
80
120
160
200
240
0
200
400
600
800
1000
1200
1400
1600
1800
179-1

Let me talk now about some recent cost estimates. This slide shows estimates for various gasification processes using western subbituminous coal to produce 250 million standard cubic feet per day of SNG. This report was published in October 1976, and it examines the investments, operating costs, and resulting prices of the HYGAS, BI-GAS, CO_2 Acceptor and Synthane processes compared with similar figures for Lurgi gasification technology. Note that constant prices can be plotted as straight lines to a close approximation.

One sees that the HYGAS steam-oxygen case seems to be the most attractive process at approximately \$4.25 per million BTU. Lurgi is plotted at about \$5.50 per million BTU.

I want to caution that these are estimates of process at varying levels of development and that we will continue to review them. Conditions other than those assumed in the Braun study affect the results and some feel that the HYGAS Steam/Iron and the Synthane cases could be cast in a more favorable light by a new basis. Let me point out, however, that although a 15 percent project contingency was included in all of the Braun estimates, no process contingencies were applied to reflect the varying technical information available for the processes. Lurgi data is commercial quality while the other processes have data of PDU or pilot plant quality. If one applies process contingencies accordingly, one would find that all of the estimates would change positions on the plot in a different manner. Lurgi, of course, would have the lowest process contingency of about five percent. As a result of this, new plot would show much less price advantage for the newer processes compared with Lurgi.

We do not have a comparable plot for coal liquefaction at this time, although we have made comparisons between the H-Coal, Exxon Donor Solvent and Solvent Refined Coal processes. A common accounting basis was used - the same discounted cash flow rate, depreciation rate, and so forth - but large differences still remain that are a function of the investment. We realize that this is the result of having different firms produce the basic designs. We are now planning to visit Sterns Roger, Fluor, and Exxon, to attempt to resolve differences in design methods and to put the investments on a more consistent basis.

Until we have confidence that the engineering procedures are on a consistent basis, we can't make a comparison of the processes.

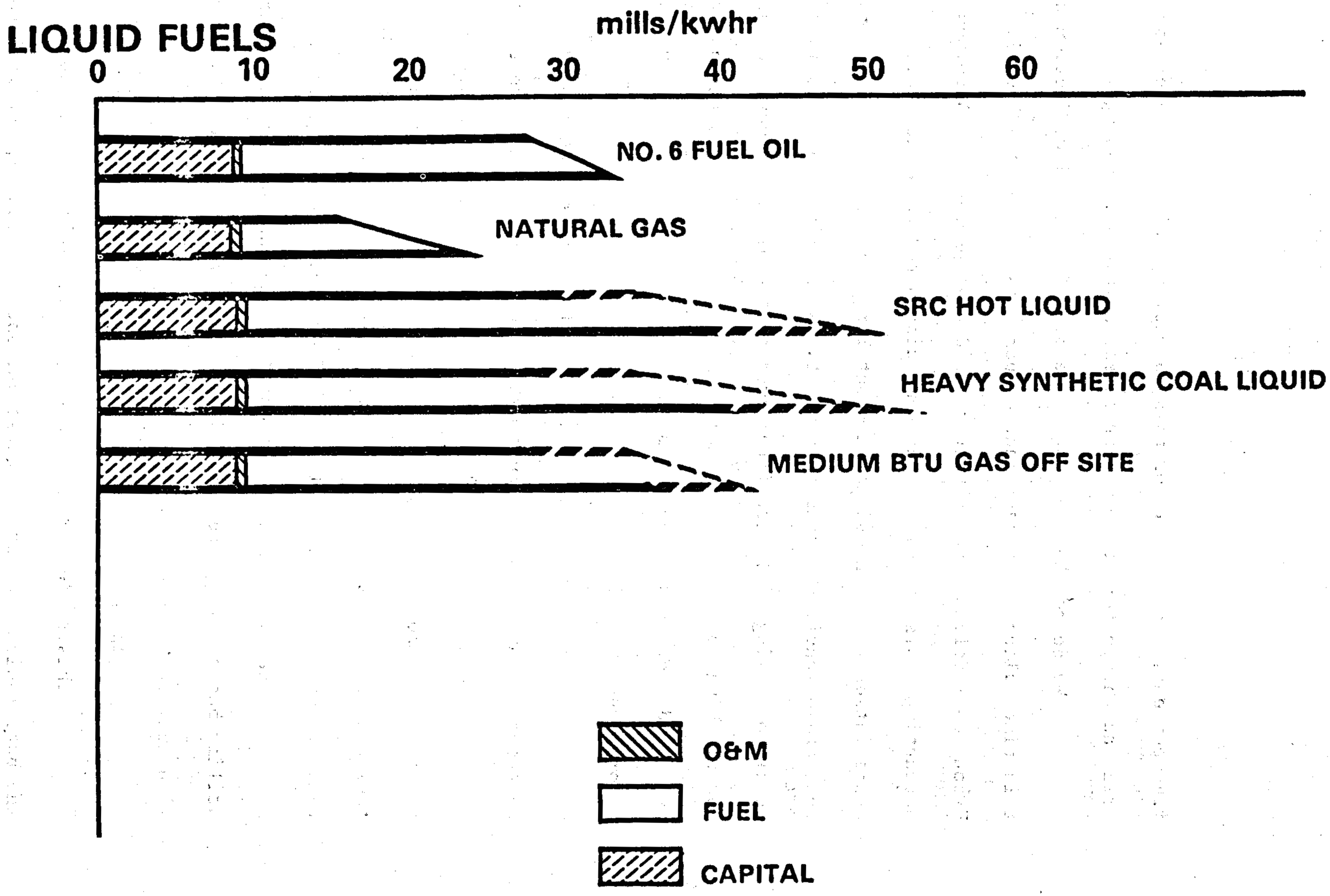
However, on a preliminary basis, liquefaction processes are indicated to produce synthetic crude at $30 per barrel or higher; a fuel oil product may be $5 per barrel less. This assures a 15 percent rate of return on a discounted cash flow, 100 percent equity basis.

The next three slides show come comparisons on an electric utility basis. They are derived from a recent report done by Gilbert with fuel costs added.

(Slide 6)

This slide shows new plants using various liquid fuels. The bars indicate capital, operation, and maintenance, and fuel costs

NEW ELECTRIC UTILITIES



components, respectively. The fuel cost component is slanted to show a range of fuel cost, giving an indication of sensitivity.

Using a cost for No. 6 fuel oil of $2.12 to $2.86, the cost of electricity ranges from 28 to 33 mills per kilowatt hour. For natural gas which costs $.52 to $2 per million Btu, the range is 16 to 24 mills per kilowatt.

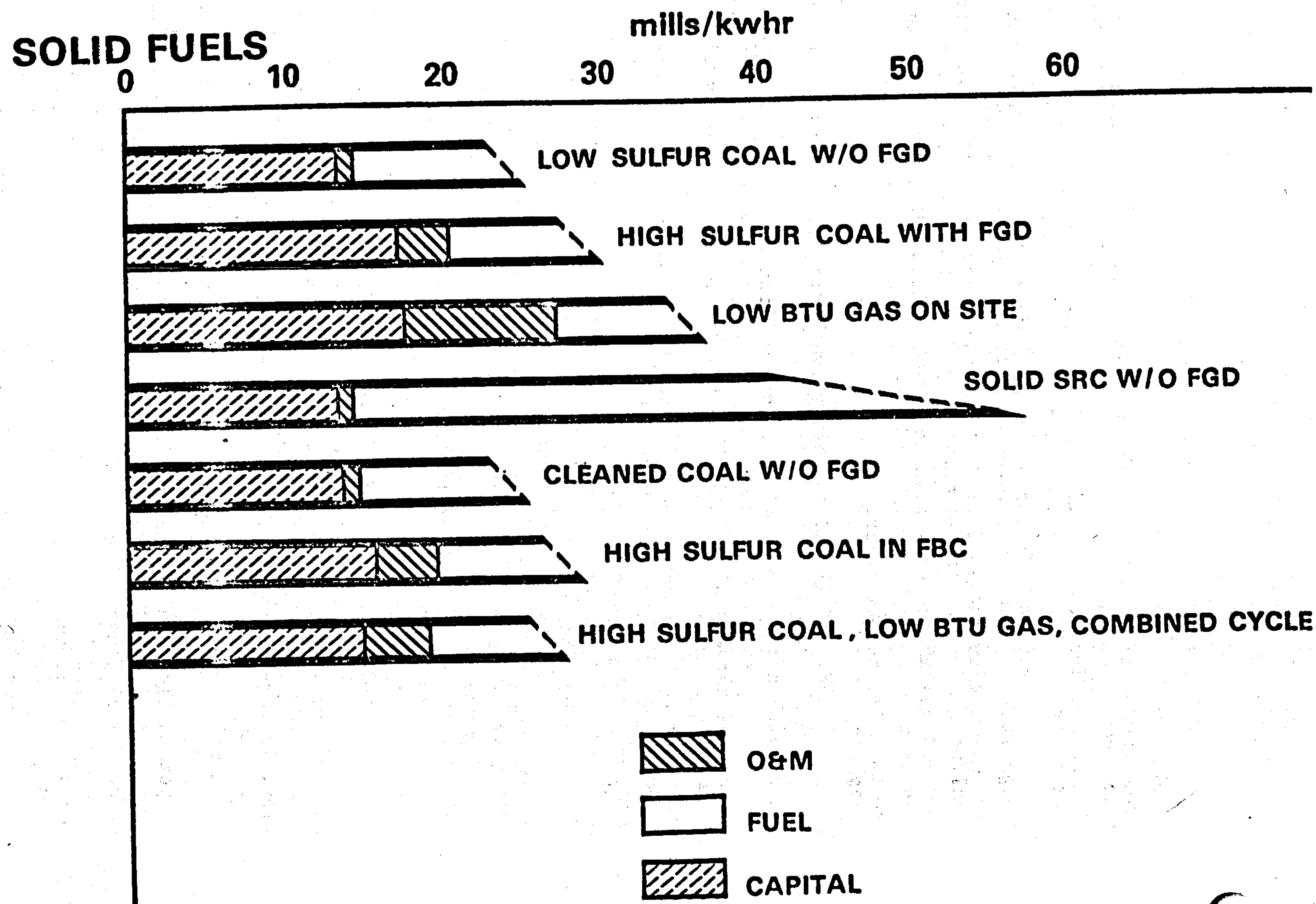
SRC hot liquid and heavy synthetic coal liquid, both estimated within a range of $3 to $5 per million Btu, produce electricity at a cost between 35 and 50 mills per kilowatt hour. The medium Btu off-site case assumes a cost for the gas between $3 and $4 per million Btu and produces electricity between 35 and 42 mills per kilowatt hour. These last three cases are more expensive than using fuel oil or natural gas, but they are based on coal which is much more secure as a commodity.

(Slide 7)

Solid fuel comparisons are shown on the next slide for new electric utilities. Low sulfur coal, without flue gas desulfurization, is very attractive. The fuel cost range assumed is $1 to $1.25 for a million Btu. High sulfur coal is assumed to cost 75 cents to $1 per million Btu at the utility and requires flue gas desulfurization. This results in greater capital and operation and maintenance costs, but the fuel cost is less.

Low Btu gas on site, requires additional capital and operating and maintenance costs, but again the fuel is the cheaper high

NEW ELECTRIC UTILITIES



sulfur coal. Solid SRC, without flue gas desulfurization, is assumed to cost \$3 to \$5 per million Btu and produces by far the highest cost of electricity. Cleaned coal, without flue gas desulfurization, uses high sulfur coal and is very competitive with low sulfur coal. High sulfur coal in fluid bed combustion is also an attractive alternative as is the case of high sulfur coal in a low Btu gas combined cycle application.

(Slide 8)

The effect of retrofit on the delta cost of electricity in mills per kilowatt hour is shown in this slide. For solid fuel plants, flue gas desulfurization adds about 10 mills per kilowatt hour. Solid SRC adds quite a bit. Clean coal adds the least of the three.

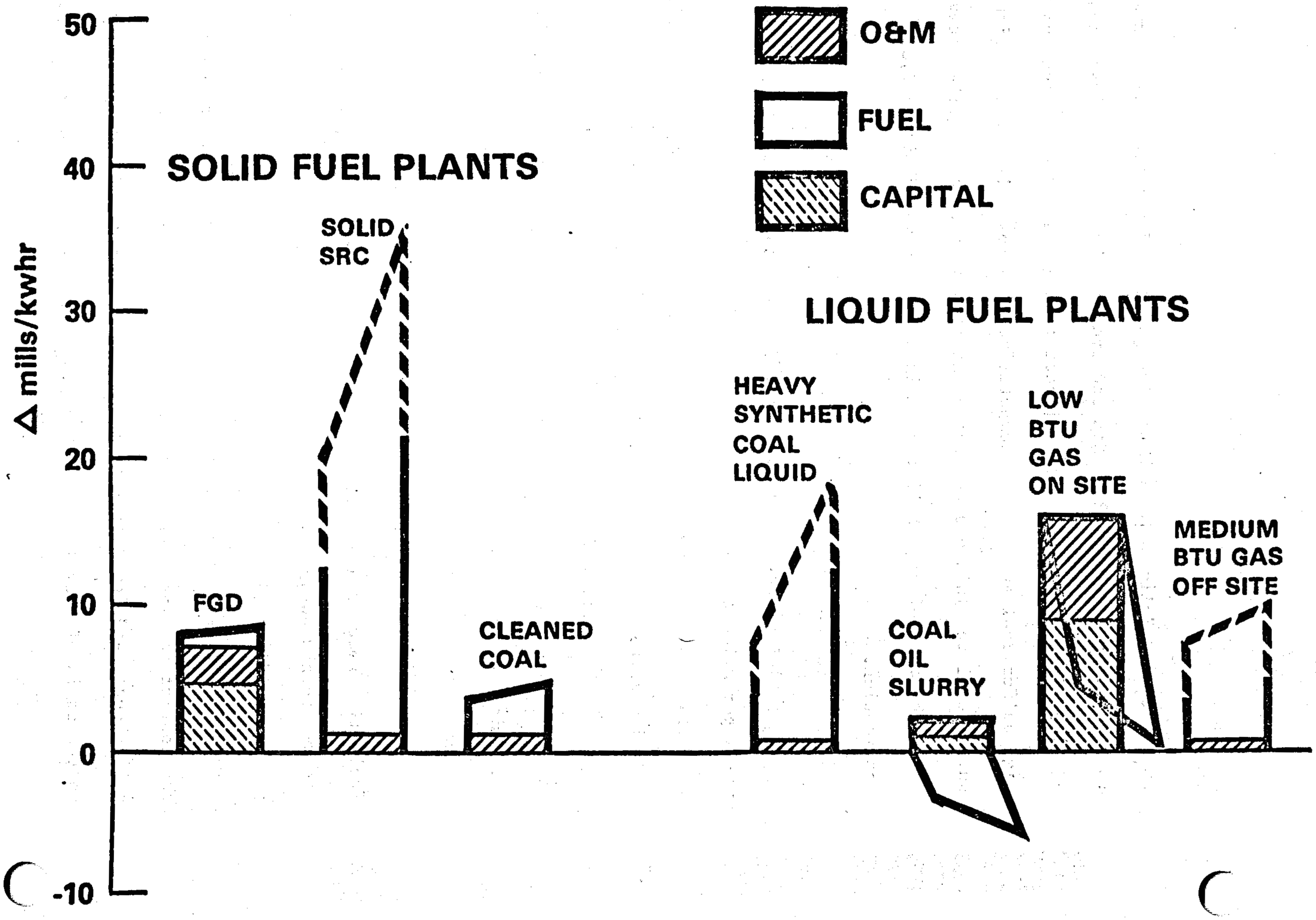
For liquid fuel plants, the retrofit of \$3 to \$5 per million Btu heavy synthetic coal liquid adds about 20 mills. And in the coal-oil slurry retrofit, substituting coal for part of the No. 6 fuel oil, a small saving results.

Low Btu gas on site, using high sulfur coal, replacing No. 6 fuel oil, produces a saving that results in no added cost. Finally, medium Btu gas bought off site adds about 10 mills.

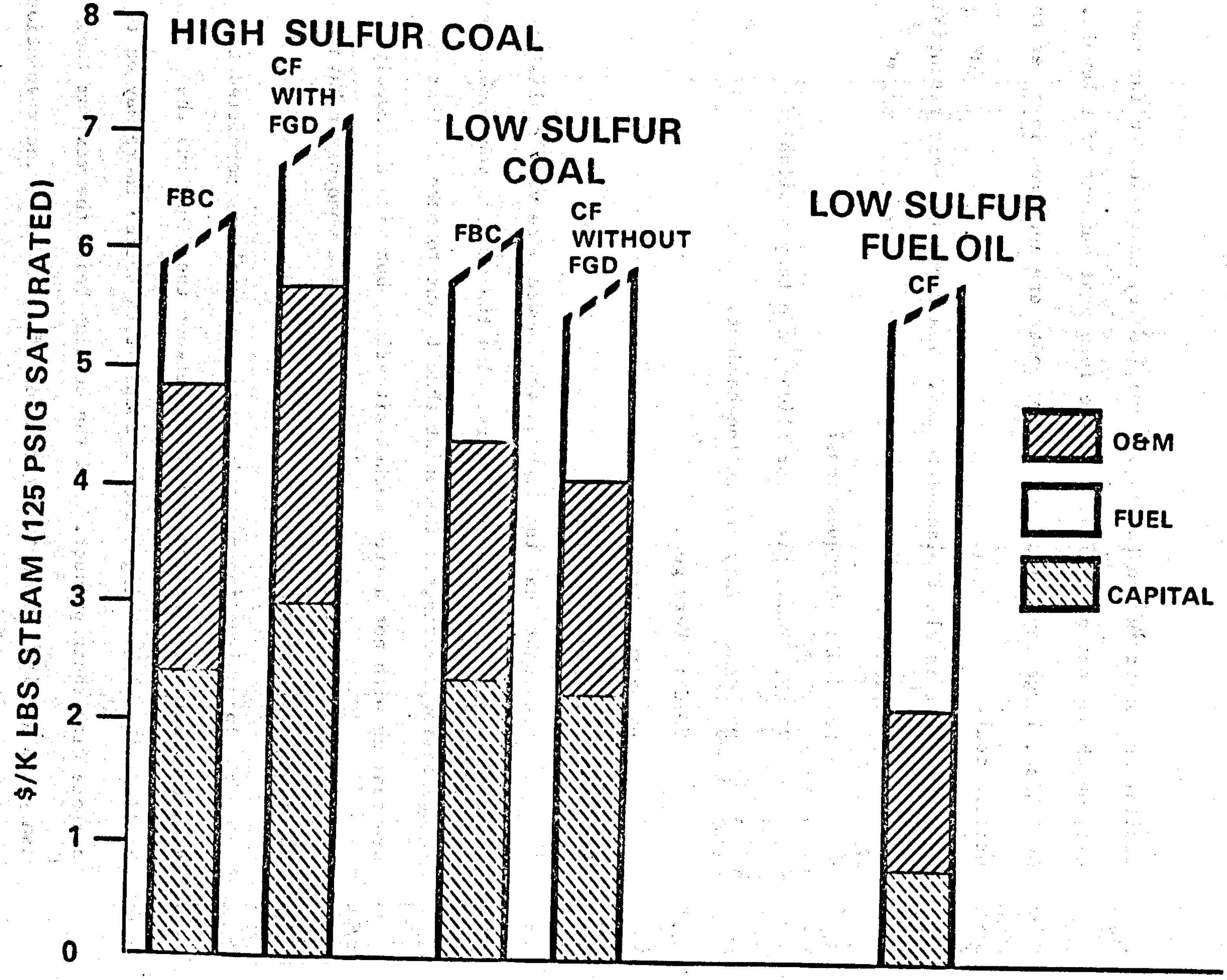
(Slide 9)

The last slide was a study done a year ago that indicates the cost of new industrial boilers. As you see for high and low sulfur coal, and low sulfur fuel oil, there is not a lot to choose from on the basis of overall cost. The plot makes the point, however, that

RETROFIT OF ELECTRIC UTILITY



NEW INDUSTRIAL BOILERS



183-2

capital and operating costs can be minimized by using low sulfur fuel oil, which may not be available in the future at current cost levels. Otherwise, large capital and operating costs are incurred in order to utilize coal.

That is all I planned to say. Thank you for your attention.

(Applause.)

DR. KANE: Any questions?

VOICE: Those last four slides, are they available?

DR. KANE: They are in the handout.

VOICE: Very good.

DR. KANE: Yes.

DR. BARON (Shell):

I thought that the figures you showed were very realistic and so were your contingency factors. And the numbers you showed are in the believable range. The point that I want to make is that we are dealing with not a free market situation, but with a monopoly situation in which the OPEC countries acting as a monopolist have a problem of setting their prices.

In a situation normally, when a monopoly is permitted to act, they set their prices somewhere between the floor and the ceiling, the floor being whatever competitive source there may be to compete with their product. And the ceiling being the maximum they can get away with, without a revolution of some kind. The revolution may be due to economic causes, disruption of society, or other.

The major point I want to make here is that in our case, the floor will be set by the prices you have shown. Say, minimum $20, as much as $30 a barrel, on the order of $5 per million Btus, something like that.

But interestingly enough, the ceiling which normally would be the ceiling, which the OPEC countries have chosen, even after you allow for importation and everything, is more like about $14, $15 a barrel. So we have a fantastic situation, in which the ceiling is below the floor. I'm using this poetic way of expressing myself to make the point of terrible danger, and that any government action that would arbitrarily and unnecessarily widen the gap between the ceiling and the floor, will contribute to increased instability.

Thank you.

DR. KANE: Further questions or comments?

If not, Dr. Phillips has an announcement, then we will let you go.

DR. PHILLIPS: Well, the first announcement is that I think we can all be back in an hour and seven minutes, namely, at 1:45, please, for the afternoon session.

I point out to all of you that there are restaurant facilities available, both in this Quality Inn and across the street at the Hyatt Regency.

Would you please fill in the forms if you wish to participate in tomorrow afternoon's smaller discussion groups.

(Whereup, at 12:38, the meeting was recessed, to reconvene at 1:45 p.m., this same day.)

\- - - - - - -

AFTERNOON SESSION

DR. KANE: I have a couple of announcements to make before we commence.

Let me remind all of you that wish to participate in our smaller discussion groups tomorrow afternoon, we do request that you indicate that; and it would be helpful if you would fill out one of those checklists that The MITRE Corporation has supplied.

Because of the uncertainties in fossil energy research meetings, we got somewhat out of order in our program this morning, but I believe we now have the opportunity to get back into the agenda as it was written up. So we will have first a talk by Dr. Kropschot, the talk on Overview of ERDA Research, agency-wide. That will be followed by the talk by Watkins; the talk by Holzer and Zucker; we have already done the talk by Dr. Alex Mills, and then we will proceed on through the program as it is printed.

So I now call on Dr. Richard Kropschot--Overview: ERDA Research.

DR. KROPSCHOT: I would just like to spend a few minutes putting the program, for the rest of the next day and a half, in perspective and to call your attention to the fact that what we were doing this morning was an attempt at giving you an overview of the broad based program going on in ERDA; and now I would like to deal with the research, the program that Dr. Phillips and I have been working on, and the reason for this meeting; and address what we are trying to do in soliciting your help in getting feedback to provide input into the planning session and the planning activities for the research in ERDA.

The Energy Reorganization Act of 1974 assigned to the Administrator of ERDA the central responsibility for policy planning, coordination suport and management of research, development, and demonstration for all the energy sources. (Slide 1) In addition, there are other elements of the Act but it is this legislative issue that we are trying to respond to today. For the remainder of our meeting, we would like to discuss the energy-related research in the near, mid, and long-term program.

We must recognize that the definition of "research" means different things to different people and we have great difficulty in obtaining a consistent definition. (Slide 2) However, research (Basic, Applied, Technology Base) as defined in ERDA IAD 0800-5 can and must be one of the Agency missions and should be justified as such.

In our definition, we include the basic research developed from the fundamental sciences and the broadly-applicable technologies.

What we do not include are the programs which respond to the pilot and demonstration plants. And, again, part of those programs can and do overlap into the research. The boundary is fuzzy, but the definition is many times only a problem in semantics.

Energy Reorganization of 1974

Central Responsibility for
- Policy Planning
- Coordination
- Support
- Management

of Research (and Development)
for all Energy Sources

Near - Mid - Long term:

What is Research?

Basic
Applied
Broadly Appicable Technology

— Different things/different people
— What it is not

Using this definition, the ERDA-side program in research (Fossil only being a part of it) is $400 million annually. We have excluded the High Energy and Nuclear Physics program and the Environment and Safety Research from our inventory. The fossil research component is about $40 million annually and managed by four different Assistant Administrators (AFE, ASGA, AC and AES).

About a year ago, as Mr. Fri and Dr. Kane mentioned this morning, the Administrator of ERDA and the Assistant Administrators developed a group of management goals. One of these goals was to strengthen the Basic Energy Sciences (Slide 3) Program within the Agency and they assigned to Dr. Kane the responsibility for the quality of that Program. Dr. Phillips and I have been assisting Dr. Kane in his quest for an answer to this difficult task. The Federal role that we see emerging is outlined in Slide 3 responding to the Reorganization Act as well as other key elements which justify Federal involvement.

Slide 4 shows the key elements for a strong research program. Where are the <u>needs</u> for research; what are the <u>opportunities</u>; do we have the <u>resources</u> and can we provide the <u>leadership</u>? We have asked each of the speakers not only to address what they are doing, but to point out new opportunities. Do we have an infrastructure in place to take advantage of opportunity in an adequate way and can we provide the leadership to complete the job.

- Strengthen the Basic Energy Sciences Program
- Quality and Adequacy
- Federal Role
  - Reorganization Act
  - Broad Public Benefit
  - Sheer Size
  - Difuse Benefits
  - Risk
  - Balance of Trade
  - Scientific and Technical Leadership

OPPORTUNITY:
NEED:

RESOURCES

LEADERSHIP

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Slide 5 is our schedule for the meeting. We have completed the Introductory Session. For the rest of the time through tomorrow noon, we will present to you the Fossil Energy Research Program and the research opportunities. We must recognize that in order to respond to these opportunities, we must provide adequate resources (Industry, Multidisciplinary laboratories and Universities).

In our handout, we addressed several issues and questions (Slide 6) that we have developed in concert with groups of people within the Agency. They are the key issues and are asked when determining the nature of the research program; the quality and adequacy of the new research, the balance, etc. Is the balance between research and the demonstration program correct? How can we use your input to make these decisions?

As Dr. Kane mentioned, the issue of crosscutting technologies needs serious consideration. Dr. Phillips and I felt that there were several areas (Slide 7) that deal with the broad-based disciplines: materials, combustion, instrumentation, nondestructive testing and so on, that have impact on more than one technology and are falling through the cracks.

The feedback seminars that we planned tomorrow afternoon are (hopefully) designed to get your input. We will divide up into smaller groups of 10 to 15 each and, with the aid of the staff from The MITRE Corporation, provide a mechanism for obtaining your input.

Schedule

- Introductory Session
- Research Program
- Research Opportunities
- Resources
  - Industry
  - ERC's
  - National Labs
  - Universities

Quality and Adequacy
New Research needs/opportunities
Balance research/demonstration
Industrial/University/Government Research
Technology Transfer
Management of Research
Cross-cutting Technologies

Feedback Seminars

CROSS-CUTTING TECHNOLOGIES

DISIPLINES

MATERIALS
COMBUSTION
INSTRUMENTATION
NON DESTR TESTING
MATHEMATICAL MODEL
SUPERCONDUCTIVITY
DATA BASE
CATALYSIS
CORROSION
ABRASION - WEAR

FACILITIES

PULSED NEWTON SOURCE
SYNCHROTRON RADIATION
LASER DIAGNOSTICS

To ask for input from you with this limited information is perhaps unfair, difficult or maybe impossible. But many of you (most of you) are working in the field of fossil energy and know a lot about the ERDA program. So we're starting at a pretty high level of knowledge. Also, I would like to call your attention to the fact that the decision making process of Fossil Research is being done during each budget cycle. We're asking for your help in providing input to that decision process.

(No response.)

DR. PHILLIPS: We will then proceed with our program.

The next speech will be a topic in fossil energy division research, oil, gas and shale technology presented by J. Wade Watkins.

MR. WATKINS: Thank you. Ladies and gentlemen, I had the same problem Dick Kropschot mentioned in trying to categorize research.

In 30-odd years, and some of them have been, indeed, especially recent ones. In 30-plus years of being involved in government R&D, it's never been clear in my mind, the line of demarcation between basic or fundamental research, applied research, engineering development, et cetera.

I think other people have the same difficulty.

In preparing this presentation --

(Laughter.)

-- I assumed that I was to focus primarily on basic research as compared with our entire program, which is what I had planned, and therefore, I am not going to go into detail about our cost-shared contracts with industry for field demonstrations or similar in-house programs and some of our other activities, but more the overall general program as compared with what we think may be basic research.

I'd like to point out that there's an attractive young lady in the back of the room who has a limited number of copies, hard copies, of the vugraphs I will present, which also includes vugraphs I will not use, because I'm not going to touch in detail on our applied programs.

In trying to rack up what we have in basic research, I took all of our headquarter's contracts and went through those categorically myself and said, well, this either is or is not basic research, which ignored such activities as cost-shared industry contracts, support research, computer modeling, environmental compliance, like EIA's, EIS's, EDP's, and a host of other things that just by no stretch of the imagination could I consider to be basic research.

And I went to the Energy Research Centers and National Laboratories and said, "Look, please tell me what you think you're doing for us that is basic research."

And that reinforced my confusion no end, because I had some of the National Lab directors come back and say, well, look, we're not doing anything for you that's basic research. It's all applied research. Conversely, I had one ERC director say, everything we're doing is basic research.

I knew this couldn't be right, so I rather categorically excised some of the things that had been in there, and then finally came up with a total, which I am not prepared to defend when I show it to you later. I can assure you it's not off by an order of magnitude, but it could be 25 percent more or less or something like that.

Okay. May I have the first slide, please.

(Slide 1)

You probably have seen this already. It identifies where we are, the Division of Oil, Gas and Shale Technology, one of seven divisions under Phil White.

Next one.

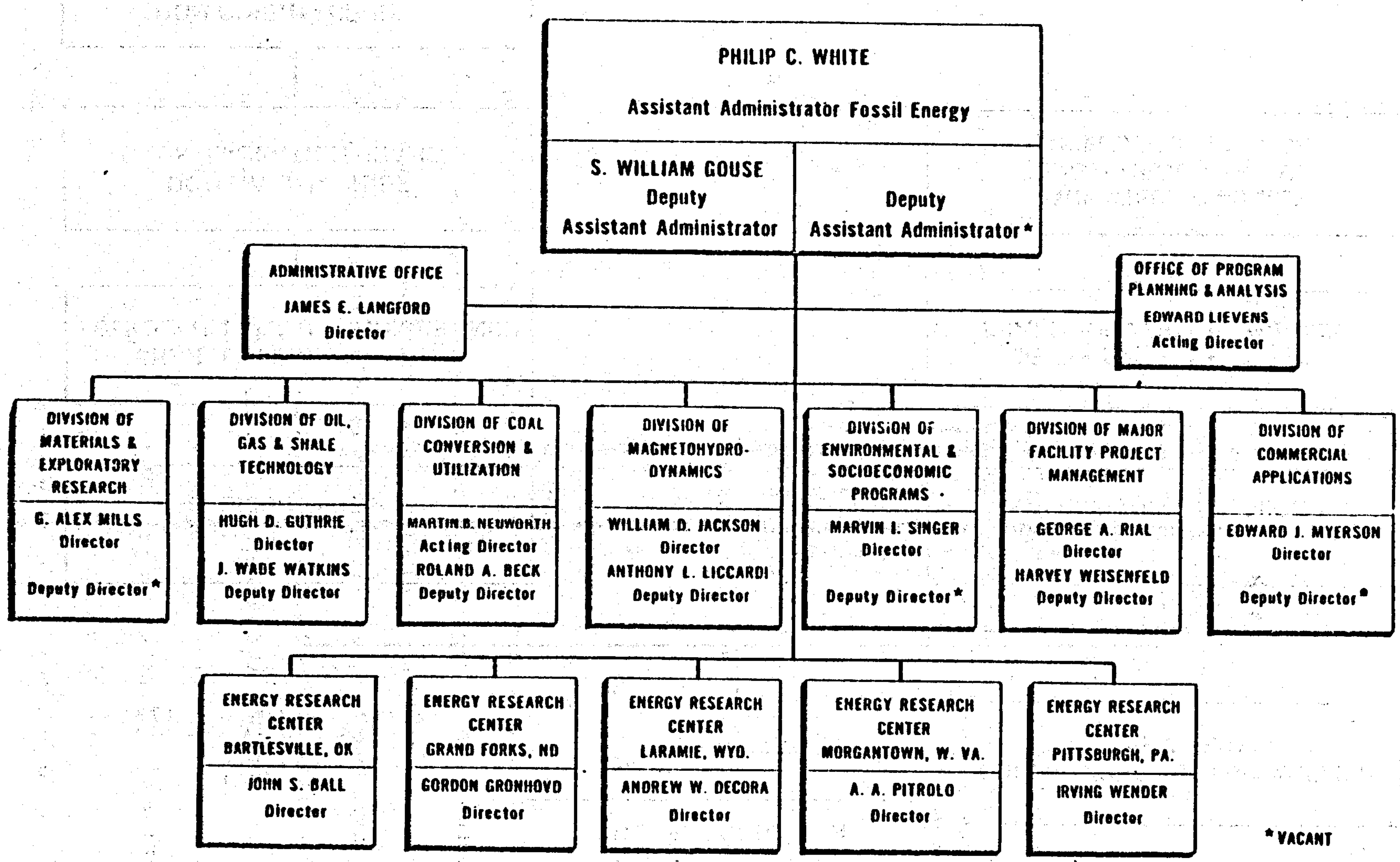
(Slide 2)

This is our division organization. We have two assistant directors, Jerry Hamm, for oil and gas, with 3 branches, Charles Perry, in petroleum stimulation or, better known as enhanced oil recovery, Don Ward, gas stimulation or enhanced gas recovery and Don Guier, drilling and offshore technology.

On the other side, Larry Burman, for in situ technology, with two branches. Jerry Ramsay, shale conversion, and Paul Wieber, underground coal gasification. Okay.

(Slide 3)

Objectives. I'll let you read the objectives, and point out that under implementation we do put a very heavy emphasis on


PHILIP C. WHITE
Assistant Administrator Fossil Energy
S. WILLIAM GOUSE
Deputy
Assistant Administrator
Deputy
Assistant Administrator*
ADMINISTRATIVE OFFICE
JAMES E. LANGFORD
Director
OFFICE OF PROGRAM PLANNING & ANALYSIS
EDWARD LIEVENS
Acting Director
DIVISION OF MATERIALS & EXPLORATORY RESEARCH
G. ALEX MILLS
Director
Deputy Director*
DIVISION OF OIL, GAS & SHALE TECHNOLOGY
HUGH D. GUTHRIE
Director
J. WADE WATKINS
Deputy Director
DIVISION OF COAL CONVERSION & UTILIZATION
MARTIN B. NEUWORTH
Acting Director
ROLAND A. BECK
Deputy Director
DIVISION OF MAGNETOHYDRO-DYNAMICS
WILLIAM D. JACKSON
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Deputy Director*
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Director
ENERGY RESEARCH CENTER GRAND FORKS, ND
GORDON GRONHOVD
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ENERGY RESEARCH CENTER LARAMIE, WYO.
ANDREW W. DECORA
Director
ENERGY RESEARCH CENTER MORGANTOWN, W. VA.
A. A. PITROLO
Director
ENERGY RESEARCH CENTER PITTSBURGH, PA.
IRVING WENDER
Director
*VACANT

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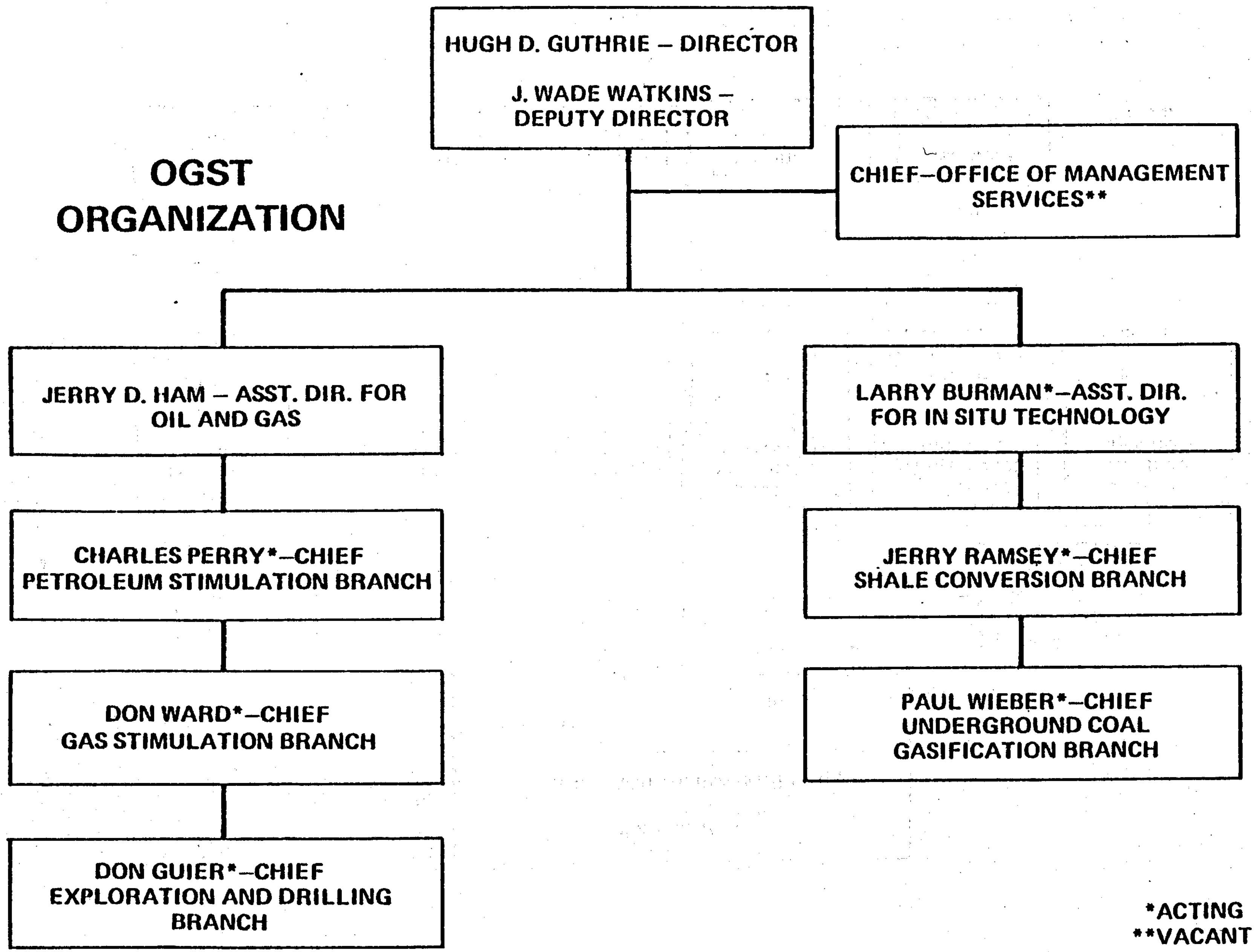
OGST ORGANIZATION



ERDA DIVISION OF OIL, GAS, AND SHALE TECHNOLOGY

R&D OBJECTIVES

- MAXIMIZE EFFICIENCY OF PRODUCTION OF DOMESTIC DEPOSITS OF NATURAL GAS, PETROLEUM, HEAVY OILS, OIL SHALE, TAR SANDS, AND UNDERGROUND COAL CONVERSION

IMPLEMENTATION

- PROVIDE FUELS AT LOWEST POSSIBLE COST AND MINIMUM ADVERSE EFFECT ON ENVIRONMENT AND ECOLOGY
- EFFECT RAPID TECHNOLOGY TRANSFER
  - SYMPOSIA
  - QUARTERLY PROGRESS REPORTS
  - PUBLICATIONS AND PRESENTATIONS

rapid technology transfer. We do this through symposia. We have an annual symposium on enhanced oil and gas recovery, and periodic ones on such subjects as underground coal gasification and oil-shale retorting.

It's also done through quarterly progress reports on all of our contracts which have a very wide distribution, and it is done through technical and scientific publications and presentations.

(Slide 4)

Our research targets are some 290 billion barrels of normal gravity oil, more than 100 billion barrels of heavy oil, at least 30 billion barrels of bitumen in tar-sand deposits, principally identified in the state of Utah; more than 600 trillion cubic feet of natural gas in low permeability formations in the Rocky Mountain basins, and an unquantified but sizable amount in similar deposits in eastern shales, coal seams and geopressured aquifers.

In our contracts we have been shooting for at least 50 percent funding from industry and actually have exceeded that.

Our goals are to add to proved reserves by 1985, 3 billion barrels of oil and 10 trillion feet of natural gas, as a result of our program, and to increase daily production by an increment of 800,000 barrels of oil and 3 billion cubic feet of natural gas.

(Slide 5)

In in situ technology the resources are tremendous, and please remember, I'm talking about resources and not reserves. 1.8

PETROLEUM AND NATURAL GAS

- RESOURCE TARGETS
  - 290 BILLION BARRELS OF NORMAL-GRAVITY OIL
  - 107 BILLION BARRELS OF HEAVY OIL
  - 30 BILLION BARRELS OF BITUMEN
  - 600 TRILLION CUBIC FEET OF NATURAL GAS
- EXPECTED INDUSTRY PARTICIPATION
  - ABOUT 50 PERCENT
- EXPECTED ADDITIONS TO RESERVES BY 1985
  - 3 BILLION BARRELS OF OIL
  - 10 TRILLION CUBIC FEET OF NATURAL GAS
- EXPECTED INCREASED PRODUCTION BY 1985
  - 800 THOUSAND BARRELS OF OIL PER DAY
  - 3 BILLION CUBIC FEET OF NATURAL GAS PER DAY
- PROVED DOMESTIC RESERVES AT END OF 1975
  - 32.7 BILLION BARRELS OF CRUDE OIL
  - 228.2 TRILLION CUBIC FEET OF NATURAL GAS

IN SITU TECHNOLOGY

- RESOURCE TARGETS

  1.8 TRILLION BARRELS OF OIL EQUIVALENT FROM OIL SHALE

  1.8 TRILLION TONS OF COAL AMENABLE TO UCG

- EXPECTED INDUSTRY PARTICIPATION

  UP TO 50 PERCENT

- EXPECTED PRODUCTION BY 1985

  150 THOUSAND BPD EQUIVALENT FROM OIL SHALE

  50 THOUSAND BPD EQUIVALENT FROM UCG

trillion barrels equivalent of shale oil, 1.8 billion barrels of oil equivalent from coal formations that we feel should be amenable to underground coal gasification and that at the present time are not considered to be economically minable.

Here, again, we are shooting for 50 percent, at least, from industry, and we would expect 150,000 barrels of oil per day from oil shale by 1985 and 50,000 barrels equivalent from underground coal gasification.

(Slide 6)

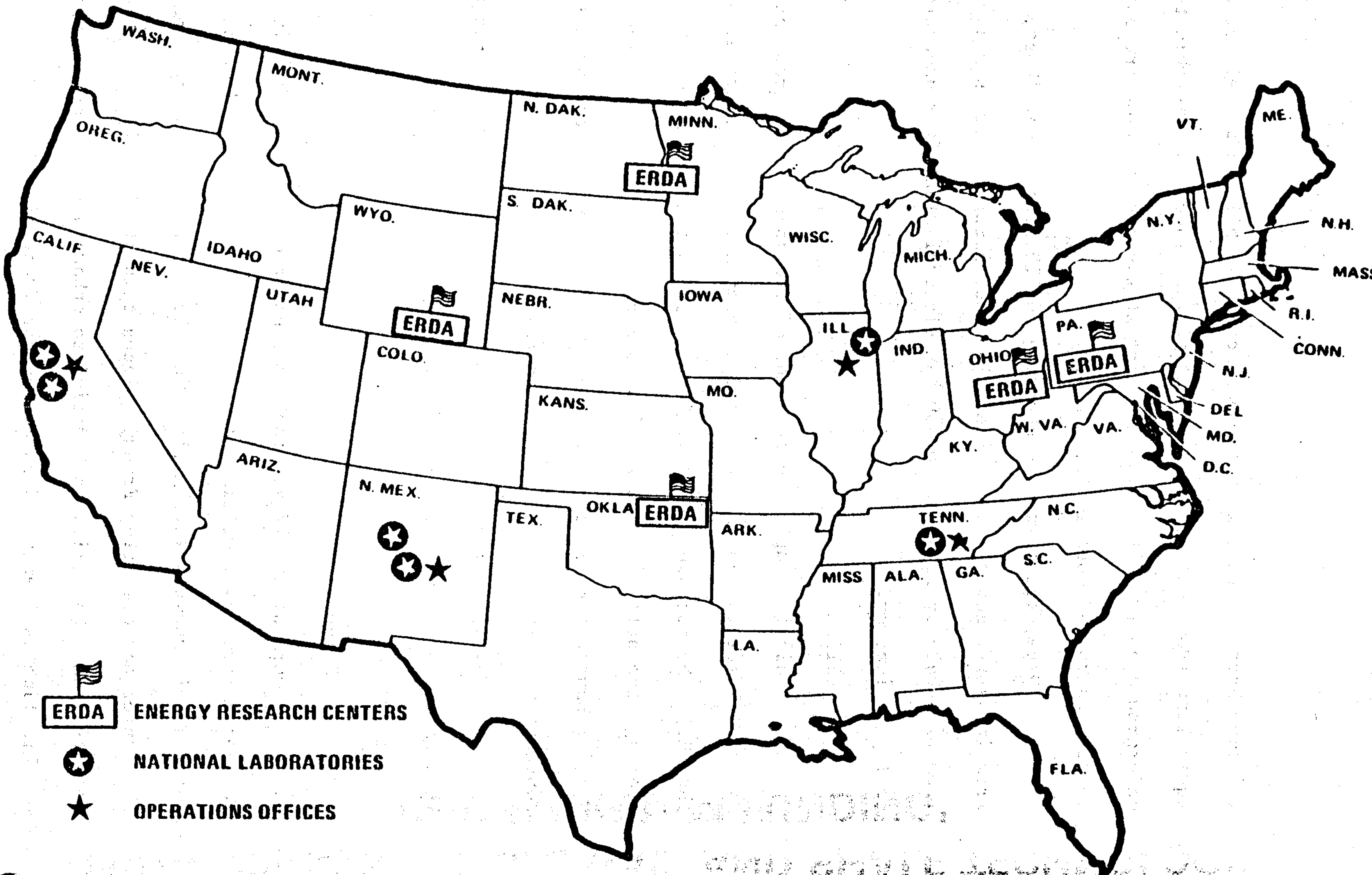
This is simply the location of the in-house programs at the National Laboratories and the Energy Research Centers, starting with the ERC's, Morgantown, West Virginia, Bartlesville, Oklahoma, Laramie, Wyoming, the national laboratories, Oak Ridge, Argonne, Los Alamos, Sandia, Lawrence Berkeley, Lawrence Livermore, and we do have a small contract with Mounds which is not on the map.

The operations offices with which we deal, are Oak Ridge, Chicago, Albuquerque, San Francisco, and Nevada, which also is not on the map.

(Slide 7)

Our budget, if you look at the bottom line, you see it increased from $64.3 million in '76 to $73.4 million in '77 and, whereas this shows $110.1 million in '78, the report that came out of the conference committee Friday, places this at $115 million, which results from a $4.9 million addition to enhanced gas recovery, which on this line is identified as nonnuclear fracturing.

LOCATION OF ERDA FOSSIL ENERGY RESEARCH CENTERS AND NATIONAL LABORATORIES



ERDA DIVISION OF OIL, GAS, AND SHALE TECHNOLOGY R&D PROGRAM FUNDING[1]

($ IN MILLIONS)

	FY 1976	TQ	FY 1977[2]	FY 1978[3]	
OIL & GAS TECHNOLOGY	(43.2)	(8.9)	(42.9)	(71.1)	76.0
FLUID INJECTION	25.7	4.6	23.8	46.1	
NON-NUCLEAR FRACTURING	13.5	3.1	14.9	22.0	26.9
EXPLORATION, DRILLING, OCS, RIO BLANCO TSTG	2.2	.7	2.4	1.6	
PROCESSING & UTILIZATION	1.8	.5	1.8	1.4	
IN SITU TECHNOLOGY	(21.1)	(4.0)	(30.5)	(39.0)	
OIL SHALE	13.7	2.0	21.0	28.0	
COAL (UCG)	6.1	1.7	8.2	11.0	
SUPPORTING RESEARCH	1.3	.3	1.3	—[4]	
TOTAL	64.3	12.9	73.4	110.1	115.0

[1]BUDGET AUTHORITY

[2]ACT PL 94 - 373

[3]REVISED PRESIDENTIAL BUDGET

[4]FY 78 SUPPORTING RESEARCH INCLUDED IN OIL SHALE

Okay.

(Slide 8)

In ERDA, fossil energy has 7.6 percent of the funding in FY '77, and 8.3 percent in FY '78, as the President's budget went to the Congress.

(Slide 9)

Our division's share in '77 was 15.4 percent and in '78, 17 percent, again based on the President's initial budget.

(Slide 10)

Personnel wise, Fossil Energy has four percent of the total. We have nine percent of the Fossil Energy share.

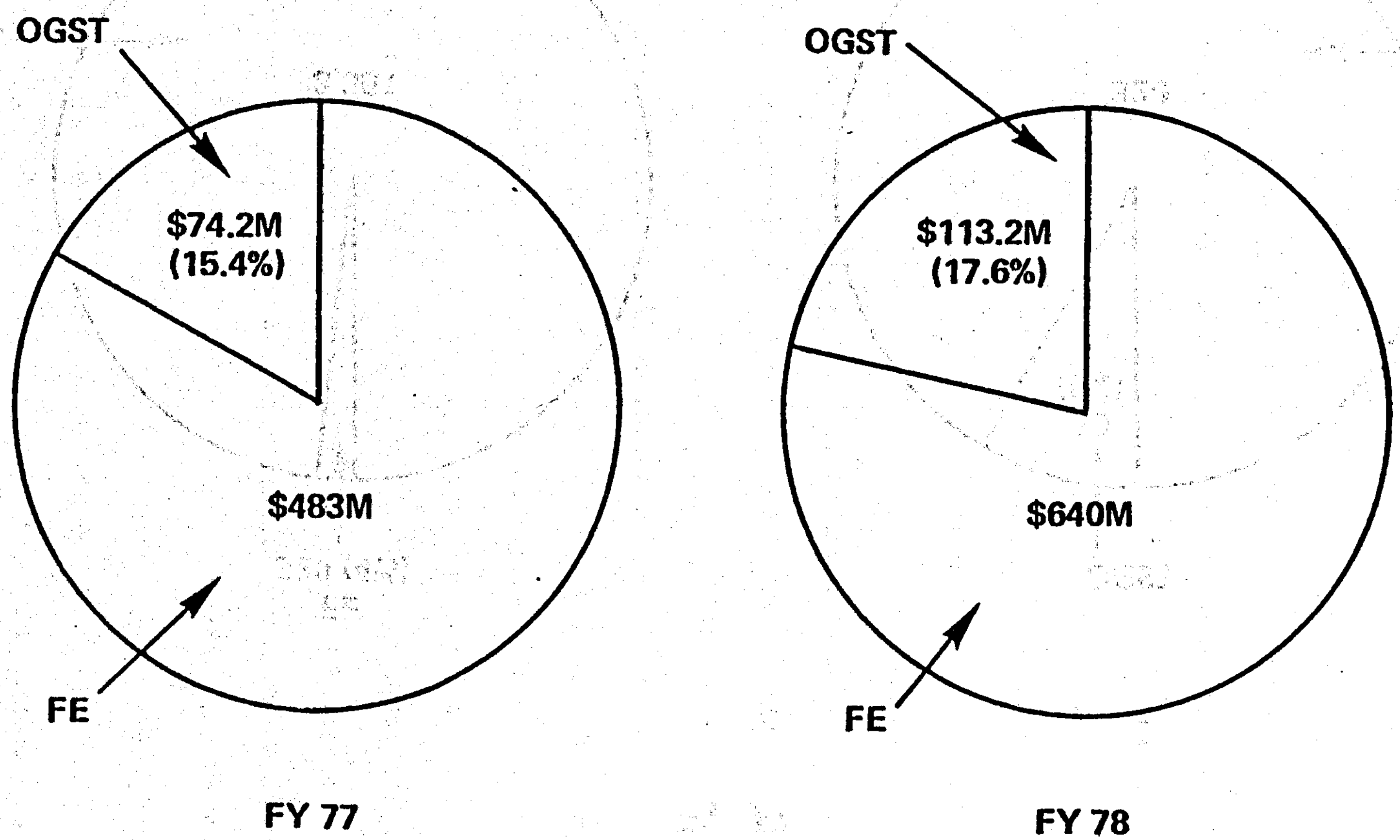
(Slide 11)

In FY '77, we were putting $24 million into enhanced oil recovery, $21 million into oil-shale technology, 8.2 million into underground coal gasification, $15 million into enhanced gas recovery, $3 million in supporting research, and $2.4 million into drilling and offshore technology. And this is going to industry-$35 million, National Labs $14 million, Energy Research Centers about $20 million, universities $1.6 million and supporting research, other government agencies, $3.5 million.

(Slide 12)

Now, this is my rackup on what we are doing in basic research which, as I said, may or may not be right and may be open to question.

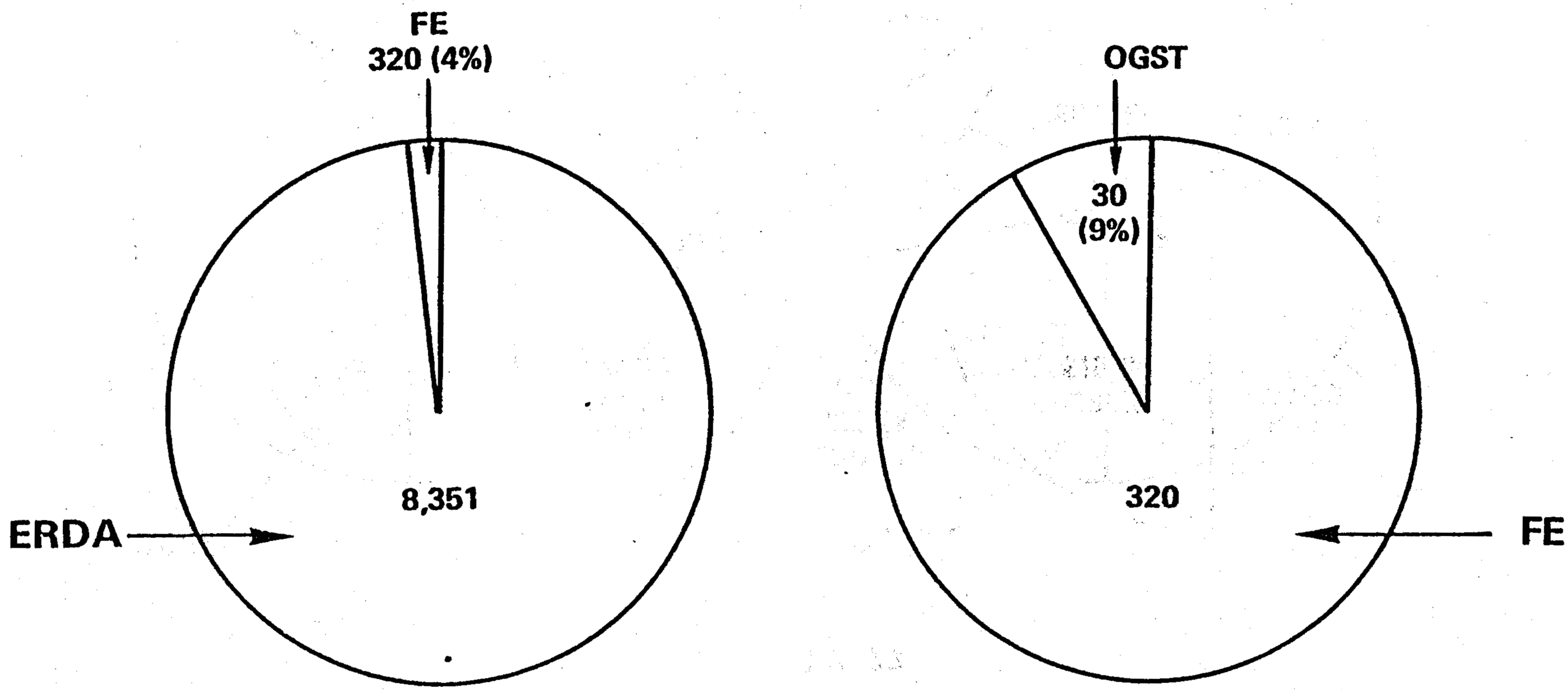
OGST'S SHARE OF FOSSIL ENERGY'S FUNDING[1]



[1]BUDGET AUTHORITY INCLUDING OPERATING EXPENSES AND PLANT AND CAPITAL EQUIPMENT

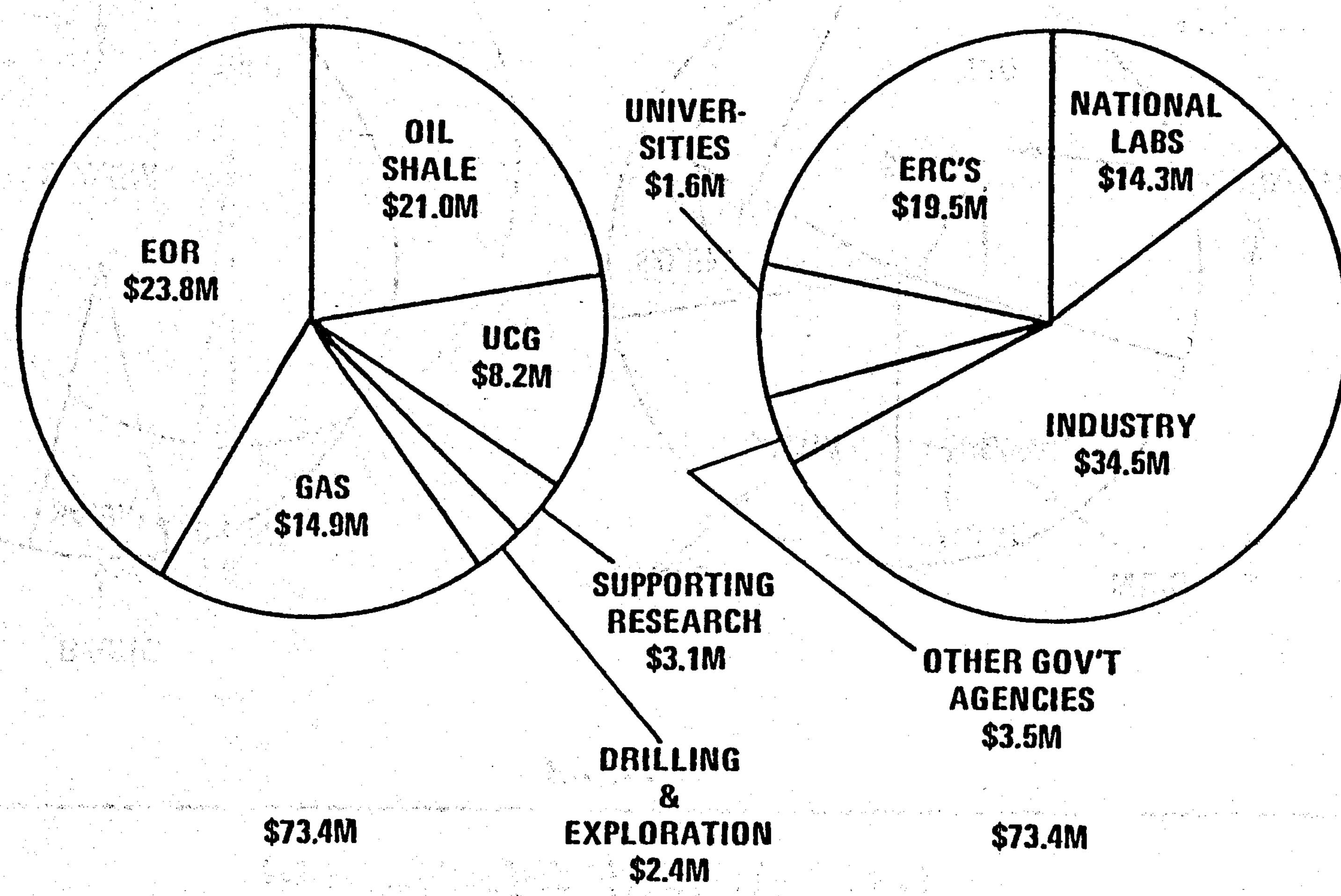
PERSONNEL RESOURCES

FY 77



HOW AND WHERE OGST SPENDS ITS MONEY

FY 77

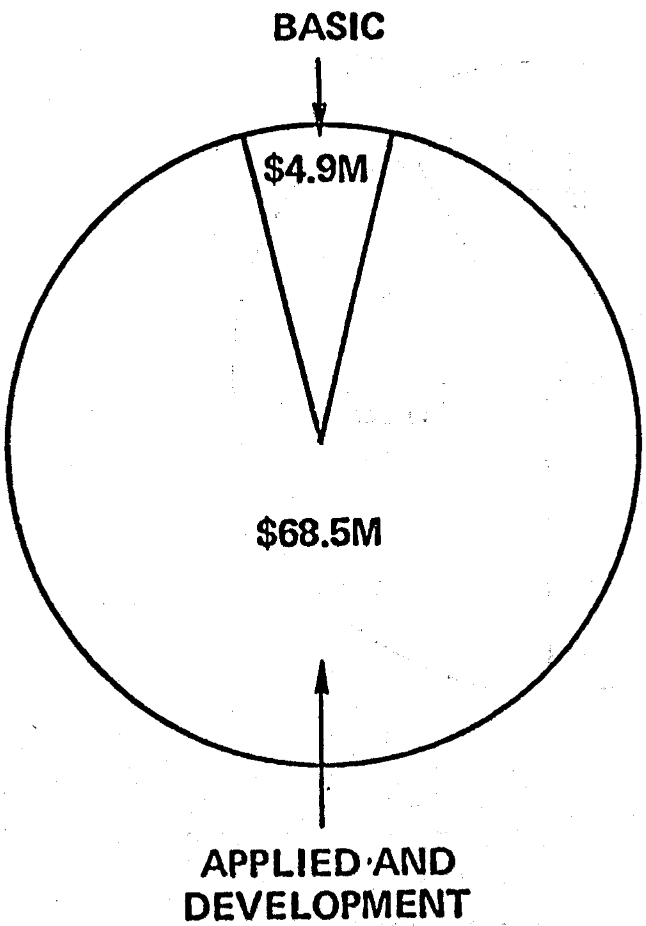


BY TECHNOLOGY

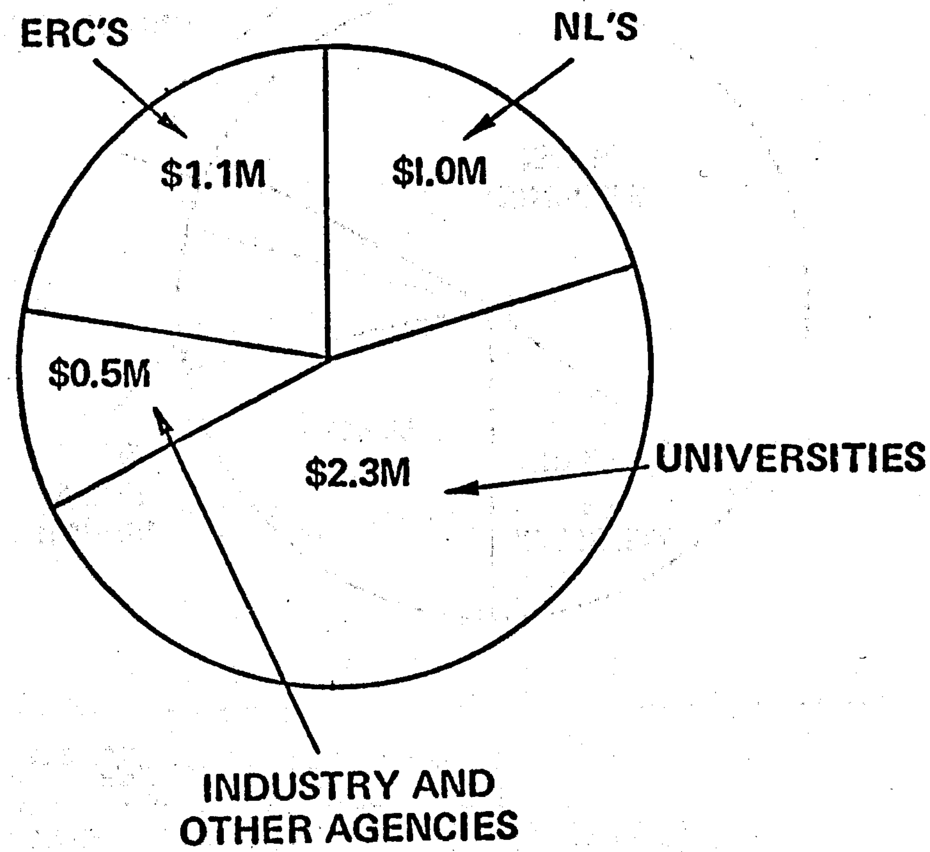
BY RECIPIENT

[1]OPERATING EXPENSES ONLY

OGST BASIC RESEARCH
FY 1977



BY CLASSIFICATION



BY RECIPIENT

EXAMPLES OF PRESENT AND POTENTIAL OGST BASIC RESEARCH

OIL SHALE CHARACTERIZATION AND BEHAVIOR

OIL IDENTIFICATION

PROPERTIES AND BEHAVIOR OF EOR CHEMICALS

EOR TRACERS

ROCK MECHANICS

SURFACE CHEMISTRY

THERMODYNAMIC PROPERTIES OF FLUIDS

REACTION KINETICS

ENVIRONMENTAL QUALITY AND REACTIONS

I totaled it up as 4.9, say $5 million, out of a total budget of $71 million, which leaves 68.5 in nonbasic research. Of this amount, the Energy Research Centers get $1.1 million, National Labs about $1 million, universities $2.3 million, and industry and other agencies a half-million dollars.

(Slides 13-23)

Now, I started to prepare two vugraphs here, showing what we are doing at present in basic research and what the needs might be in oil, gas, and shale technology for additional basic research. And as I tried to write this down, it occurred to me that I cannot differentiate the two. Possibly our immediate needs, if not our long-range needs, are simply more of what we are doing in some areas.

But let me run through these rather rapidly. One thing is oil-shale characterization and behavior. We have several projects going in this area. Oil identification, we have one at the Bartlesville Center. Properties and behavior of enhanced oil recovery chemicals. Here again, we have several projects at universities, National Laboratories and in-house at Energy Research Centers.

Enhanced oil recovery tracers, one project at Oak Ridge. This is to follow the subsurface flow of injected fluids.

Rock mechanics, applicable to virtually everything we're doing, because everything we're doing is in situ or underground, and

FOSSIL ENERGY RESEARCH PROGRAM

PETROLEUM AND NATURAL GAS

- STIMULATION OF PETROLEUM AND NATURAL GAS PRODUCTION
- EXTRACTION OF HEAVY OIL AND OIL FROM TAR SANDS
- CHARACTERIZATION OF PETROLEUM RESIDUES AND BITUMEN-LIKE MATERIAL
- QUALITY OF CRUDE OILS AND PRODUCTS
- IDENTIFICATION OF OIL SPILLS
- THERMODYNAMICS
- IMPROVED DRILLING TECHNOLOGY
- OFFSHORE TECHNOLOGY

FOSSIL ENERGY RESEARCH PROGRAM

IN SITU TECHNOLOGY

- IN SITU RETORTING
  - PROCESS DEVELOPMENT
  - SUPPORTING RESEARCH
- CHARACTERISTICS OF OIL SHALES
- OIL SHALE: NEW PROCESS TECHNOLOGY
- MAINTENANCE OF ANVIL POINTS FOR OBSERVATION OF RESEARCH BY DEVELOPMENT ENGINEERING, INC.
- ENVIRONMENTAL PROBLEMS ASSOCIATED WITH OIL SHALE PROCESSING AND UCG
- UNDERGROUND COAL GASIFICATION
  - PROCESS DEVELOPMENT
  - SUPPORTING RESEARCH
- IN SITU SHALE GASIFICATION (EASTERN AND WESTERN SHALES)

EOR FIELD TEST CONTRACTS SUMMARY

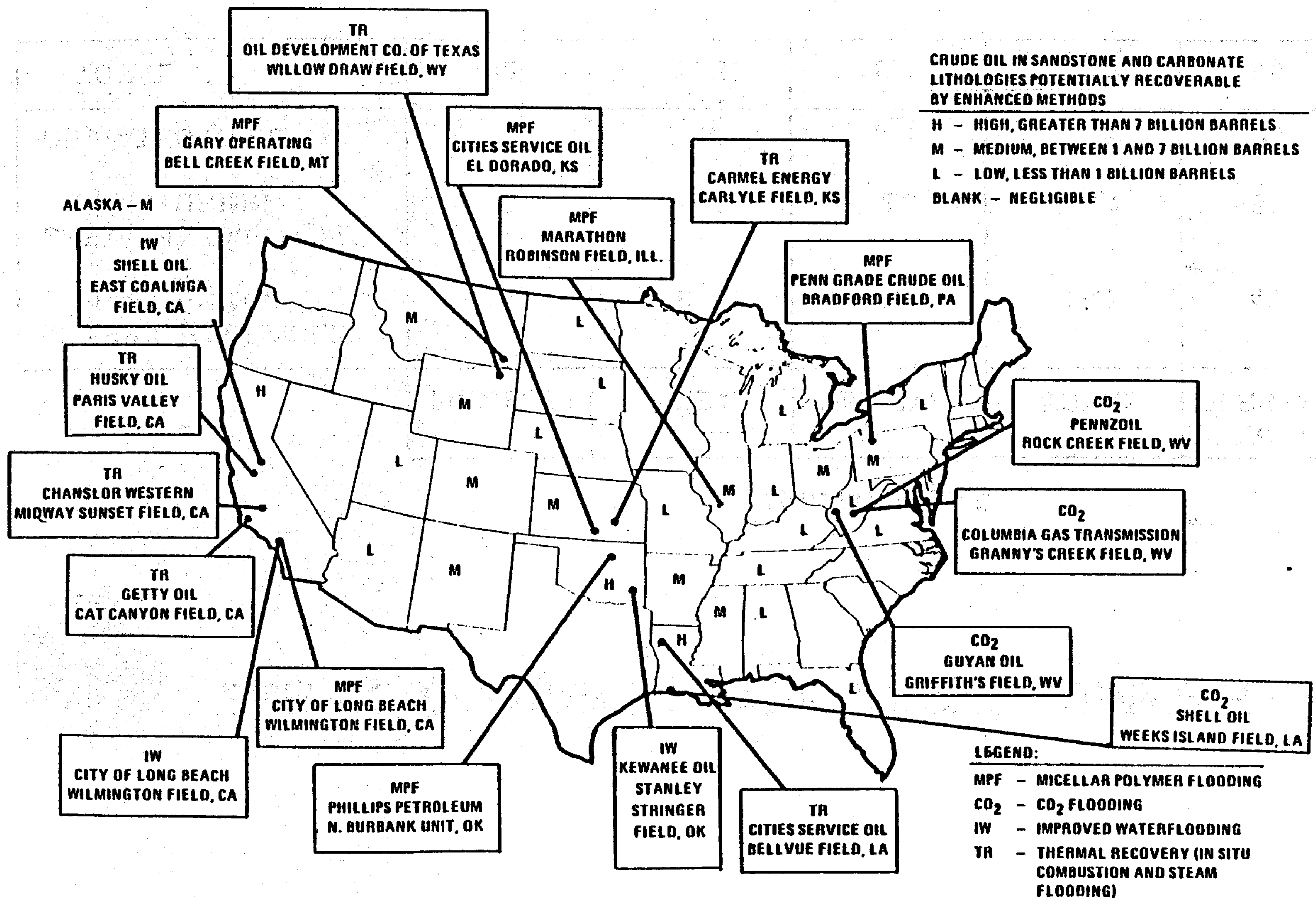
($ IN MILLIONS)

	PROJECTS	ERDA	INDUSTRY	TOTAL	ERDA PERCENT
MICELLAR-POLYMER	6	35.6	57.5	83.1	30
CO_2 FLOODING	4	1.5	5.7	7.2	20
IMPROVED WATERFLOOD	3	9.0	16.4	25.4	35
THERMAL RECOVERY	6	10.5	24.0	34.5	30
TOTAL	19	55.0	103.6	150.2	36

EOR FIELD TEST CONTRACTS

PROGRAM	TOTAL FUNDING (MILLIONS)	GOVERNMENT CONTRIBUTION	PERFORMER	LOCATION	STATUS
MICELLAR-POLYMER FLOODING	13.1	5.4	CITIES SERVICE, INC.	EL DORADO, KS	UNDER INJECTION
	9.8	3.4	PHILLIPS PETROLEUM CO.	BURBANK FIELD, OK	POLYMER INJECTION
	4.2	2.2	PENN GRADE CRUDE OIL CO.	BRADFORD FIELD, PA	DRILLING COMPLETE
	5.0	2.5	GARY OPERATING CO.	BELL CREEK FIELD, MT	PILOT DEMONSTRATION UNDERWAY
	7.0	3.5	CITY OF LONG BEACH	WILMINGTON FIELD, CA	INJECTION WELL TESTING
	44.0	14.0	MARATHON OIL CO.	ROBINSON FIELD, IL	SITE PREPARATION UNDERWAY
CO_2 FLOODING	3.2	1.2	GUYAN OIL CO.	GRIFFITHS FIELD, WV	BEGINNING INJECTION
	1.4	0.5	COLUMBIA GAS TRANSMISSION CORP.	GRANNY'S CREEK FIELD, WV	INJECTING CO_2
	2.6	1.0	PENNZOIL CO.	ROCK CREEK FIELD, WV	INJECTING WATER
			SHELL OIL COMPANY	WEEKS ISLAND FIELD, LA	INITIAL DEVELOPMENT
IMPROVED WATERFLOODING	3.9	1.2	KEWANEE OIL CO.	STANLEY STRINGER FIELD, OK	PRODUCING TERTIARY OIL
	7.6	2.2	SHELL OIL CO.	EAST COALINGA FIELD, CA	UNDER INJECTION
	14.0	5.6	CITY OF LONG BEACH	WILMINGTON FIELD, CA	DRILLING INJECTION WELLS
THERMAL RECOVERY	7.3	2.5	HUSKY OIL CO.	PARIS VALLEY FIELD, CA	INJECTING AIR
	0.8	0.7	CARMEL ENERGY CO.	CARLYLE FIELD, KS	INJECTING GAS AND STEAM
	8.7	2.0	GETTY OIL CO.	CAT CANYON FIELD, CA	CYCLIC STEAM STIMULATION
	8.2	3.1	CITIES SERVICE, INC.	BELLEVUE FIELD, LA	INJECTION TESTS
	8.2	1.7	CHANSLOR WESTERN CO.	MIDWAY SUNSET FIELD, CA	INJECTING STEAM
	1.3	0.5	OIL DEVELOPMENT CO. OF TEXAS	WILLOW DRAW FIELD, WY	UNDER INJECTION

POTENTIAL FOR ENHANCED OIL RECOVERY AND LOCATIONS OF SELECTED ERDA FIELD TEST CONTRACTS



EGR COST-SHARING CONTRACTS SUMMARY

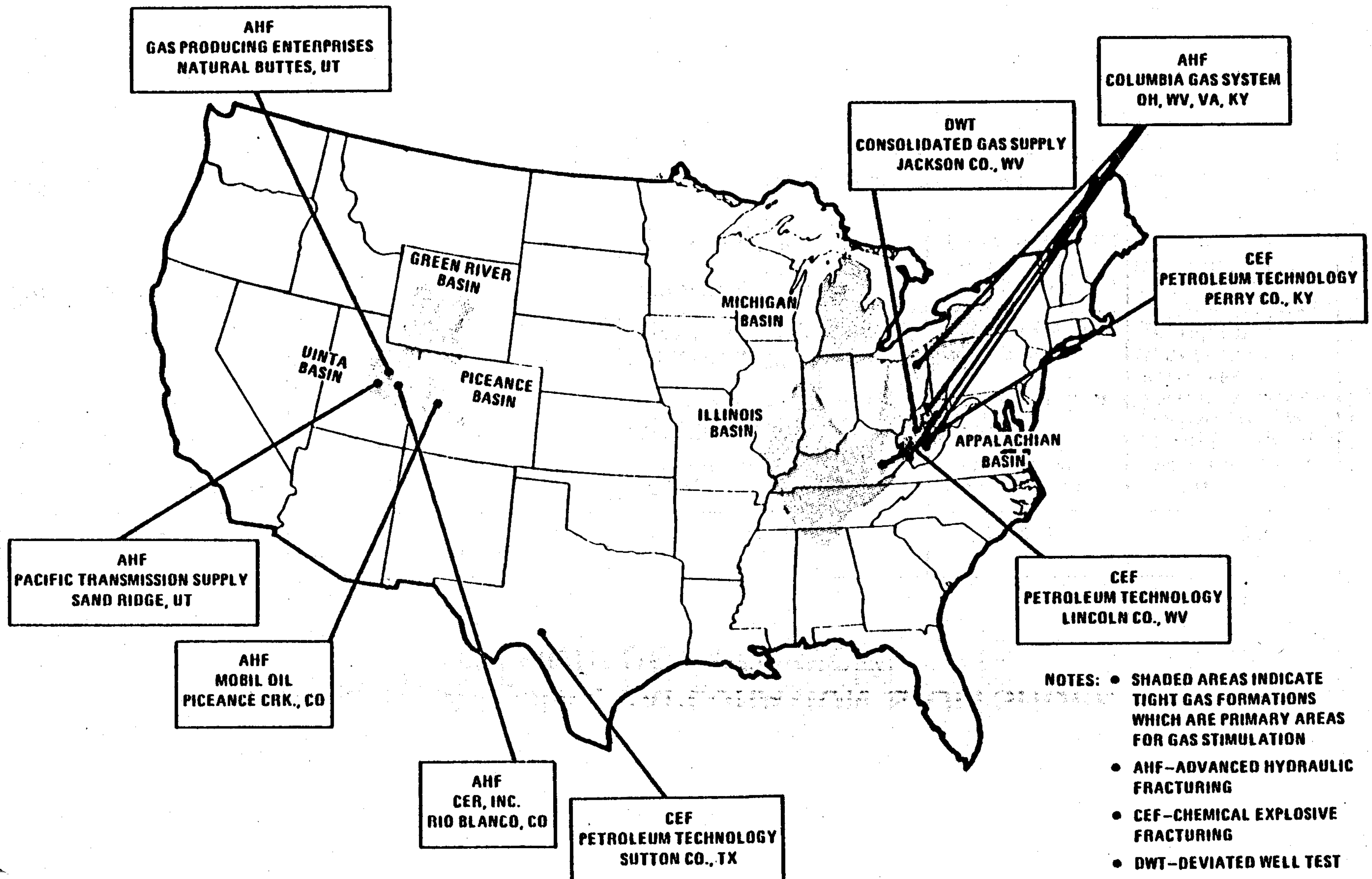
($ IN MILLIONS)

	PROJECTS	ERDA	INDUSTRY	TOTAL	ERDA PERCENT
MASSIVE HYDRAULIC FRACTURING	6	12.5	16.2	28.7	43
CHEMICAL EXPLOSIVE FRACTURING	3	2.4	2.3	4.7	51
DEVIATED WELL	1	.6	.2	.8	75
TOTAL	10	15.5	18.7	34.2	45

CURRENT MAJOR EGR CONTRACTS

PROGRAM	TOTAL FUNDING (MILLIONS)	GOVERNMENT CONTRIBUTION	PERFORMER	LOCATION	STATUS
MASSIVE HYDRAULIC FRACTURING	3.6	2.0	CER, INC.	RIO BLANCO CO., CO	FINAL TEST NOV 76
	4.3	2.1	COLUMBIA GAS SYSTEM, INC.	LINCOLN CO., WV	3 WELLS DRILLED; 3 OF 9 STIMULATIONS COMPLETE
	4.8	2.5	COLUMBIA GAS SYSTEM, INC.	OH, WV, VA, KY	DRILLING SELECTION
	7.0	2.2	GAS PRODUCING ENTERPRISE, INC.	NATURAL BUTTES, UT	2 WELLS STIMULATED; 10 REMAINING
	6.6	2.6	MOBIL OIL CORP.	UINTAH BASIN, UT.	DRILLING SPRING 77
	2.4	1.1	PACIFIC TRANSMISSION SUPPLY CO.	SAND RIDGE, UT	DRILLING OCT 76
CHEMICAL EXPLOSIVE FRACTURING			PETROLEUM TECHNOLOGY CORP.	1. PERRY, LESLIE, LETCHER COS., KY	
	4.7	2.4	PETROLEUM TECHNOLOGY CORP.	2. SUTTON CO., TX	STIMULATION NOV 76
			PETROLEUM TECHNOLOGY CORP.	3. LINCOLN CO., WV	
DEVIATED WELL TESTS	.8	.6	CONSOLIDATED GAS SUPPLY CORP.	JACKSON CO., WV	DRILL SITE SELECTION

POTENTIAL AREAS FOR GAS STIMULATION AND LOCATIONS OF ERDA CONTRACTS



NOTES:
- SHADED AREAS INDICATE TIGHT GAS FORMATIONS WHICH ARE PRIMARY AREAS FOR GAS STIMULATION
- AHF–ADVANCED HYDRAULIC FRACTURING
- CEF–CHEMICAL EXPLOSIVE FRACTURING
- DWT–DEVIATED WELL TEST

CURRENT DRILLING, EXPLORATION & OFFSHORE TECHNOLOGY PROJECTS

PROGRAM	TOTAL FUNDING (MILLIONS)	GOVERNMENT CONTRIBUTION	PERFORMER	LOCATION	STATUS
DRILLING & EXPLORATION	4.00	2.00	TELECO, INC.	MIDDLETOWN, CT	INSTRUMENT DESIGN IN FIELD TESTS
	2.07	.99	GENERAL ELECTRIC	HOUSTON, TX	RESEARCH CONDUCTED
	.45	.45	SANDIA LAB	ALBUQUERQUE, NM	RESEARCH CONDUCTED
	.27	.27	TERRATEK, INC.	SALT LAKE CITY, UT	BIT AND ROCK SIZE DETERMINED
OFFSHORE TECHNOLOGY	.075	.075	GURC	HOUSTON, TX	FINAL REPORT PENDING
	.35	.35	SANDIA LAB	ALBUQUERQUE, NM	FINAL TRANSMITTER TESTING

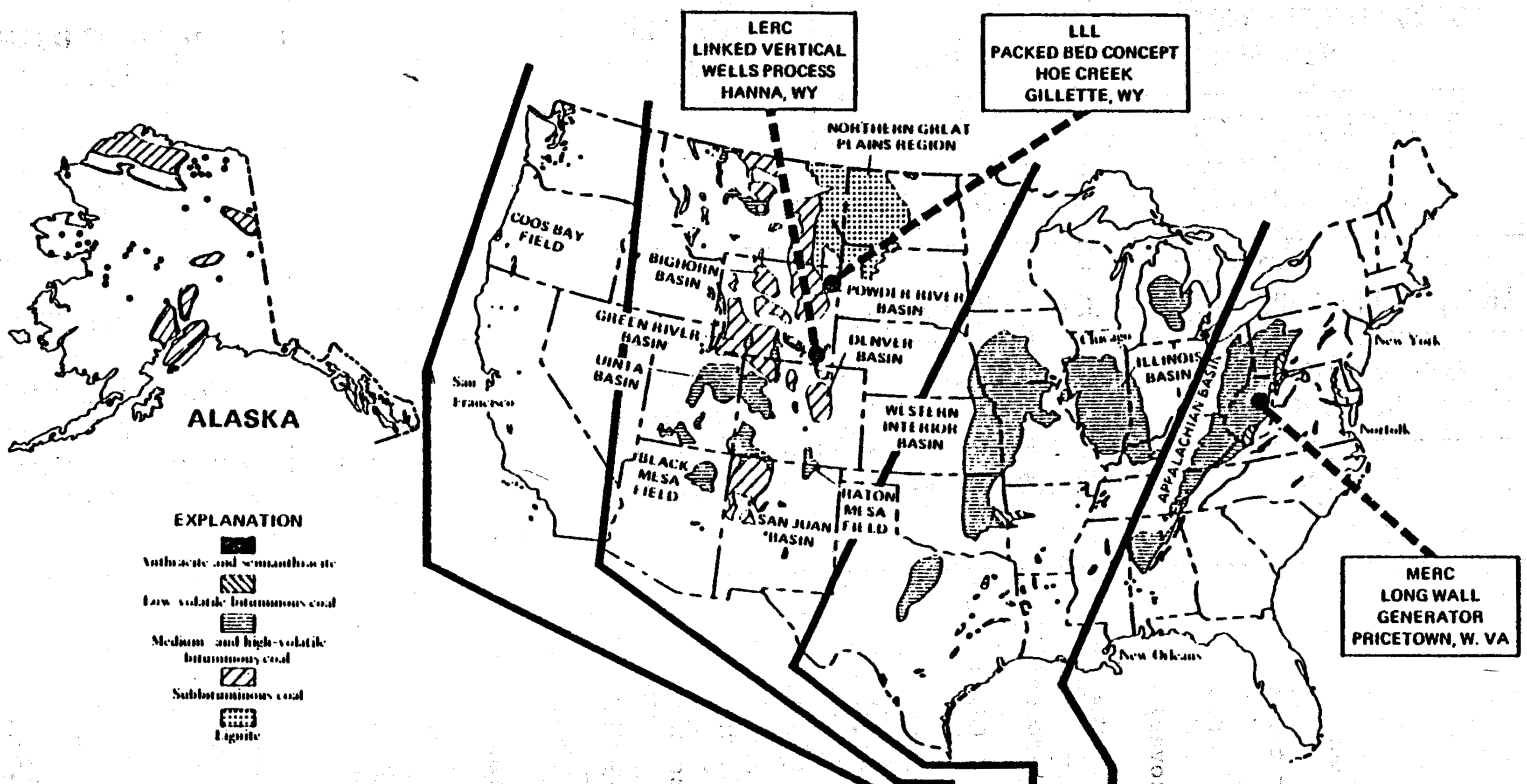
CURRENT MAJOR OIL SHALE PROJECTS WITH INDUSTRY

MAJOR PROJECTS	PERFORMER	LOCATION	STATUS
ANTRIM SHALE	DOW	MIDLAND, MI	4 YEAR CONTRACT AWARDED
TRUE IN SITU	TALLEY-FRAC	ROCK SPRINGS, WY	CONTRACT UNDER NEGOTIATION
SOLUTION MINING	EQUITY	RIO BLANCO COUNTY, CO	4 YEAR CONTRACT AWARDED
VERTICAL MODIFIED IN SITU	OCCIDENTAL	DEBEQUE, CO	CONTRACT UNDER NEGOTIATION
HORIZONTAL MODIFIED IN SITU WITH NOTICE-ABLE OVERBURDEN DISTURBANCE	GEOKINETICS	UINTAH COUNTY, UT	CONTRACT UNDER NEGOTIATION

CURRENT UNDERGROUND COAL GASIFICATION PROJECTS

PROJECT	FY77 FUNDING (MILLIONS)	PERFORMER	LOCATION	STATUS
LINKED VERTICAL WELLS (INTERMEDIATE, THICK)	3.3	LERC, SLA	HANNA, WYO.	TEST 3 ONGOING TEST 4 BEGINS SEPT.
PACKED BED (THICK)	2.7	LLL	HOE CREEK, WYO.	FRACTURE EXPERIMENT PLANNED
DEVIATED WELLS, LONGWALL (THIN)	1:0	MERC	PRICETON, W. VA.	PRELIMINARY TEST DESIGNED—WILL BE FIELDED IN THE FALL
DIPPING & DRY BEDS & ADVANCED CONCEPTS	1.2	ANL, ORNL, LASL, UNIV INDUSTRY	VARIOUS	RFD ISSUED RESPONSE EXPECTED 7/1

COAL FIELDS OF THE CONTERMINOUS UNITED STATES (8), (9), (10)



TOTAL COAL TO 6000 FEET (BILLIONS OF TONS):	2,029	103	3,263	620	352 - 6,367 TOTAL
ESTIMATED UCG RESOURCE (BILLIONS OF TONS):	640	15	920	140	80 - 1,795 TOTAL

*DIVIDE THESE NUMBERS BY 1.1 TO OBTAIN TONNES.

all of our technologies involve some kind of permeability enhancement, usually through fracturing.

Surface chemistry, very basic, particularly to our enhanced oil-recovery program.

Thermodynamic properties of fluids applies primarily to EOR, but secondarily to enhanced gas recovery.

Reaction kinetics is important in underground coal gasification.

Oil shale in situ retorting and gasification and thermal methods of enhanced oil recovery.

And, of course, environmental quality and reactions, the reactions part of which includes the environmental R&D, as distinguished from environment-compliance activities.

That's a rather rapid rackup, ladies and gentlemen. I think I've stayed within my time, to allow time for any questions.

DR. PHILLIPS: Thank you.

This talk is open for comments and discussion. Yes. Give your name, please.

MR. HILL: George R. Hill.

Do you have any work going on in safety in production, offshore drilling, preventing oil spills?

Is that in your bailiwick at all?

MR. WATKINS: Preventing oil spills is not; the prevention of and cleanup of contamination of oil spills is considered to be a province of the Coast Guard. We are doing work on oil identification from which you might be able to identify the source of an oil spill upon water from knowing the --

MR. HILL: -- depending upon a technique development to prevent it?

MR. WATKINS: Right. In safety, our work is only peripheral and it's very largely done in cooperation with our division of ESP, environmental and socioeconomic programs and in Dr. Liverman's shop. But we are becoming more interested in safety in our production and stimulation operations, yes.

DR. PHILLIPS: Dr. Holloway.

DR. HOLLOWAY: Holloway, from Exxon. What limits the amount of basic research you do in universities? And a related question, is it possible it's too small by an order of magnitude?

MR. WATKINS: In answer to your question, the only thing that limits it is the amount of supporting research that we feel we need to be viable with our applied research programs. Perhaps we do need more. I wouldn't say by an order of magnitude. My own opinion is that in the properties of mycellar and polymer chemicals, for example, we probably have all going on that is necessary to support our program.

Conversely, in the area of carbon dioxide and some of the other things, perhaps we don't have enough. So, there is nothing to prevent our program being higher. If fact, it has been increasing year by year and very possibly it should be quite a bit higher than it is at present.

DR. PHILLIPS: If I might take the Chairman's prerogative --

MR. WATKINS: Surely.

DR. PHILLIPS: I note there is nothing here on this list, sir, about instrumentation.

It would seem to me that in the in situ world that your group lives in, instrumentation for knowing what is going on down there must be very important.

MR. WATKINS: Oh, it is. It is, indeed.

DR. PHILLIPS: Can you say something about that?

MR. WATKINS: Yes. We have a very appreciable instrumentation effort being conducted primarily at Sandia Laboratories. This is instrumentation to determine what is happening in our in situ oil-shale retorting tests and in our underground coal gasification, as well as being applicable to enhanced gas recovery, where we are doing massive hydraulic fracturing and/or chemical-explosive fracturing. This is an appreciable effort. I don't know how much of it was racked up into the basic-research category that I came up with or the total figures, but part of it is instrument development and part of it, of course, is instrumentation for support of the project. But we are very cognizant of this.

DR. PHILLIPS: Miss Fox?

MS. FOX: Phyllis Fox. You stated that your activities were confined strictly to in situ. Are there any activities at all in the area of surface retorting of oil shale?

MR. WATKINS: At present, no Phyllis, except where our supporting, basic research and environmental research might be applicable to above-ground, as well as under-ground processing. There is, certainly, some overlap there. Now, we don't know what is going to happen in FY '79. We are trying to get an initiative into the budget for research on advanced above-ground retorting processes, but from here to OMB to the Congress is a long hard road, you know.

DR. PHILLIPS: If there are no other questions, we thank you, Mr. Watkins, and proceed with the meeting.

I will call next for Fred Holzer and his talk on In Situ Research.

MR. HOLZER: My purpose here is to describe to you very briefly the kind of in situ research being done at the national laboratories, to the best of my ability. But I really can't do that without also talking at some length about the work being done at the energy research centers.

Much of the work that I will describe is interdisciplinary in nature, with lab and field work - both theoretical and computational - and much of it has also been done by industry.

Most of the work that I will describe is being done at the Los Alamos Scientific Laboratory, the Lawrence Livermore Laboratory, Sandia Laboratory at Albuquerque, the Laramie Energy Research Center, and the Morgantown Energy Research Center. And if I am slighting those or others, please forgive me.

Let me start with my own definition of in situ research --

(Vugraph #1)

-- the study of underground processes leading to a conversion of a solid into either a gas or a liquid. I've restricted myself to coal gasification and shale oil from oil shale, although I would like to point out that in situ methods can have much wider application than that. For instance, a very active industrial process is now being carried out in uranium leaching in situ and recovery of oil from tar sands and heavy oil; some tar sand work has started at Laramie.

The motivation for this work is shown on the next vugraph.

(Vugraph #2)

Aside from the tempting targets of very large resources are the potential advantages of being cheaper and quicker with less environmental impact, and last, but perhaps not least, the potential for recovering those kind of resources which seem very difficult, if not impossible, to attack by conventional techniques at this time. I am primarily referring to the deep, low-grade resouces.

I would like to concentrate on two examples.

(Vugraph #3)

IN SITU RESEARCH IN COAL AND OIL SHALE

DEFINITION

THE STUDY OF UNDERGROUND PROCESSING METHODS IN WHICH CHEMICAL REACTIONS ARE INITIATED AND SUSTAINED IN A PREPARED VOLUME OF COAL OR SHALE, LEADING TO THE PRODUCTION OF A GAS (OF USEFUL ENERGY CONTENT) OR LIQUID PETROLEUM FROM THE ORIGINAL SOLIDS.

MOTIVATION

1. POTENTIALLY AN ALTERNATIVE TO MINES AND SURFACE PLANTS.

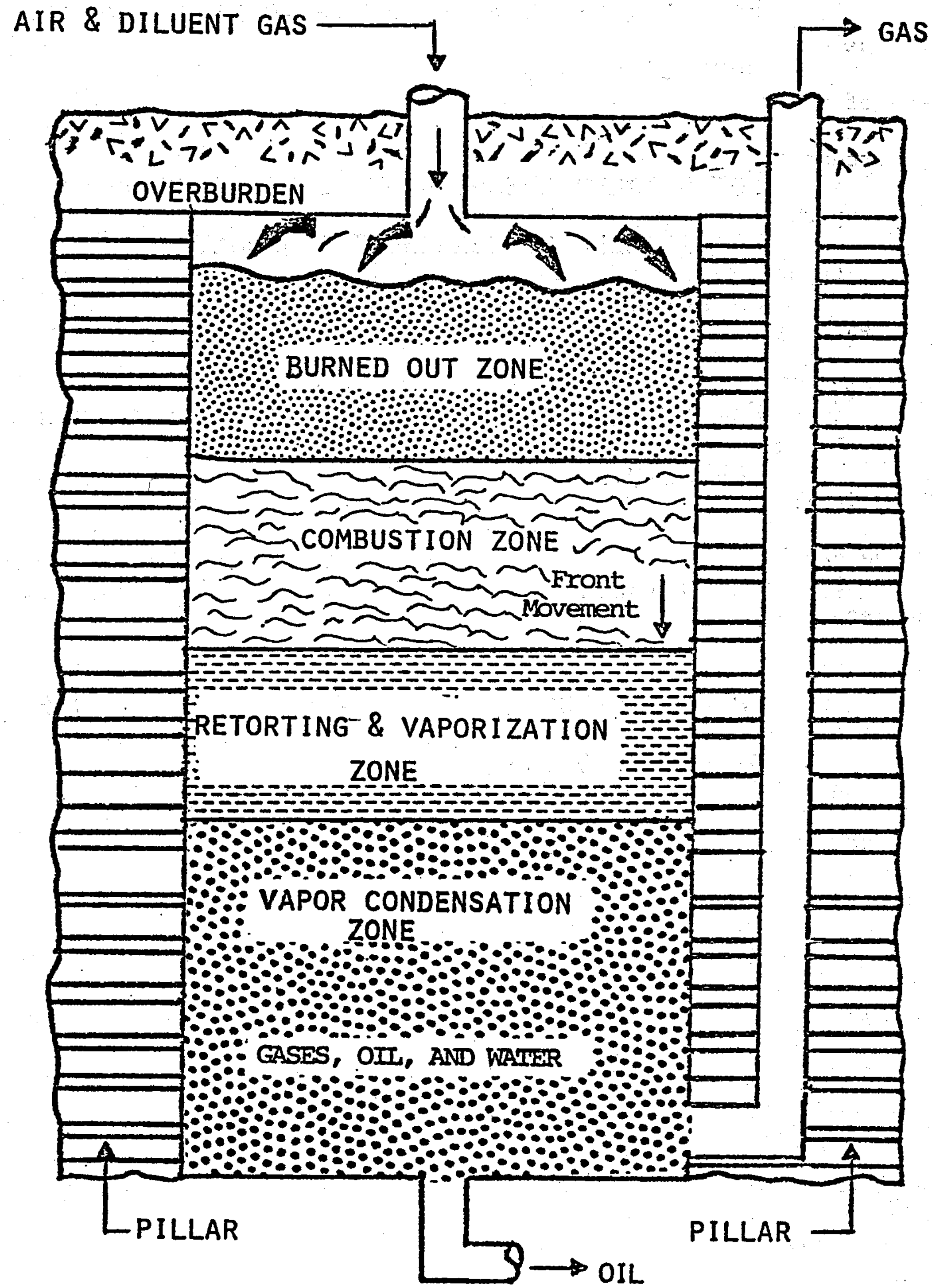
2. POTENTIALLY CHEAPER, BY ELIMINATING OR DRASTICALLY DECREASING THE AMOUNT OF MATERIAL THAT MUST BE HANDLED.

3. POTENTIALLY QUICKER, SINCE NO LARGE PLANTS ARE REQUIRED.

4. POTENTIALLY LESS ENVIRONMENTAL CONSEQUENCE.

5. POTENTIAL FOR MAKING DEEPER DEPOSITS, LOWER GRADES RECOVERABLE.

IN SITU OIL SHALE RETORTING



This first one is the so-called modified in situ retorting of oil shale. It requires the physical removal of about 10 to 20 percent of the volume to be retorted and the redistribution of this 10-20 percent an interstitial void between the particles after breaking up the remaining 80-90 percent of the rock.

Beyond that, the concept envisions a vertical retort similar to what might be carried out on the surface, with air injection at the top and gas and oil recovery from the bottom.

I might just point out that the amount of low Btu gas involved in in situ retorting of shale is a very large amount; if its Btu value can be kept steady and high enough, the gas can be utilized to generate electricity at the mine.

The second example --

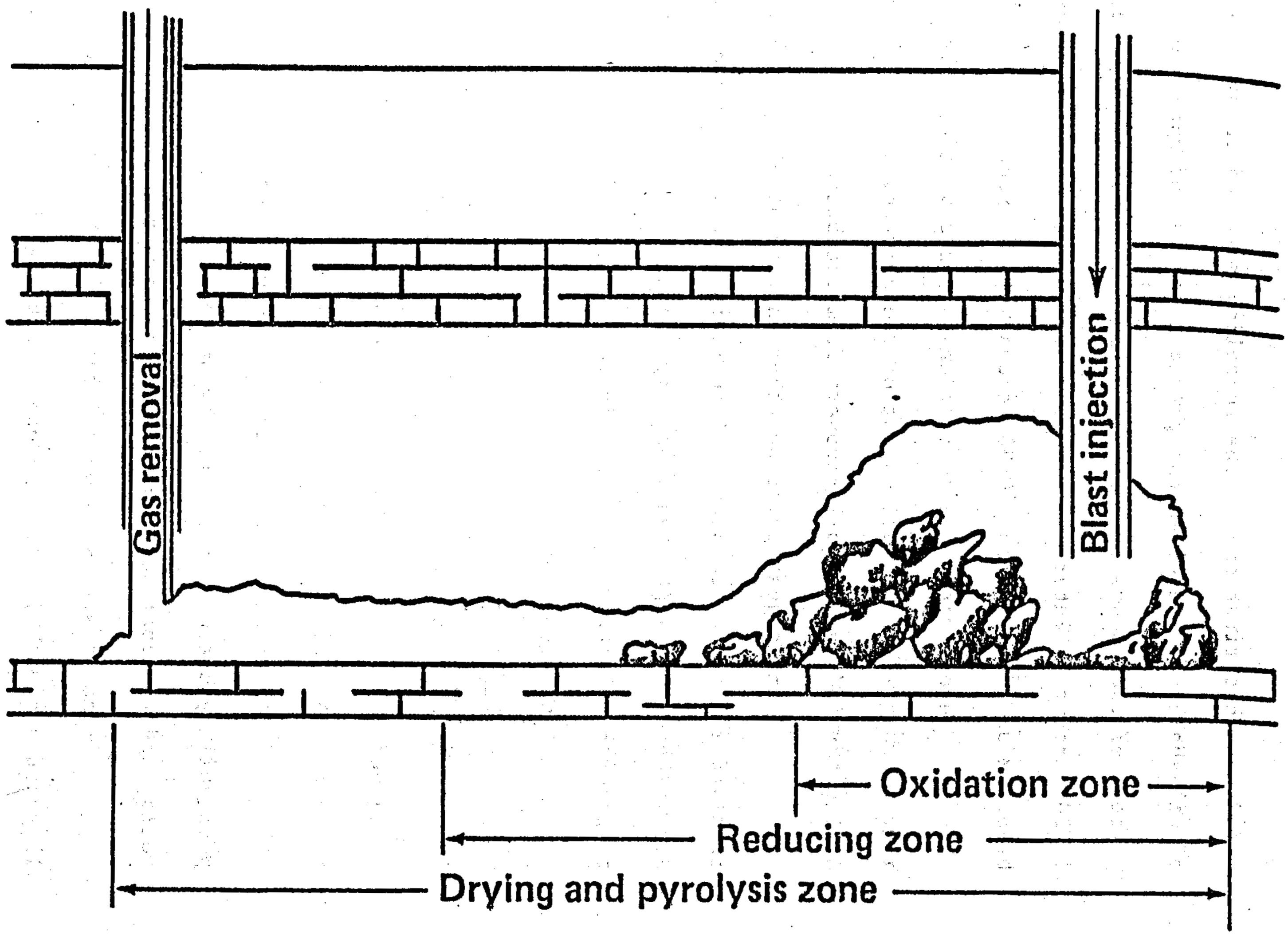
(Vugraph #4)

-- is the in situ gasification of coal, primarily of flat-lying beds. Here again there are a number of versions; some for instance, deal with steeply dipping beds.

I'm going to primarily talk about the method in which a low permeability channel is created by one means or another between two wells, and the coal between them is then gasified.

The in situ work on oil shale probably began between 10 to 15 years ago with its prime proponents being the Lawrence Livermore Laboratory and the Laramie Engineering Research Center. Coal gasification is a very much older subject, first suggested in the last

REVERSE COMBUSTION OF FLAT LYING COAL BEDS



century, and in 1931 it was started on a research basis in the Soviet Union. The Soviet Union has, in fact, put this technology on a commercial basis, starting in the late '50s or early '60s and is still operating three fairly sizable projects in in situ underground coal gasification.

In this country, while there has been sporadic effort following World War II, probably only in the last six or seven years has any sizable effort taken place.

(Vugraph #5)

The barriers to this type of work, of course, are many. The primary one, perhaps, is that up to now, with our resource and reserve availability, there has been no overriding need for it.

And it is difficult. It is difficult to adjust knobs and read meters, when you're dealing with processes underground.

Of course, all of these things, as you may have guessed and I am sure know, add up to higher costs.

I would like to guide you through a few of the items here to show you the status of these selected technologies and indicate the need for future work.

(Vugraph #6)

This vugraph shows the major research topics we believe need to be addressed. A good number of them are being addressed in developing these technologies.

Barriers

1. Up to now little need in the U.S., and very little experience with underground chemical engineering.

2. Methods for deposit preparation are still in early stages of development, and must be investigated on a large scale in the field.

3. Remote measurement and control of the reaction process is needed.

4. Many of the relevant properties of coal and oil shale are only now being determined.

MAJOR RESEARCH AREAS & TOPICS

LABORATORY EXPERIMENTAL RESEARCH

- REACTIONS, KINETICS, ANALYSIS
- LAB-SCALE RETORTING

LABORATORY CALCULATIONAL RESEARCH

- BED/DEPOSIT PREPARATION
- PROCESS MODEL

FIELD EXPERIMENTATION

- DEPOSIT CHARACTERIZATION
- DEPOSIT PREPARATION
- INSTRUMENTATION
- PROCESS EVALUATION

I'd like to add one word to those brought out by some discussion, particularly the environmental aspects. I personally quite firmly believe that research in the environmental aspects has to go hand in glove with, and at the same time as, research in the basic technology. I think doing one without the other is not very productive.

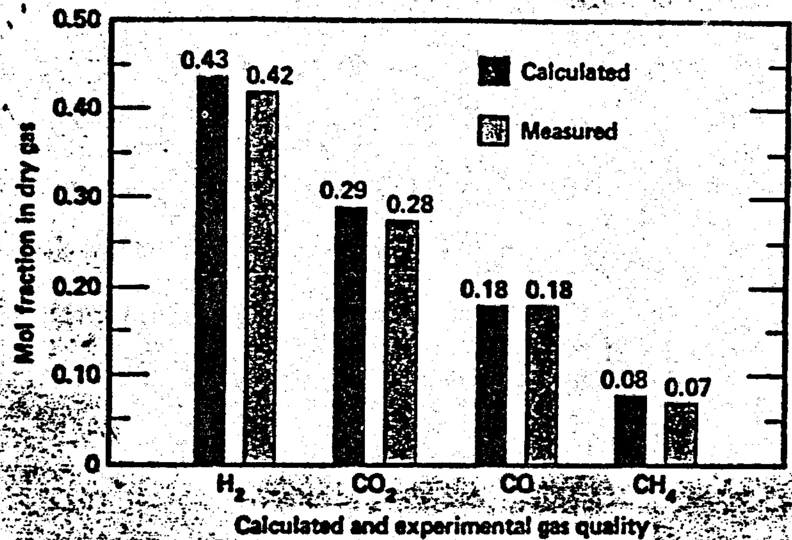
(Vugraph #7)

This vugraph, then, shows some of the coal reactions, both coal and char, with air, oxygen, steam, in the various temperature regimes of gasification, pyrolysis and drying, that go on when a temperature wave, which now is fairly broad, moves through a coal deposit.

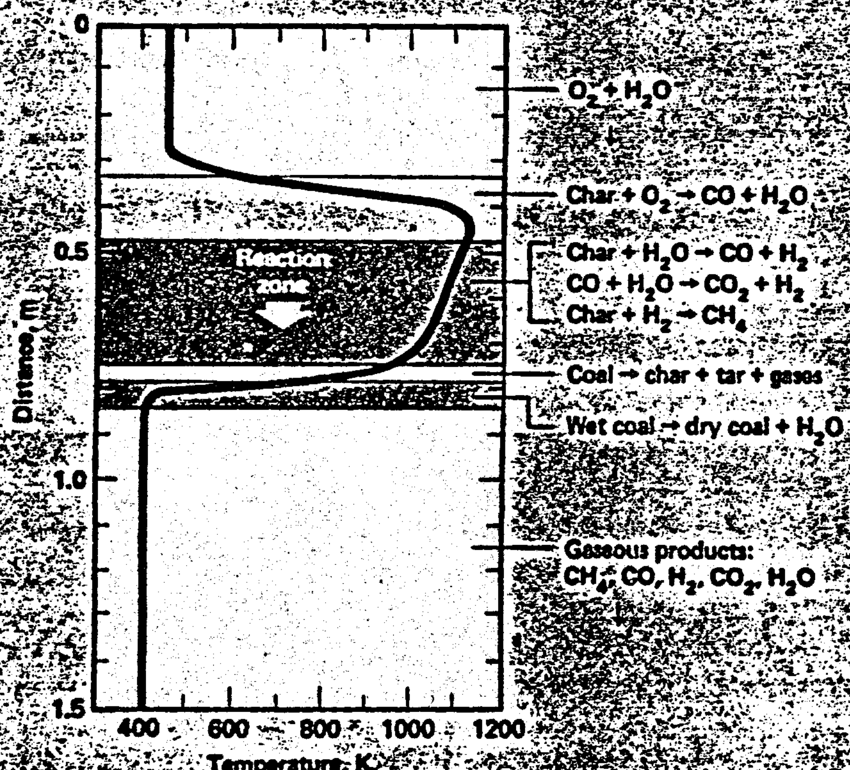
A very similar graph shown on the next vugraph holds true for oil shale.

(Vugraph #8)

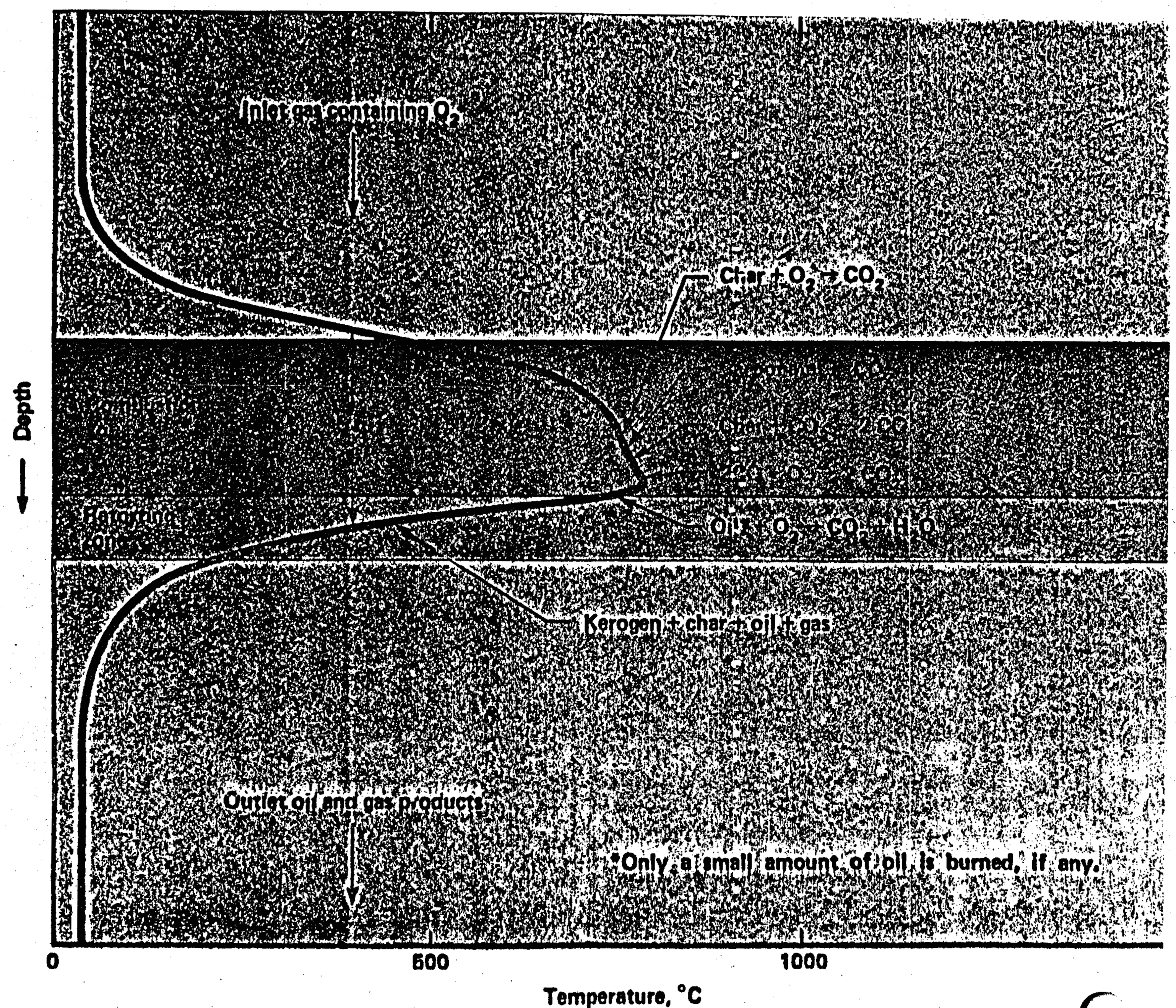
Again, pointing out the very close relation between these two subjects, I might point out that the reactions in shale are considerably more complex than the ones that we're dealing with in coal. Not only do you have to deal with the decomposition of kerogen in oil shale, but subsequently, you have to deal with the reactions of the carbonate material left behind in the rock which makes up most of the shale. The reactions of carbonates with water vapor, carbon dioxide, and carbon monoxide, particularly in the presence of very finely divided silica, is something that is not at all well-undersood.



0.50
0.40
0.30
0.20
0.10
0
Mol fraction in dry gas
0.43
0.42
0.29
0.28
0.18
0.18
0.08
0.07
Calculated
Measured
H_2
CO_2
CO
CH_4
Calculated and experimental gas quality



0
0.5
1.0
1.5
Distance, m
400
600
800
1000
1200
Temperature, K
Reaction zone
$O_2 + H_2O$
Char + $O_2 \rightarrow CO + H_2O$
Char + $H_2O \rightarrow CO + H_2$
$CO + H_2O \rightarrow CO_2 + H_2$
Char + $H_2 \rightarrow CH_4$
Coal → char + tar + gases
Wet coal → dry coal + H_2O
Gaseous products:
CH_4, CO, H_2, CO_2, H_2O


Inlet gas containing O_2
$Char + O_2 \rightarrow CO_2$
$CO + O_2 \rightarrow CO_2$
Retorting zone
$Oil^* + O_2 \rightarrow CO_2 + H_2O$
Kerogen + char + oil + gas
Outlet oil and gas products
*Only a small amount of oil is burned, if any.
Depth
0
500
1000
Temperature, °C

There is a very strong suggestion now from the work that has been done that these reactions are really much more important than people have perhaps realized.

A good part of experimentation, aside from purely analytical, kinetic, and reaction chemistry is something that I might like to call macroscopic experiments, and is done in controlled and instrumented retorts.

Big pressure vessels can be instrumented and controlled rather closely. These vessels span the spectrum of sizes.

(Vugraph #9)

This shows two very large ones in operation at the Laramie Energy Research Center for oil shale; the larger one of the two is able to handle 150 tons of shale.

(Vugraph - photo not available)

The next vugraph shows a much more modest one that Lawrence Livermore Laboratory uses to study reactions in coal; here the instrument cables are disconnected and the thing rides on trunnions for easier loading.

Data from both the material properties and the retorts are integrated into a computational framework, a model if you will, which serves to determine the sensitive variables, to plan retort experiments, to establish design criteria, and to optimize and control in situ retorting designs.

The 10-Ton and 150-Ton Oil Shale Retorts

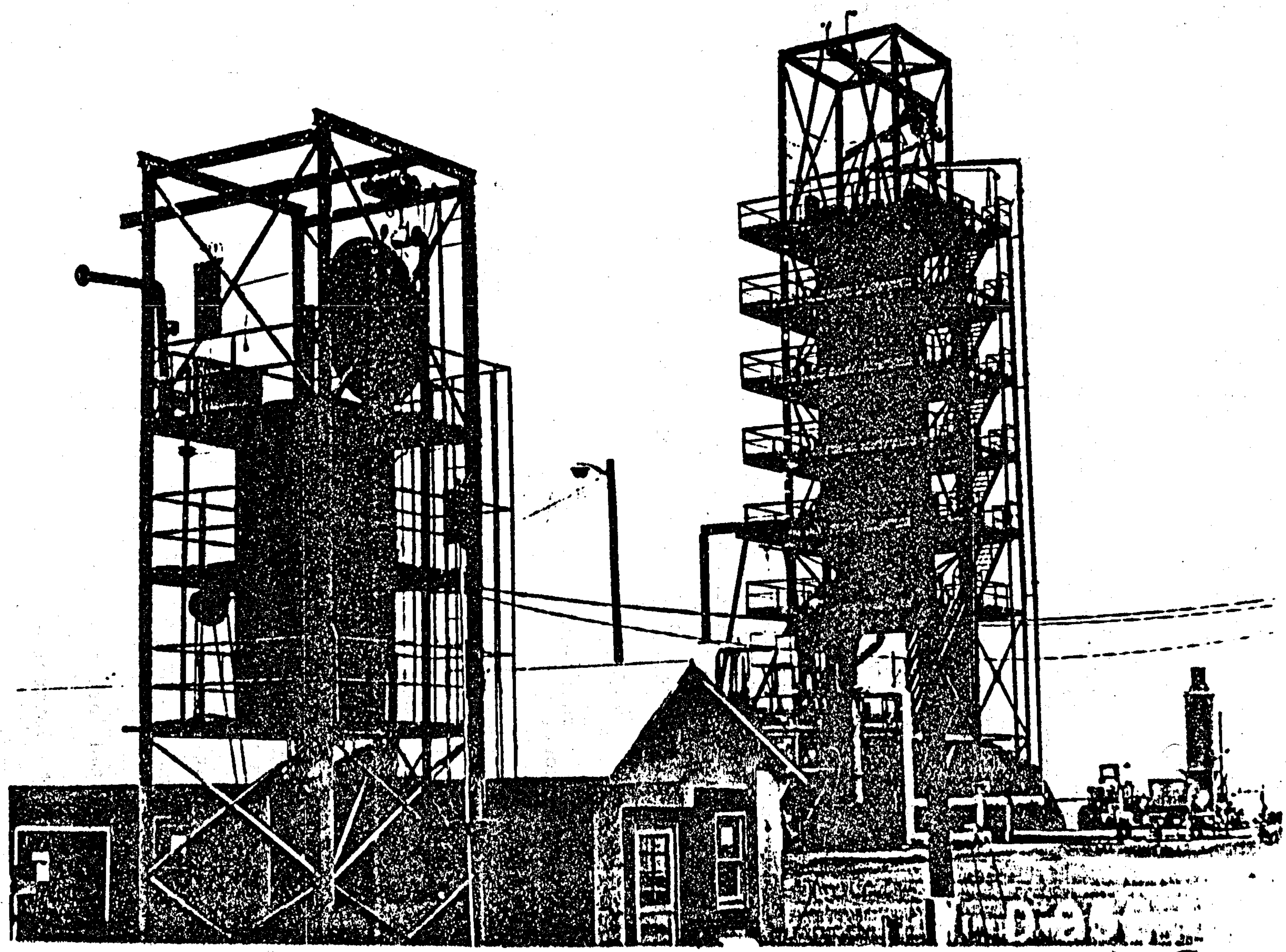


Photo provided by the Bureau of Mines

(Vugraph #11)

This vugraph shows a conceptual schematic of a central role that I believe, we will see these rather complex computer-based models take on in the near future.

Just to give you some idea of what is in some of these models that are in operation, the next vugraph lists the contents of an oil shale retort in operation at the Lawrence Livermore Laboratory at this time.

(Vugraph #12)

It includes hot gas and combustion retorting and takes into account particle size distribution, temperature compositions, flow rates, end yields as an output, and not only oil yield and rate of recovery, but the details of temperature, pressure, and composition within a retort during the retorting cycle.

This particular model is still in the process of being added to and developed, and the next vugraph--

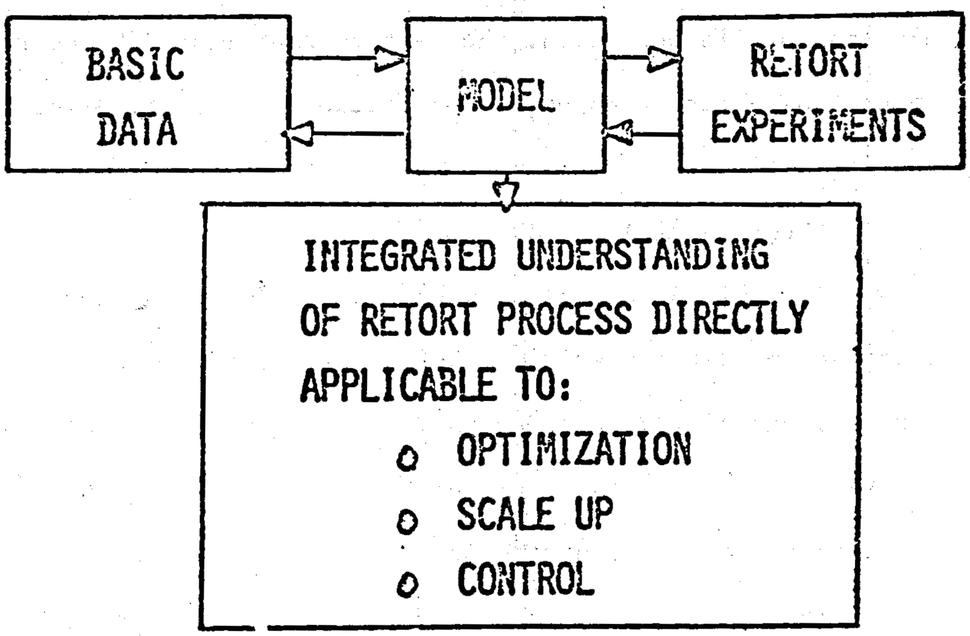
(Vugraph #13)

--depicts the need for further development of this type of model.

Just to give you an example of the kind of output that a model like that can produce, this next graph shows the temperature front as it is calculated to exist after passing some 40 meters downward into an in situ retort for two rather distinct particle sizes differing by an order of magnitude.

RETORTING - EXPERIMENTAL APPROACH

APPLIED RESEARCH



SCOPE OF PRESENT OIL SHALE RETORT MODEL

- One-dimensional model
- Hot-gas retorting and combustion retorting
- Shale particle size distribution
- Temperature and composition of shale particles
- Temperature, composition, and flow rate of gas stream
- Oil yield, rate of oil recovery, and rate of water recovery

FURTHER DEVELOPMENT OF MODEL

- Improvement in the numerical methods
- Improvement in the values of the sensitive chemical and physical properties
- Inclusion of additional gas and solid components
- Variations of initial bed properties in axial direction
- Chemical reaction of water with carbon residue
- Change of bed permeability due to softening of high-grade oil shale or due to accumulation of high-viscosity oil
- Loss of gas or heat to surroundings
- Water intrusion from surroundings
- Sweep efficiency of input gas

(Vugraph #14)

I think you can see that the smaller particle size distribution undergoes considerably different reactions and reaction rates than the larger ones.

In practice, of course, depending on how one prepares the deposit, which is a separate topic in itself, one might find an average or the situation peaked towards one or the others.

I've mentioned that an important, and I believe vital, component in this kind of business is field experimentation.

Let me take you very quickly through the status of some of these field activities.

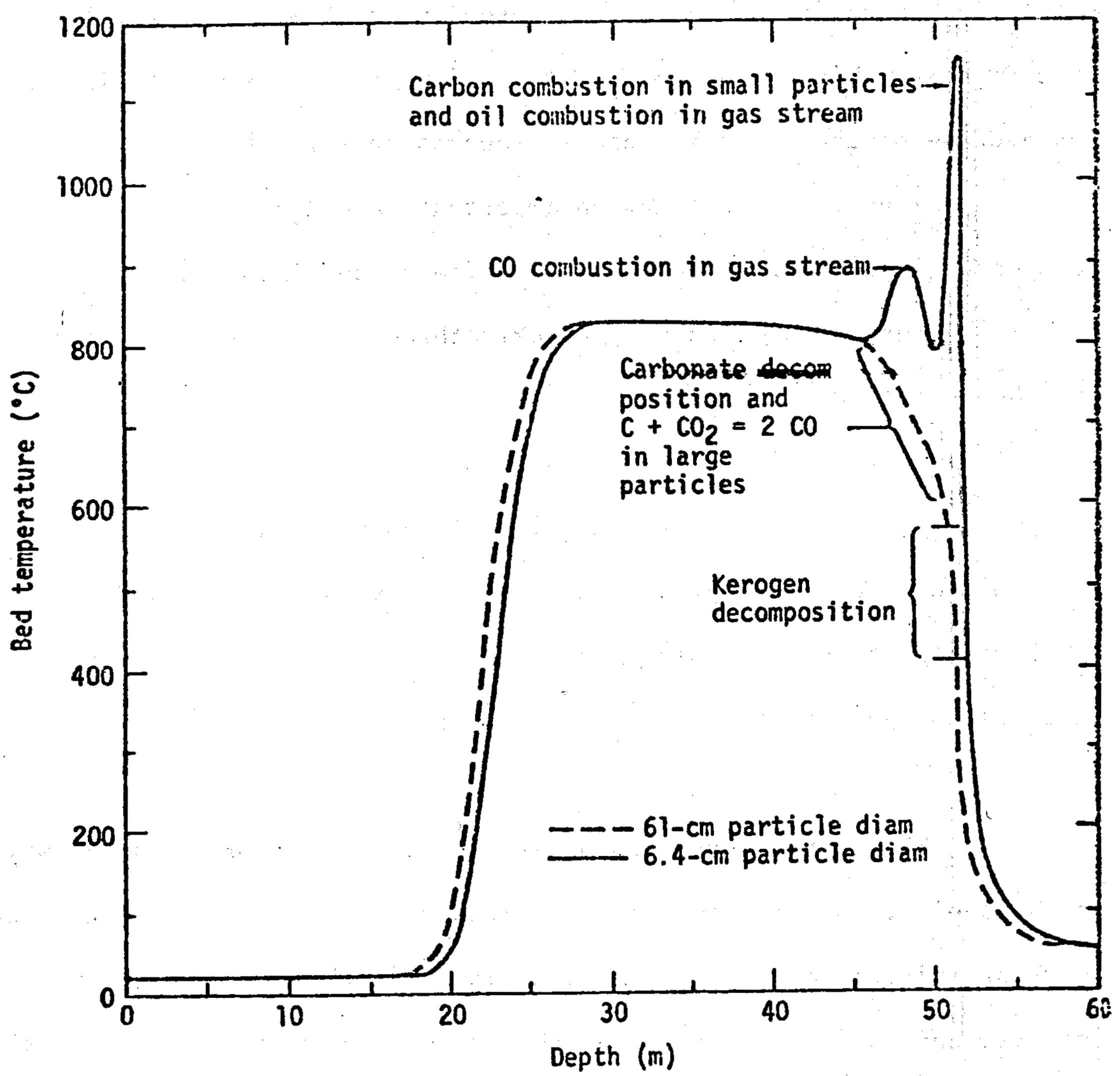
(Vugraph #15)

Here I show you a plan view of isotherms as a function of time, of what I believe is the most successful underground coal gasification experiment conducted to date, the one by the Laramie Energy Research Center near Hanna, Wyoming.

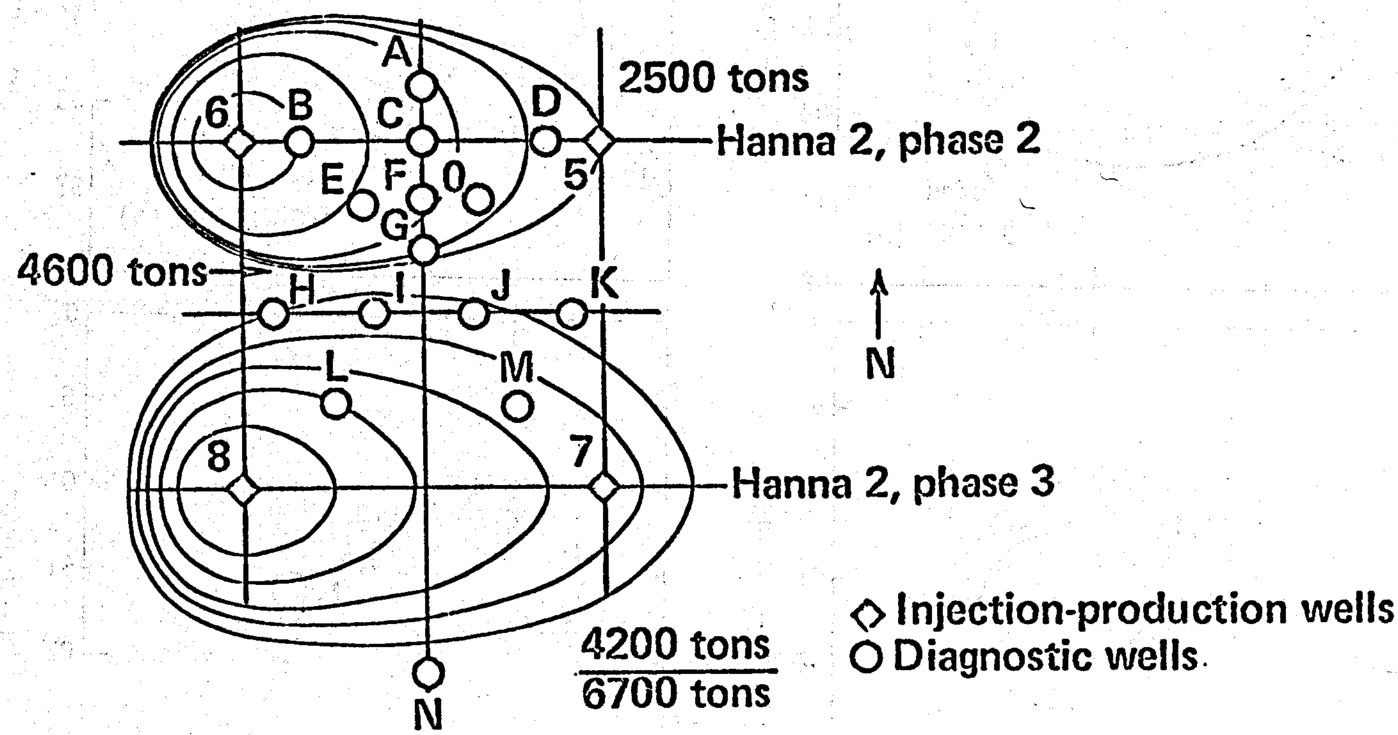
(Vugraph #16)

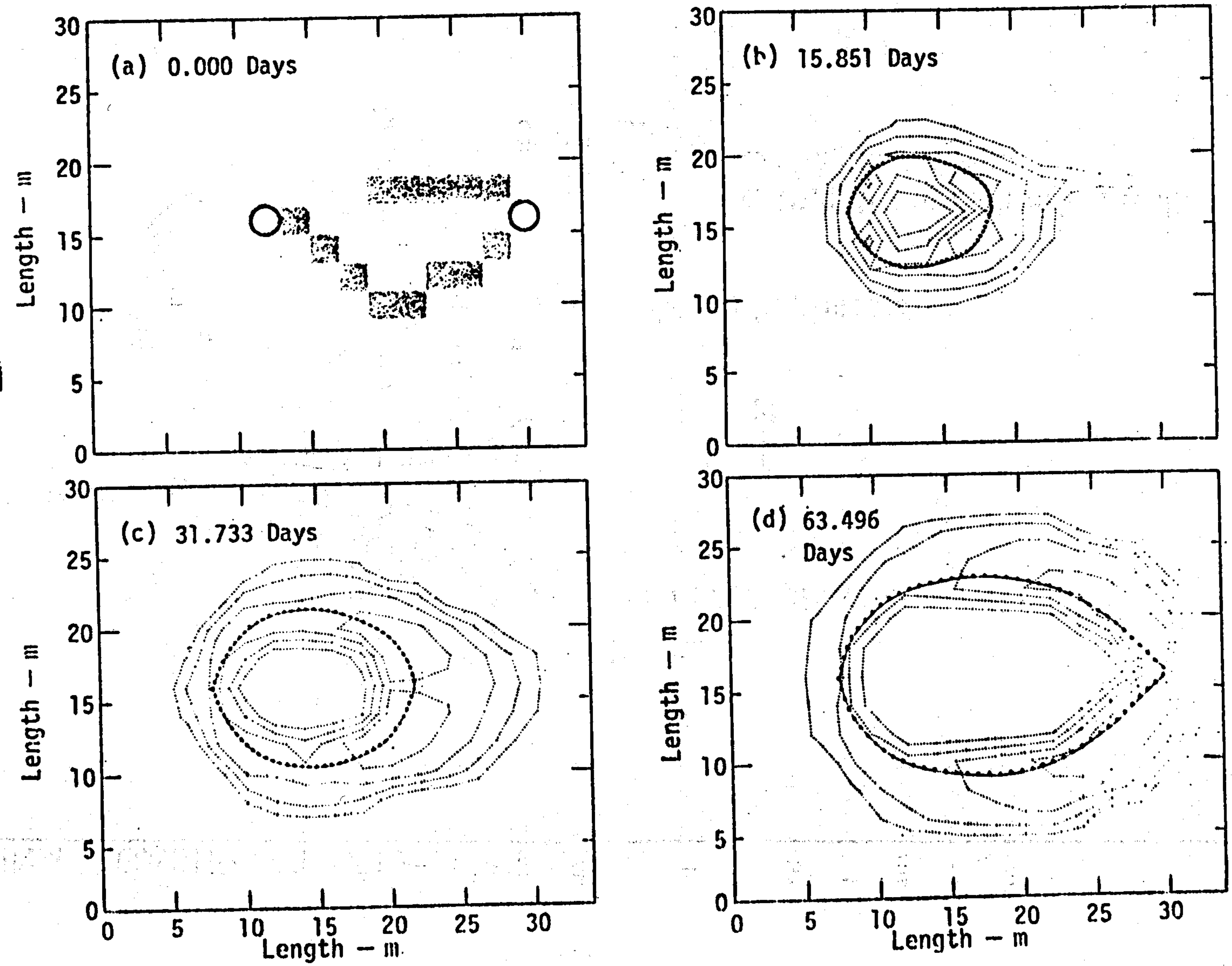
The next vugraph again depicts what can be done in the way of a model; these are model calculations of those isotherms, starting with an initial channel geometry, depicted in the upper left-hand square, and you can see that the channel was not very straight. It's determined by the initial permeability distribution of the material, and it is a credit to the instrumentation developed primarily by the Sandia Laboratories to even elucidate where that channel was.

ESTIMATED TEMPERATURE PROFILE FOR AN IN SITU RETORT WITH AIR INPUT



HANNA II GASIFICATION PATTERNS




(a) 0.000 Days
(b) 15.851 Days
(c) 31.733 Days
(d) 63.496 Days
Length — m
Length — m
0
5
10
15
20
25
30

(Vugraph #17)

In this vugraph I attempt to list some of the instrumentation that has been employed at Hanna, as well as at other sites. Instrumentation consists of primarily two kinds. One, simple and practical instrumentation of temperature, pressure, gas composition, and the other, remote monitoring instrumentation, in which acoustic, seismic, as well as electrical systems, are used.

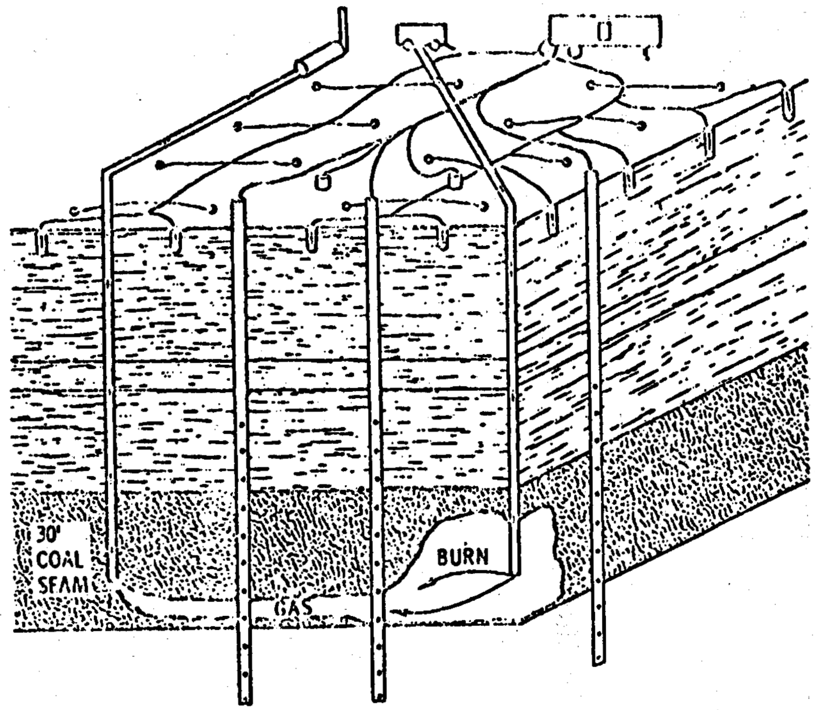
It is especially those latter ones that I personally feel need to be developed and pushed very vigorously, not only for their obvious utility in these experiments, but as we go deeper, measurement becomes more expensive and difficult. For a number of reasons, we need to look beyond the borehole, and I think mention has already been made of the Devonian shale problem, in which fractures beyond the borehole may be a key to the efficient recovery of gas from the resource.

I know I have left out many items and topics. However, let me just conclude by giving a summary of the research needs and opportunities, as I see them.

(Vugraph #18)

I have talked very little, as you can tell, about deposit preparation which entails the science of rock mechanics, both in the fragmentation aspect and the stability and subsidence aspect. There is a great deal more to be done in field instrumentation and field experimentation.

INSTRUMENTATION AND PROCESS CONTROL DEVELOPMENT FOR IN SITU COAL GASIFICATION



PARTICIPATION ON LERC TESTS:

Hanna I		1973-74
Hanna II	ϕI	1975
Hanna III	ϕ2, 3	1976
Hanna IV		1977-78
Hanna V		1978-79

6-77

REMOTE MONITORING INSTRUMENTATION - PROCESS MAPPING

Electrical Potential
Electrical Resistivity
Induced Seismic
Passive Acoustic

DIAGNOSTIC INSTRUMENTATION - PROCESS UNDERSTANDING

Temperature
In Seam Gas Sampling and Pressure
Subsidence: Tilt and Displacement

ACCOMPLISHMENTS:

Thermal Data/Analysis Provided Excellent Process Description

In Seam Gas/Pressure Methods Proven Feasible

Acoustic Emission Mapped Overburden Subsidence

Electrical Techniques - Contour Maps of Changing Process

Induced Seismic - Delineate Process Boundaries

SUMMARY OF TOPICS IN NEED OF FURTHER WORK

MATERIAL BEHAVIOR

- MECHANICAL PROPERTIES
- CHEMICAL REACTIONS AND KINETICS

DEPOSIT PREPARATION

- RUBBLIZING, CHANNELING
- STABILITY, SUBSIDENCE

PROCESS MODELS

- SENSITIVITY OF VARIABLES, FLUID INFLUX
- RETORT OPERATION, OPTIMIZATION

INSTRUMENTATION

- DEPOSIT CHARACTERIZATION
- PROCESS MONITORING

FIELD EXPERIMENTATION

- OIL SHALE FIELD EXPERIMENTS
- STEAM-OXYGEN COAL GASIFICATION

We really have not had a good oil shale field experiment, although there have been one or two industrial experiments. But the information from those experiments is not available.

In the coal gasification area, even though things look exceedingly promising, much work needs to be done in trying to tailor a linkage between two wells, rather than let nature dictate what this linkage looks like, and work is proceeding on high explosive development, including shaped charge development. In order to upgrade gas energy content, gasification with steam and oxygen, instead of just air, seems a very promising and certainly indicated approach.

Thank you very much.

(Applause)

DR. PHILLIPS: Thank you, Fred.

DR. PHILLIPS: The Floor is open for comments and discussion. Yes, Dr. Smith?

DR. SMITH: Roland Smith, General Electric. You and the previous speaker both mentioned the work I believe Sandia is doing on instrumentation. How much of this instrumentation is applicable to, say, a commercial operation, as opposed to development operations, and how do you anticipate getting that information transferred to industrial use?

MR. HOLZER: I believe a good bit of that is applicable to commercial operation. Clearly, one would not want to go with the experimental type of instruments. I personally believe that one must go with the most reliable ones, which, at the present time, are thermocouples, although the emplacement of sufficient thermocouples which, after all, only measure the situation and temperature at any one specific point, has its obvious limitations.

I think, however, it is absolutely necessary for control and monitoring of an underground burn in order to know when to increase the flow rate, when to decrease it, and when to change the mixture of gases. In oil shale retorting, for instance, one has the liberty of changing the oxygen concentration or adding nitrogen, or water, in the form of steam.

I feel quite confident that all of the government installations having experience and capability in instrumentation (and that does not just include Sandia, of course) stand ready to transfer this experience and knowledge to industrial companies. And there is a very good base already there. There are a number of industrial companies that, with very little additional experience, would be very capable of doing this. EG&G is one company that comes to mind, and I know there are others.

DR. PHILLIPS: Yes.

DR. NELSON: Nelson. I presume this illustrates a lack of knowledge about the techniques that, in some degree, control the temperature in your in situ retorted shale oil; is that right?

MR. HOLZER: To some degree, yes.

DR. NELSON: That being the case, I would anticipate that the kind of problems are whether the carcinogens to be formed in the various cracking will vary in accordance with the temperatures.

Is there an orderly postured program to characterize these components? In other words, are you exploiting this present pilot stage to get that additional information?

MR. HOLZER: Yes, I think there definitely is. Whether it is of the same order in all experiments, I can't really tell you; I suspect it probably is not. But I do know that analysis for organic materials, things like phenols, and so on, are being analyzed and, in fact, the next experiment that the Laramie Research Center is carrying out at Hanna is specifically slanted towards the environmental monitoring. I know the Lawrence Livermore Laboratory in their coal gasification experiment near Gillette, Wyoming, has monitored phenols and particularly their transport in the groundwater system around the experimental site.

DR. NELSON: These are not carcinogenic, per se.

MR. HOLZER: You're correct.

DR. PHILLIPS: I would like to return to the first question on instrumentation. I think that those of you that know the history of one of the predecessor organizations of ERDA, AEC, know that out of AEC - in fact, the high energy physics program and nuclear physics program - came a line of instrumentation called KEMAC, and many factories across the nation and the world use that type of instrumentation.

I am sure you have a lot of NIM and KEMAC instrumentation in your hospital Dr. Nelson.

So this is a sample of the crosscutting technology that came out of the field that can certainly help other fields, as well.

Are there other comments or questions?

MR. HOLZER: One more question, I think.

MS. FOX: Phyllis Fox. Phil White, this morning mentioned some of the problems that may be associated with the intrusion of groundwater into abandoned in situ retort chambers. Do you have any research program in the area of identifying the impacts of these abandonments in in situ retort chambers - how the groundwater reacts, both on the short-term and long-term?

MR. HOLZER: You must realize that there are very, very few of the in situ reorting volumes in existence at this time, and they certainly have not been in existence for very long. So the long-term question is a very difficult one to answer. But, yes, indeed, these sites are being monitored by both gas and liquid withdrawals from wells around here, and analyzed for organic, as well as inorganic substances. And I might add, in that respect, ERDA, and the AEC previously, have a very long history of not walking away from those kinds of sites. I know we are monitoring similar experimental sites that were done 15 years ago.

MS. FOX: Have you thought about and anticipated what types of control technology might be utilized if a problem is identified, of which significant environmental impact could be expected?

MR. HOLZER: I'm a very poor person to answer that question, Phyllis. Perhaps, there is an expert who is willing to do that for me.

MR. HAYNES: Bill Haynes. I'm not really an expert. I think, Phyllis, we are trying to anticipate these problems. The simulated in situ retorts, the big ones that he showed the pictures of. We are taking the spent material from that, soaking it up in water, and trying to see what kind of things we would have. First, you have to see what the problem is, anticipate it, then you try to go at the control. But you have to see if you can anticipate this. And, true, it's kind of hard to do it down underground, but we're trying to do it on a - what shall I say, rather a large-small scale?

MR. HOLZER: I think the important thing is not to let the opportunities for this type of monitoring and evaluation and early detection of potential problems slip past us.

I personally believe that's exceedingly important. And, as I say, I've always taken the position that technology and environmental research are two very closely related aspects and need to be done concurrently.

DR. PHILLIPS: I think that's certainly right. We all agree on that. If it weren't for environmental questions, we would all still be burning coal and all cities would look like Pittsburgh used to look when I was a young man. Thank goodness it doesn't look that way now.

I believe we must proceed then with our program. The next talk, again on National Laboratory research, is by Alex Zucker.

DR. ZUCKER: Coal, gas, and oil are time-tested energy resources. Why, one may ask, should it now suddenly be necessary to mount multi-million dollar research programs in technologies where so much is known, so much experience exists? The answer is very simple: circumstances have changed and created conditions which require action, and moreover the fossil energy resource is crucial to the future of the nation. What we do about it in the next decade will affect our way of life for generations. We define four Fossil Energy Imperatives:

1) Easily recoverable oil and gas will be exhausted within the next few decades. This means that we have to produce transportable fuel from other sources, that we have to extract oil and gas from more untractable formations, and that we have to develop alternate technologies. <u>We have to do something</u>.

2) While there are many options open to us, only a few can be developed to mature technologies because the costs are so high in terms of capital investment and technical skill. <u>We can not do everything</u>.

3) The energy industry is enormous, and its impact on the economy, and finally on the well being of each us, is profound and difficult to alter with any short time constant. <u>What we do can not cost too much</u>.

4) The enormity of the energy industry reflects not only on the economy, but also on that vast and intricate system in which we live, that currently goes by the name of environment, safety, and health. A small deleterious effect, tolerable in an industry of modest size, can become ruinous when examined in the context of billions of tons. Doubts in this area can, and should, slow things down until the answers are clear. <u>What we do can not harm us</u>.

From my vantage point the situation calls for a research effort of proportions commensurate with the industry:

a) we depend on research to provide data, systematizations, and ideas which will enable us to develop alternatives to oil and gas at a price that will not be ruinous to the economic welfare of our citizens;

b) we depend on research to explore, by laboratory scale research, by mathematical modelling, by scientific analysis, the plenitude of options, and to narrow these to a promising few;

c) we depend on research to inform us of those deleterious consequences of energy industries that we now perceive only dimly, and thus avoid costly and time-consuming paths that lead nowhere.

National Laboratories are large multiprogram research institutions that have some characteristics which make them useful and productive partners in a field like fossil energy research.

First, National Laboratories possess a rich tradition of successful research. Reactors, accelerators, fusion devices, fuel cycles, and weapons, all offer concrete evidence that National Laboratories can produce concrete results. The vast panoply of research papers shows that multifaceted scientific research, from quarks to corrosion, from neutrino physics to nu bodies in chromatin, has found fertile soil there. Much knowledge relevant to fossil energy exists in these Laboratories, and in many cases, for example materials science, aqueous chemistry, or environmental research, the Laboratories lead the world.

Second, National Laboratories conduct their research in a multidisciplinary framework where organic chemists might work along with atomic physicists, or chemical engineers with microbiologists. This kind of scientific environment enables the scientist to attack a problem in a holistic fashion, while at the same time the very size of a National Laboratory places at his disposal equipment to which he would otherwise not have easy access. Furthermore, the Laboratory environment provides stimulating exchanges of ideas that not infrequently lead to important discoveries.

Third, in many National Laboratories research is carried out alongside mission-funded technical development. This assures a cross fertilization whereby real-life development problems are known to the scientist who may be doing long-range research and affect his line of work, while, conversely, it serves as a conduit of the newest scientific information through the scientist to the engineer who might be having problems with his process.

I'll illustrate the thesis set forth previously - namely that research is indispensable to the utilization of fossil energy under the new ground rules, and that National Laboratories can and are making important contributions toward the solution of fossil energy problems. I'll mention some representative examples, not their importance, and relate them to the overall fossil energy program. It is worth pointing out that in many instances National Laboratories, through the knowledge and experience of their staffs, have been able to provide quick fixes for acute problems, contrary to the popular belief that the payoff in scientific research is decades away.

Slide 1. Sandia accomplishments in materials research: a) extend drill life by a factor of five; b) altering 310 stainless steel alloy increases sulfidation resistance; c) developed TiB_2 coating resistant to erosion and corrosion.

Slide 2. Argonne has drawn on its high energy physics expertise to build superconducting magnet for MHD development.

Slide 3. Oak Ridge: microprobe analyses show variation of organic sulfur distribution in coals.

Slide 4. Solvent refined coal pilot plant has pipe-plugging problem. X-ray diffraction and micro-probe analysis at ORNL diagnoses the trouble and suggests a cure.

Slide 5. Thermocouple failures plague synthane gasifier pilot plant. Argonne scientists diagnose the problem, recommend high-chrome stainless steel, and fix the problem.

Slide 6. The Argonne Biomedical and Environmental Research Program concerned with coal shows the breadth of the problem. Parallel efforts with different program elements are carried out at Brookhaven, Berkeley, Oak Ridge, Los Alamos, Battelle North-west, Livermore.

Slide 7. Knowledge of chemical bonding in coal compounds may enable us to break linkages at low tempera-ture and pressure. Oak Ridge chemists show that methyl-like bonds can be broken at 400°C with vitrinite as the hydrogen donor.

Fossil energy research is not a frill, it can not be regarded as an activity to be tolerated while the real work on coal liquefaction or tertiary oil recovery is carried out by performance-oriented achievers. Research in fossil energy is essential if the goals set out earlier are to be achieved at a price that is within our means. Let me illustrate. Slide 8 shows a conceptual design of a HYGAS coal gasifier. Note the enormous size (220 feet tall), the high temperatures (up to 1900°F), and the complex internal structure. Now we examine in Slide 9 metals currently available for high tempera-ture service. Engineers like to design equipment for service at

SANDIA LABORATORIES
RESEARCH ACCOMPLISHMENTS

MATERIALS RESEARCH

DRILLING

USE OF A HIGH TEMPERATURE, HIGH STRENGTH BRAZING TECHNIQUE HAS EXTENDED THE LIFE OF THE GE COMPAX DRILL BIT BY A FACTOR OF 5.

SULFIDIZATION RESISTANCE

ADDITION OF 2% TI OR 3% AL TO 310 SS SIGNIFICANTLY INCREASES RESISTANCE TO SULFUR ATTACK WITHOUT CHANGING PROCESSABILITY.

EROSION

A VERY HARD TiB_2 COATING HAS BEEN DEVELOPED THAT IS VERY RESISTANT TO EROSION AND CORROSION.

1. Sandia accomplishments in materials research: a) extend drill life by a factor of five; b) altering 310 stainless steel alloy increases sulfidation resistance; c) developed TiB_2 coating resistant to erosion and corrosion.

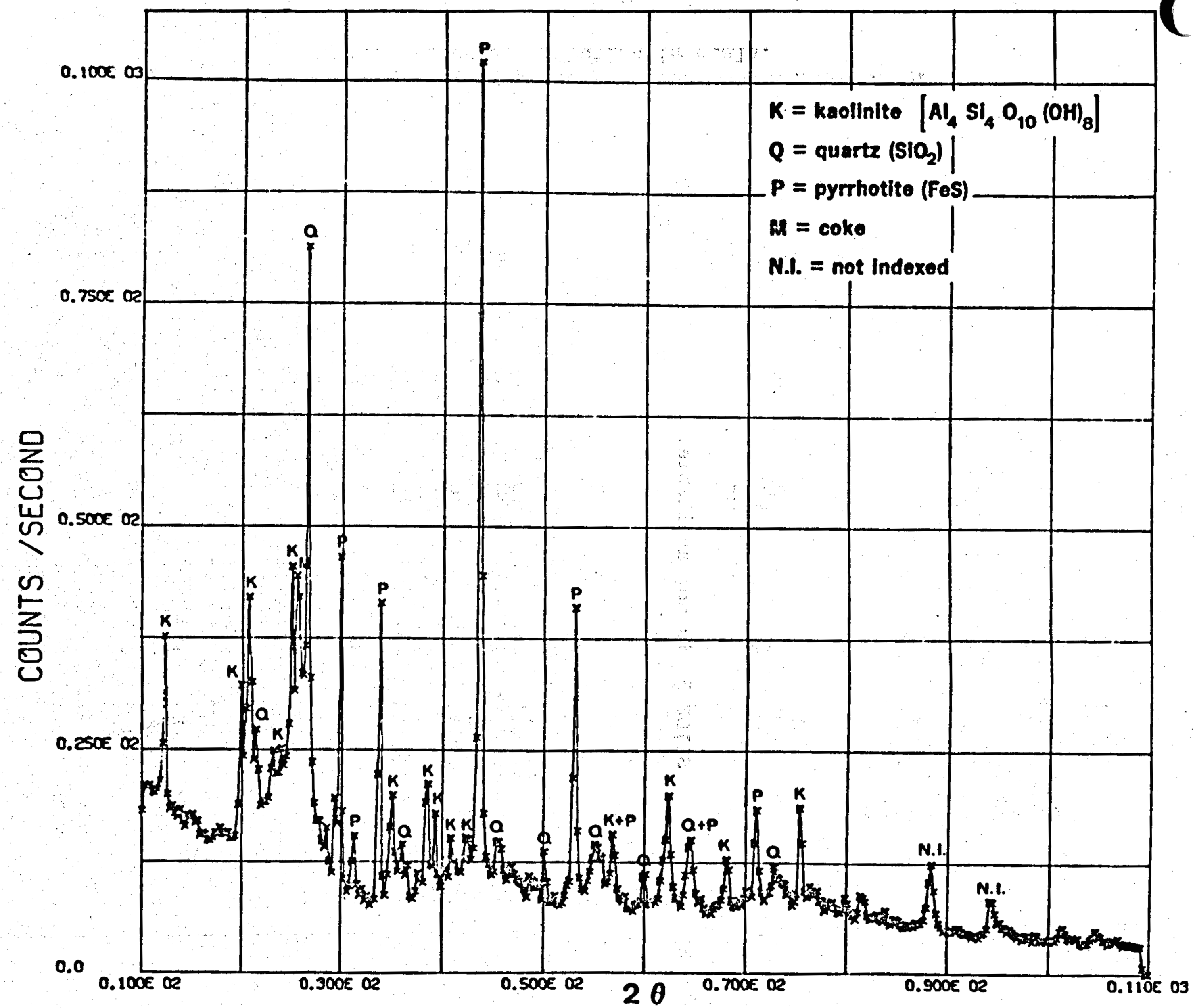
SLIDE 12 is not available.

ORNL

MICROPROBE ANALYSES OF ORGANIC SULFUR IN MACERALS OF FIVE HIGH-VOLATILE BITUMINOUS COALS

		MACERAL GROUP SULFUR CONTENT		
COAL NAME	LOCATION (STATE)	EXINITE	VITRINITE	INERTINITE
HAZARD NO. 7	EAST. KENTUCKY	600	330	200
NO. 9 COAL	WEST. KENTUCKY	1925	810	250
DEAN SEAM	TENNESSEE	1250	800	300
NO. 5 BLOCK SEAM	W. VIRGINIA	600	330	270
NO. 6 ILLINOIS	ILLINOIS	1000	680	300

3. Oak Ridge: microprobe analyses show variation of organic sulfur distribution in coals.



X-RAY DIFFRACTION DATA FROM SRC COKE SAMPLE

4. Solvent refined coal pilot plant has pipe-plugging problem. X-ray diffraction and microprobe analysis at ORNL diagnoses the trouble and suggests a cure.

SLIDE 5 is not available.

BIOMEDICAL AND ENVIRONMENTAL RESEARCH PROGRAMS
CONCERNED WITH COAL

(W. K. Sinclair - - Associate Laboratory Director for Biomedical and Environmental Research)

	Program	Investigator	Division
Air	1. Multistate Atmospheric Power Production Pollution Study	Frenzen Cunningham	RER CEN
	2. Stack Pollutant Characterization Study	Cunningham	CEN
Water	3. Effects of Fossil Fuel Effluents in Aquatic Ecosystems (Non-nuclear portion of Great Lakes Program)	Edgington Harrison Sharma	RER EES EIS
Land	4. Effects of Fossil Fuel Effluents on Land Utilization	Miller	RER
	5. Land Reclamation after Strip Mining (revegetation, etc.)	Carter Cameron	EES EIS
Bio-edical	6. Fossil Fuel Effluent Toxicology in Animals	Norris	BIM
	7. Projects in Basic Biomedical Research	O'Connor	BIM
Assessment and Policy	8. Biomedical and Social-Costs of Energy Production	Grahn	BIM
	9. Regional Studies Program (National Coal Assessment)	Hoover	EES, EIS BIM
	10. Environmental Policy Analysis	Leppert	OEP
Environ-mental Control Technology	11. ECT for Coal Power Generation	Sather	EES, CEN CHM
	12. ECT for Eastern U.S. Strip Mining Sites	Johnson	EES

BIM - Biomedical Research
CEN - Chemical Engineering
CHM - Chemistry
EES - Energy and Environmental Systems
EIS - Environmental Impact Studies
OEP - Office of Environmental Policy
RER - Radiological and Environmental

6. The Argonne Biomedical and Environmental Research Program concerned with coal shows the breadth of the problem. Parallel efforts with different program elements are carried out at Brookhaven, Berkeley, Oak Ridge, Los Alamos, Battelle Northwest, and Livermore.

ORNL-DWG. 77-7235

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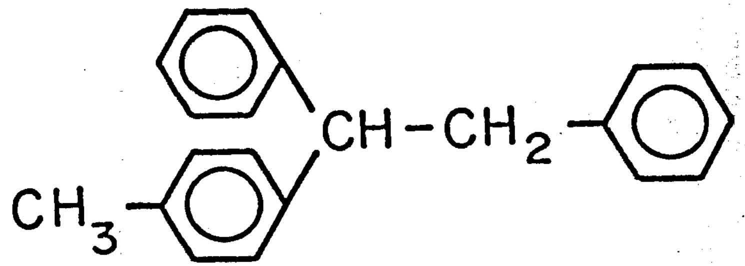

50% in 5 min

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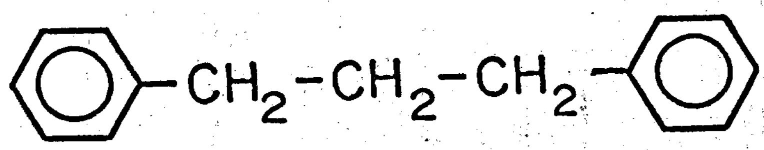
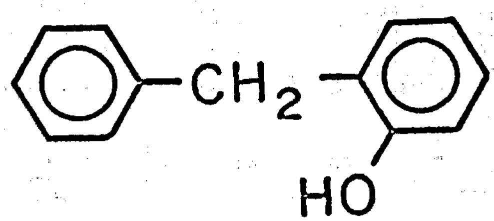


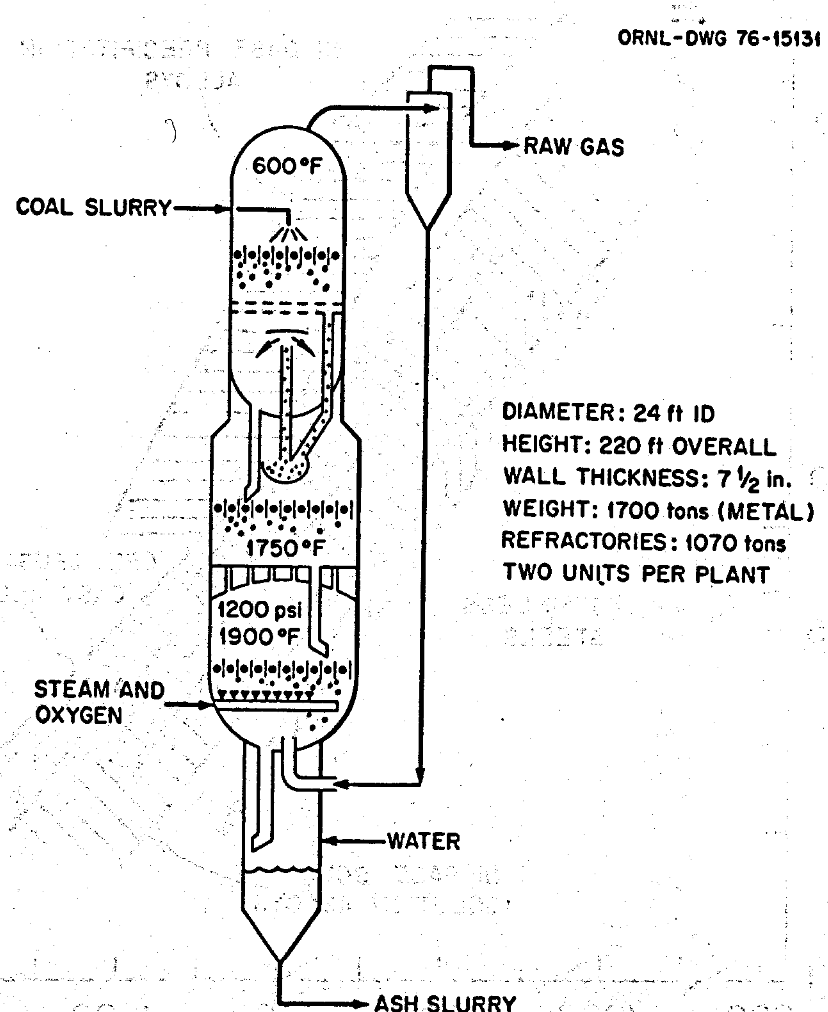
65% in 30 min

34



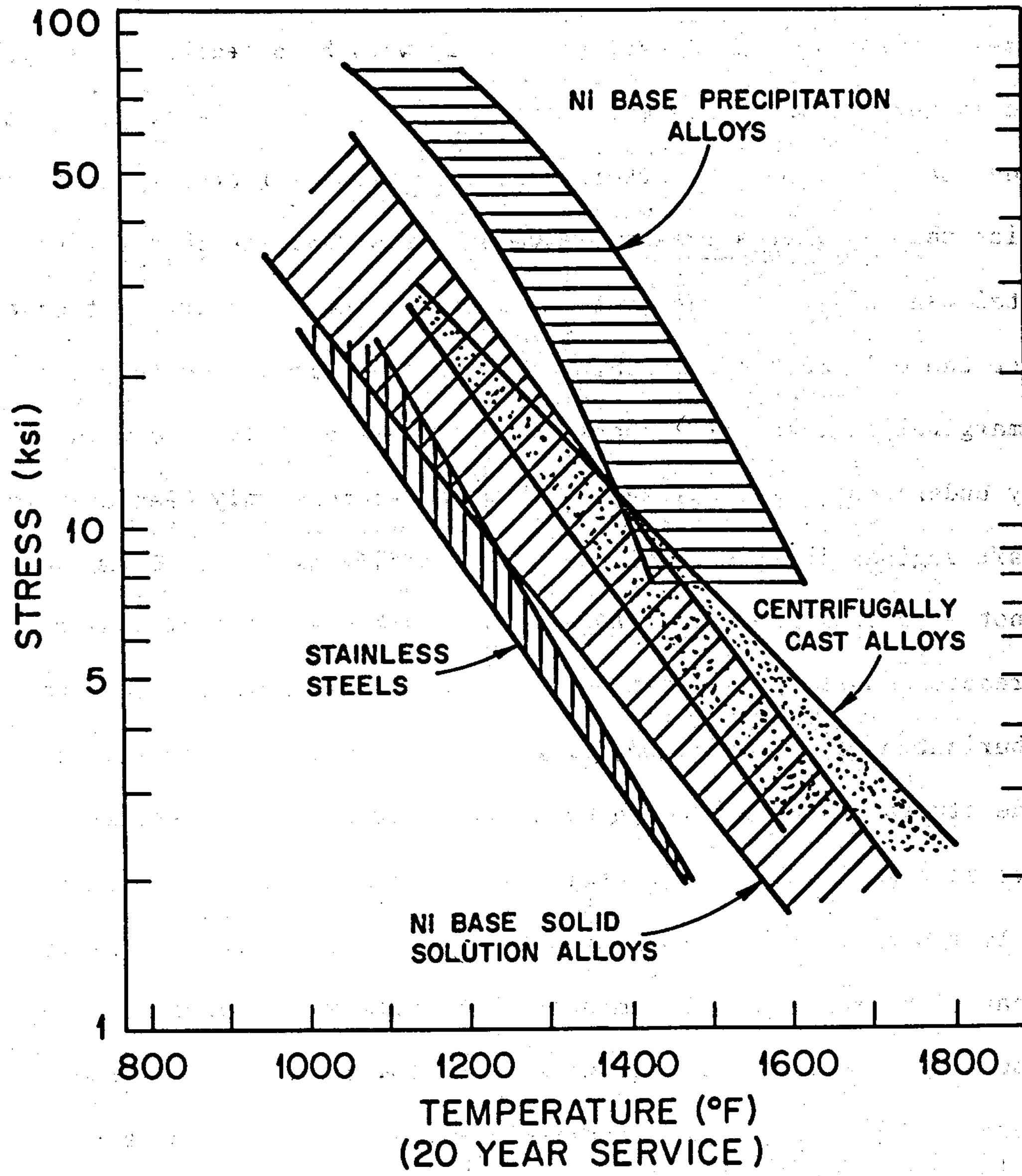
20% in 1 hr

7. Knowledge of chemical bonding in coal compounds may enable us to break linkages at low temperature and pressure. Oak Ridge chemists show that methyl-like bonds can be broken at 400° C with vitrinite as the hydrogen donor.



8. Hygas Process
Fluidized Bed, Oxygen Addition, Dry Ash Gasifier.

ORNL-DWG 76-4986R



A COMPARISON OF THE STRESS RUPTURE PROPERTIES AS A FUNCTION OF TIME AND TEMPERATURE FOR CANDIDATE CONSTRUCTION MATERIALS FOR COAL CONVERSION SYSTEMS

From: The American Iron and Steel Institute Nuclear Steel Making Task Group - May 1975 stresses between 10 and 50 ksi, especially when high temperatures can induce larger thermal stresses. One hundred ksi would be better. It is thus plain why coal converters are lined with refractories that restrict the designer's freedom, and why parts that absolutely must be metal can only be in the cooler locations, and can bear no stresses. In fact the only metals available at these conditions, and they are very marginal at that, are superalloys that are difficult to weld, poorly understood, very costly, and have heretofore only been used in aircraft engines in thin sections. Intimidating as it is, Slide 9 does not even tell the whole story. Materials used in coal conversion reactors must, besides standing the high temperatures, survive decarburization under hydrogen, oxygen and sulfur; be resistant to sulfide stress cracking; remain ductile for twenty years; resist erosive attack of particles containing quartz crystals; etc. There are only two solutions to this problem: one, develop new materials that can withstand the high-temperature hostile environment; or two, develop processes that can operate at much lower temperatures and pressures and preferably be economical in smaller units than the mastodons of coal conversion that we now contemplate.

Both solutions imply large and long-term research programs, carefully planned and managed. Many parallel lines proceed at first, followed by gradual culling, until resources are more and more concentrated in the promising salients, even as others are carried on at lower levels of effort, as reserves, in case of the unexpected collapse of a front runner.

We have already seen the general problem in materials research: develop metals and refractories that can take the heat! And not only for coal conversion, but also for MHD, and for fluidized bed coal combustion.

Slide 10. Key development issues in fluidized-bed combustion. Note important materials and chemical problems that have to be solved.

We now turn to the possibility of lowering the temperature and pressure of coal converters, or more generally impacting on the entire coal conversion process. It is the thesis of this paper that fundamental understanding of the coal conversion process is a necessary and perhaps a sufficient condition to advance our cause in this instance. An example of this kind of research is contained in a list of projects currently carried out at Brookhaven:

- desulfurization of hot combustion gases;
- kinetics of reactions between gases and carbonaceous materials;
- reaction mechanisms in the transfer of hydrogen between coal and solvent (SRC)
- chemical reactivity of carbonaceous material at high temperatures.

Then, of course, there is the whole panoply of questions that goes by the words coal structure and constituents, catalysis (heterogeneous, homogeneous), process instrumentation, modeling, etc.

KEY DEVELOPMENT ISSUES IN FLUIDIZED-BED COMBUSTION

	Atmospheric FBC Systems	Pressurized FBC Systems
1. Boiler tube corrosion, erosion and deposition	****	****
2. Limestone requirements and solid waste disposal	****	**
3. Hot flue-gas cleanup	N.A.	****
4. Turbine blade corrosion, erosion and deposition	N.A.	****
5. Coal, sorbent and ash solids handling system	***	**
6. Sorbent regeneration and sorbent utilization improvement	****	**

Note: No. of stars indicates relative importance of issue

10. Key development issues in fluidized-bed combustion. Note important materials and chemical problems that have to be solved.

Another list from Sandia deals with MHD-related research:

- particle behavior;
- heat and mass transfer;
- seed interactions and condensation.

There are lists of research areas on an even deeper level that bear on many questions in fossil energy. A partial list from Lawrence Berkeley Laboratory includes research in fluid dynamics, thermodynamics, chemical forces, catalysis of hydrocarbon reactions by metal surfaces, etc.

We maintain that the economic utilization of fossil energy, in a way that is safe and environmentally prudent, is an incomplete technology. To bring it on stream in the next two decades calls for an expanded far-flung research effort. The National Laboratories stand ready, and are capable, to contribute to such a program.

National Laboratories have the staff, the equipment, and the management with a proven performance record in the basic and applied sciences, in engineering, and in synthesizing the results of many disciplines toward specific goals. By virtue of existing scientific strength, in a system that encourages multidisciplinary research, and by their deep involvement and commitment to the fossil energy technologies, the National Laboratories can: provide data needed by the developing technologies; explore the underlying physical sciences; provide quick responses to critical problems; work effectively in the complex area that spans science and engineering;

perform vitally needed enviroment, health and safety research; and may uncover new phenomena which would revolutionize the whole energy picture.

They can do this in partnership with industry, with universities, and with the Energy Research Centers. It is also necessary to consider the time scale. Some things the Laboratories must do fast: for example, would be to provide data needed by the developing technologies and to provide quick responses to critical problems. Others must be carried out in an orderly fashion over a long time period, avoiding if possible rapid fluctuations in direction and funding. Exploring the underlying physical sciences and performing vitally needed environment, health and safety research, fall into this category. It might be necessary to say here, that without research in the physical, environmental and health sciences, the development of fossil energy technologies will soon grind to a halt for a lack of knowledge. Working effectively in the complex area that spans science and engineering, we can even meet milestones, but there is no guarantee that we'll uncover new phenomena which would revolutionize the whole energy picture in a year or a decade. All we have to go on is past precedent - when able scientists work diligently to deepen our understanding of natural phenomena, useful things emerge, sometimes in the most unexpected ways. There is no reason to believe that this will not happen in the case of fossil energy.

Thank you.

DR. PHILLIPS: Thank you, Alex.

We are open for comments and discussion.

MR. BORIS: I'm Mr. Boris, formerly with a boiler manufacturing organization. I think my remarks bear more on that than on my present employer.

Your options seem to lack a feeling for the problems that the people who have to put the hardware into the field and make it work look at. You referred, during your talk, to the HYGAS problems - and I mention this only because it's representative of a family of these. The solutions that you've indicated include the development of materials and the development of processes that can work under less demanding circumstances.

I would submit that given these as problems, a third option, which was not mentioned, is the one that will probably be taken in most of the cases, and that will be to modify the design to use today's materials and today's developed processes, to put this hardware into the field and make it work in the near term.

To seek other options is going to put us into the far term. To develop new materials--if you wish to develop a new steel, as an example of this--will require very lengthy testing; and to get boiler code approval is not an easy thing; nor is it inexpensive.

I, therefore, feel that that kind of option is not going to be too viable. The development of a new process takes a long period of time; bench-scale PDU pilot plants being examples of these.

I would like to suggest that further thought and attention be given to what must be done by those charged with the responsibility of moving technology ahead. Along the lines of what it takes to move technology ahead, I believe a comment about technology moving to a halt was mentioned.

I think technology tends to stop moving ahead when it encounters a variety of regulatory things that consume much time. The R&D people have tried hard to develop these new processes but can only take them so far until other kinds of things need to be gotten out of the way so that those who must can get these into the field.

DR. ZUCKER: Let me comment on your last point first.

Government intervention in technologies is not totally capricious. Government intervention in technologies in many cases is designed to preserve the health of the people and of the environment. The problem is that very often a technology is developed without due regard to health, safety, and environmental matters, and then that technology grinds to a halt, or is at least retarded in its development. I would not call that simple government interference.

Your first point is very well taken. Of course, it takes 25 to 30 years to qualify a material. But I would suggest that the time to start on its development is now, and not 25 years from now.

I quite agree that the most likely thing to happen is the scenario you suggest.

But the question is not: Do we develop a HYGAS process? Rather it is: At what price are we going to supply a million Btu? If we do that at \$6 or \$8, is that a serious contribution? If we do that at \$3, that's a different matter.

So it is not simply a matter of whether technology can do something. It is primarily a question of whether technology can do something at a price. My point is that if you want to lower the price, a time-tested mechanism is to try to understand the problem on a deeper level and see if it can not be solved by that understanding. There is no guarantee that it will be solved, but I think it is worth trying.

MR. LEE: Lee of IGT. You're stepping too close to HYGAS so I have to say something.

I believe your comment--I have nothing against research. I'm all in favor of that. All of us look for better materials. But I think your picture is distorted in that you show a situation wherein you expect a metal that takes simultaneously 1900 degrees, whatever it is, and 1200 psi pressure, when in fact the HYGAS reactor and the many other reactors operates with standard, conventional, buy-it-by-the-ton quantities refractory for lining, and the metal is standard carbon steel shell, and there are all the stresses taken on the pressure vessel, which only takes pressure but not temperature.

DR ZUCKER: I know that.

MR. LEE: I returned recently from visiting South Africa, seeing 3000-degree molten slag gasifiers operating under pressure. Now, obviously the part holding pressure doesn't have to see 3000-degrees simultaneously.

We've also seen coal gasification plants in operation, producing products, using conventional techniques, using conventional operators and technical key personnel like ourselves.

That doesn't say we shouldn't develop new materials, but to paint a picture as if nothing is going to work; we're going to start from scratch, developing new material--I think that's throwing the R&D picture out of focus. So I'd like to suggest that, fine, let's do R&D work; let's find better material; let's find better technology; let's understand kinetics better--I'm all in favor of that. But don't paint the picture as if coal converting is not a doable technology with today's material and today's manpower.

DR. ZUCKER: At what price?

MR. LEE: The prices are well established in the market price. If you read the design reports--they're not $6; they're not $8. And if you take it from the end-use point, from coal to your final point of use, there are reports that are available--I'd be happy to give it to you--that it's much cheaper than nuclear power.

DR. PHILLIPS: This is a very profound point. However-- and it is certainly totally germane to our consideration of ERDA's research efforts in fossil energy, but this is not a group meeting of economists or people of that sort, and in particular we are not discussing details of demonstration plants and pilot plants.

Let me remind you to refocus your attention upon the definition, at this meeting, of research--

MR. LEE: He raised the cost picture.

DR. PHILLIPS: Yeah. Well, I think that is a very important point, because this morning we heard two speakers--that they consider a number like 30 plus dollars a barrel as the present state of the art for making synthetic oils from coal. Now, if there is a different opinion on your part, I think that we all would like to know about it.

However, I do not think this forum is the place to discuss it, but rather, if you would send us in some supporting material and whatnot, then we will distribute it in our final report.

DR. ZUCKER: Let me just make one point.

I do not wish to single out HYGAS as a particular target-- nor did I say, in fact-that the pressures and the stresses are all applied at 1900 degrees. I merely put the slide on the screen to show what kinds of environments, what kinds of temperatures, what kinds of pressures one has to deal with. And the object of research, which you agree with, is to try to ameliorate that situation, and to work in areas where we can do things at lower temperatures, at lower pressures, and perhaps at lower costs.

That's really all I want to say.

DR. PHILLIPS: Are there other comments or questions?

MR. ZMOLA: Paul Zmola, Combustion Engineering.

I'm not certain that this one won't be ruled out of order also, but I feel that I have to ask. I wonder if Dr. Zucker would comment on how some of the technology that's being developed would be effectively transferred to the private sector.

I think he can take a rather broad approach to that, but I wanted to point out that I think most of us are interested in how to get into the situation of getting a good, rapid fix on problems we get into. And usually it just cannot be obtained directly from the book or the data bank; there's some application that has to be made.

DR. PHILLIPS: I rule that in order. It's very germane to talk about science and technology transfer from research to commercialization or demonstration.

DR. ZUCKER: I can comment on that starting from our experience in nuclear energy, where the laboratories and the nuclear industry grew up together, where the transfer back and forth of problems and fixes was rather simple.

This is not so here. The transfer of technology and the cooperation between the national laboratories and the ERCs is now pretty good, and getting better. The transfer of technology between the laboratories--(I don't know about the ERCs, but maybe Dr. Wender will speak to that)--and industry is complicated.

It's complicated by the patent question. And in some cases, the transfer of technology is complicated simply because we have worked together only for a few years. I believe it can be accomplished. There is interest in the laboratories--in fact, enthusiasm in the laboratories--for trying to do this kind of thing. I suggest there is also a measure of capability to do it.

DR. WENDER: Wender, Pittsburgh Energy.

Addressing the last question of course, the question of cost sharing has come up as one way of technology transfer. Another way, of course, is that the energy research centers, in contrast to the national laboratories, are completely open; and as such, the synthane process, the gasification, liquefaction processes, combustion things are open for inspection, for complete questioning outside of meetings and transfers. So there is a very good technology transfer that way.

DR. PHILLIPS: I think it's perhaps also important to point out, Dr. Wender, is it not true that the ERCs traditionally have had a significant measure of their support supplied by industry, not exclusive government support? Is that correct, sir?

DR. WENDER: Yes.

DR. ZUCKER: There is the precedent in nuclear energy; we have been able to make it work. There is really no good reason, except our own stupidity, if we do not succeed in fossil energy.

DR. PHILLIPS: Other questions or comments?

MR. CANONICO: Domenic Canonico, Oak Ridge National Labs.

I would just point out that the laboratories, too, are open to the public. I've been there a number of years and I have never had any problem having people come in for technical exchange in any way. I'm sure Alex would totally support that position.

Gentlemen, you're all invited. Any time you want--and ladies--come visit us.

DR. PHILLIPS: Very well.

I think it's a good time, right now, to take about a 15-minute coffee break. Let's come back at about 20 minutes of 4:00.

(Recess)

DR. PHILLIPS: I would like to call the meeting back to order, please.

I think that we are, remarkably, a small amount of time behind our schedule, considering the unplanned activities over on Capital Hill today.

I want to take this opportunity to say again to you what our plan for tomorrow afternoon is. We hope that we can get together as many small groups of you as possible to discuss with us the questions that we want you to respond to if possible.

I believe that each of you have a sheet that is called "The Purposes and Requested Responses of the Meeting." If you do not have one, it's available on the table up at the door. Attached to that--the last page, I believe--is a list of questions. There's about seven questions, that all have to do with the basic question that the administrator asked Dr. Kane to address and he in turn asked Kropschot and I to examine, which we now in turn are throwing the ball to you.

I believe that is all. Let's proceed, then, with our program. We have three more speakers for this afternoon.

Representing the energy research centers, research overview by Irving Wender.

DR. WENDER: The handout, available up front, contains more vugraphs than I will show.

I read some time ago that the head of GAO said that environmental effects will become more important than economics. I'd like you to think about that statement in terms of a word that I've heard a lot today, and that is "costs." I can imagine a very cheap process that someone comes up with, that works beautifully -- but no one wants to furnish a site for it, and its environmental effects will, of course, be too much for anybody to accept. It is important to keep this idea in mind.

I have not really listed research opportunities on my vugraphs. However, there are four pages of research opportunities listed at the end of the handout.

One of them, to bring it to your attention, is to determine the health effects of SO_2 and particulates, and to ask if SO_2 standards are properly set. Although this problem must be solved, most people are avoiding it. Fortunately, EPRI has instituted a research program in this area.

I, in particular, have never had any difficulty in defining basic research. I've been happy with my definition -- perhaps as happy as if I'm in my right mind.

(Laughter.)

Basic research to me has always conjured up the picture of a fellow who's doing research to discover some phenomenon or to verify an hypothesis. At the end of the experiment, he analyzes the data and then he does the next experiment based on deductions, interesting phenomena he has discovered, data needed to verify or validate his hypothesis, or just perhaps to satisfy a whim or a curiosity. He has no practical goal in his mind.

If, however, he has a goal in mind, he will use his findings to help reach that goal. That's what the British call, and what Dr. Mills calls, basic applied research.

The Energy Research Centers (the ERCs) essentially do mostly, I would say about 90 percent, basic applied research. In the past they did more basic research.

(Slide 1)

Those yellow dots on that map indicate the locations of the five Energy Research Centers. I'll start in Pennsylvania; that's the Pittsburgh Energy Research Center, called PERC; and the one below it in West Virginia is Morgantown and that's called MERC.

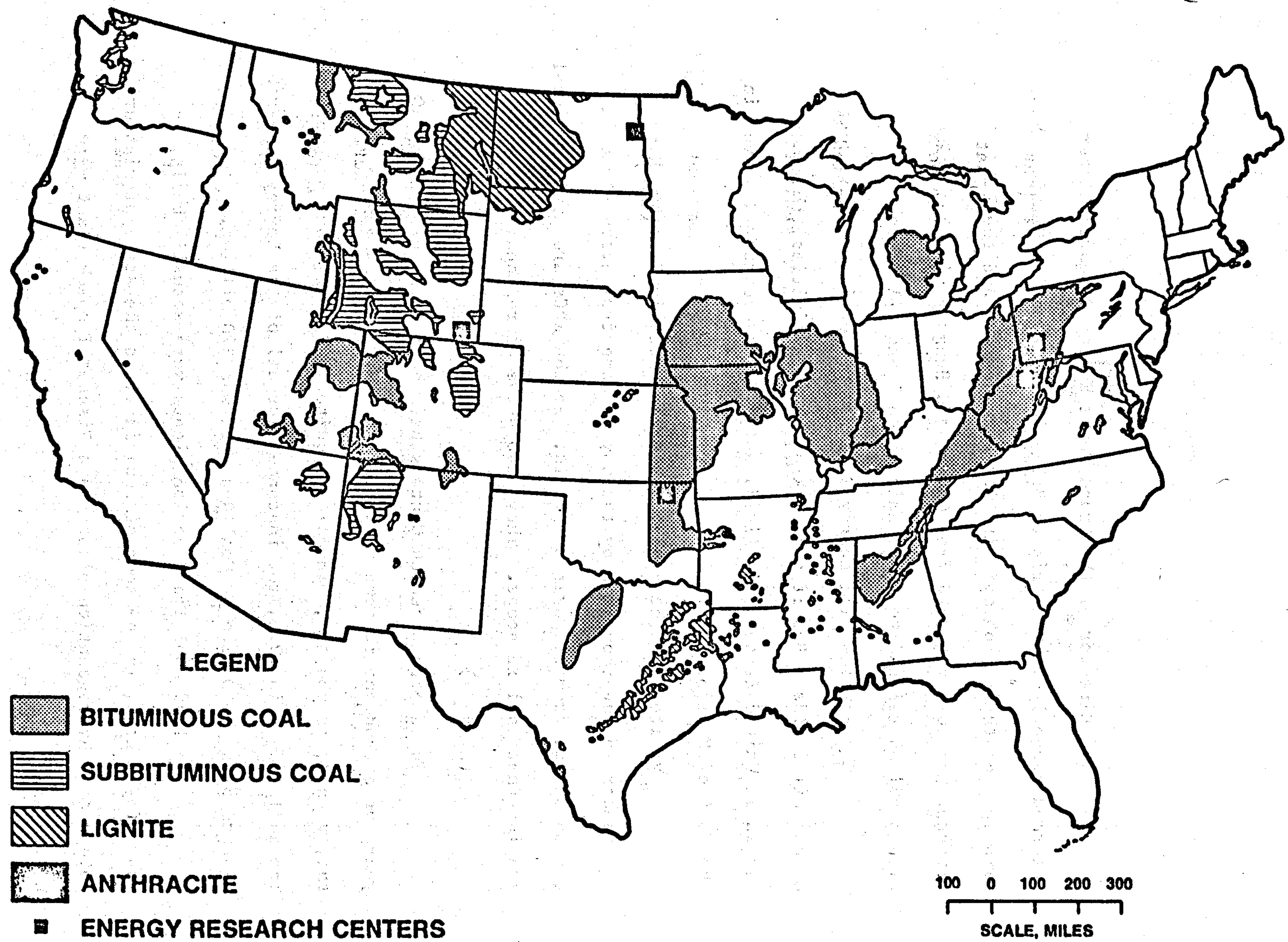
Then in Oklahoma you see Bartlesville. That's called BERC.

And the ERC in Laramie, where the pink color indicates deposits of subbituminous coal, is called LERC.

Finally, we go up north and, the acronym is somewhat funny, that's called GFERC for the Grand Forks Energy Research Center.

(Laughter.)

The Energy Research Centers are situated in regions that would lead one to believe that they are there because the resource is there. That's only partially true. For instance, the Grand Forks Energy Research Center is in North Dakota. I guess, because the lignite is there. However, the ERCs are national and international in scope. For instance, if you look at Texas you'll find a long band of lignite. It turns out that the personnel in Grand Forks are consulting with the utility people who are building a whole series of lignite-fired plants in Texas. The Grand Forks Energy Research Center is working with the people in Texas because, among other reasons, Texas lignite presents a very bad alkali ash problem; FGERC has excellent experience and know-how in this area.


LEGEND
BITUMINOUS COAL
SUBBITUMINOUS COAL
LIGNITE
ANTHRACITE
ENERGY RESEARCH CENTERS
100 0 100 200 300
SCALE, MILES

The Director of the Grand Forks Energy Research Center returned recently from a trip to Bulgaria and Rumania, helping them with some of their problems with low rank coals. And the LERC Director has just returned from Greece and Hungary, in connection with problems related to subbituminous coal and oil shale.

The Bartlesville Energy Research Center is near the center of our oil fields. But if you look at their activities, they cover the whole United States, oil fields all over the country and even in the Gulf of Mexico.

Visitors to the Energy Research Center in Pittsburgh -- who number in the thousands by the way -- come from every state in the Union and from all over the world. So the ERCs are truly national and international in scope. They also serve as regional centers.

(Slide 2)

The Energy Research Centers have been in existence for 50 years or so and one is some 60 years old. As time has gone on, they've had, as you see, minimal and quite inadequate funding support. The coal budget in 1970, for instance, for all of the Energy Research Centers plus the Office of Coal Research was $20 million.

In 1949 coal liquefaction plants were actually built, as most of you know, in the town of Louisiana, in the state of Missouri. Both a coal hydrogenation plant and a Fischer-Tropsch plant were built there.

SOME ERC BACKGROUND

- FROM 1950 TO EARLY 1970's, THE U.S. HAD MINIMAL AND INADEQUATE EFFORT ON COAL RESEARCH AND CONVERSION (BOM & OCR BUDGET IN 1970 WAS $20 MILLION).
- ERCs OBTAINED SIGNIFICANT SUPPORT (SOMETIMES MORE THAN 50%) FROM INDUSTRY AND OTHER GOVERNMENTAL AGENCIES.

The coal hydrogenation plant was operated from 1949 to 1953, producing several million gallons of gasoline. This was used to run a train from Louisiana, Missouri, to St. Louis, which is about a distance of 200 miles. The military ran some of their vehicles with these synthetic fuels from coal to demonstrate the usefulness of these fuels in current engines.

They also ran a Fischer-Tropsch plant. Here they only produced some 40,000 gallons of liquid product. This plant was started up later than the coal hydrogenation plant.

Then in 1953, someone came along with a big pair of scissors and cut these plants at the root, and they all died because of a glut of gas and oil. Hindsight is always better, of course, but it would have been of immense value to this country if those plants had been allowed to continue. I'm sure they would have been modified as demands and times changed and technology improved.

The second point is the one referred to by Dr. Phillips. With diminishing support from the government, we were forced to turn to industry and other government agencies. Fortunately, we were successful in this endeavor. We continued at a very low funding level with, at times, as much as half of an Energy Research Center's budget coming from outside sources. And we could have had more outside support but, for various reasons, the people in Washington insisted that everything done at the ERCs be related to fossil energy. So that we had to turn down quite a few industrial contracts.

It's an interesting sidelight that the Pittsburgh Energy Research Center was the laboratory which, because of its background in high pressure technology and because of the equipment it had, performed erosion and corrosion testing of the valves and piping for Admiral Rickover's nuclear submarines. That's sort of an odd turnaround.

(Slide 3)

The program of the Department of the Interior -- as you know, the Bureau of Mines is in the Department of the Interior -- kept us at a low funding level; but it was a low level over a long period of time. Under this set of circumstances the Energy Research Centers managed to do a lot of good work, and it resulted in some very useful and timely findings with resultant industrial applications.

We invented the so-called Benfield process for the cleanup of gas from oil or from coal. I'll talk about this later. There are now some 400 units -- and these are large units -- in many countries, on every continent. They are even being built in Red China now. All this came out of basic applied research on what is now called the SYNTHANE process for the conversion of coal to high Btu gas.

PERC also patented the process for the two-stage combustion of coal with low NO_x emissions.

And then ERDA came along. Dr. Neuworth, for instance, told you this morning that catalytic gasification is a third-generation

SOME ERC BACKGROUND (CON'T)

- **COMPREHENSIVE, LONG-TERM PROGRAM OF THE DOI PROVIDED SIGNIFICANT ADVANCES IN COAL SCIENCE AND PROCESS TECHNOLOGY.**
- **ERC RESEARCH PROVIDED TECHNOLOGY BASE, INVENTED NEW GAS CLEAN-UP SYSTEM – NOW 400 PLANTS AROUND WORLD, PATENTED 2-STAGE COMBUSTION FOR LOW NO_x, ETC.**
- **TO SUCCEED, A FOSSIL ENERGY PROGRAM MUST PROVIDE AN ADEQUATE AND <u>SUSTAINED</u> RESEARCH EFFORT.**

process in the sense that it doesn't need a water-gas shift reaction and practically no methanation. A very promising, simple and direct gasification process was invented by the Pittsburgh Energy Research Center. This HYDRANE (or hydrogasification) process involves the non-catalytic treatment of coal with hydrogen at about 1000°C. The product is essentially methane with no tars. No water gas shift reaction is needed and very little methanation is required. I think that a process development unit for this process should be built shortly. Its simplicity and high efficiency will make for a cheaper, more reliable route to high Btu gas from coal.

So we were ready with these discoveries and processes when ERDA came into being. And all this resulted from support over a long period of time, at a low Bureau of Mines funding level, plus significant help from industry and other governmental agencies. Over the past years, the ERCs have had long-term contracts with some large industrial firms. They gave the Energy Research Centers money to carry out needed research. And remember, the firms involved in these contracts with the ERCs had to give up all patent rights to the government.

This brings us to a most important point. To succeed, a fossil energy program must provide a sustained and adequate level of funding. If it isn't sustained, you throw away what you have discovered or invented, waste money, destroy morale -- and just don't get anywhere.

I visited Japan about two years ago, at their invitation. They used to mine about 60-odd million tons of coal a year. They are down to about 18. The result is a 99 percent dependence on oil. Unfortunately, they practically ended work on coal in their research institutes and their coal laboratories. They are now trying to build them up again, but it is an extremely hard thing to do. The cadre remaining is scattered and has gotten a bit old. And that is a lesson to all of us.

(Slide 4)

As to the ERC missions, I think this has been covered so I won't spend much time on it. We do the things shown on the vugraph. In the rest of the time, I will try to tell you some of the things that clarify and enhance this slide.

(Slide 5)

Remember that the Energy Research Centers are comprised of about 825 people who are all federal employees. The National Labs, as you know, are government owned and contractor operated. The ERCs have a different sort of outlook and a different mission, and one of our missions is to make the government a good buyer.

Fossil Energy headquarters often asks the ERCs to go out and look at a plant and then write a report. The ERCs have to be at the forefront of technology to be able to do this. The only way to be at the forefront of technology is to be doing something that is close to the cutting edge. And that is one of the important things

MISSIONS OF THE ERCs

PERFORM WORK IN FOSSIL ENERGY TECHNOLOGY AREAS

BASIC APPLIED RESEARCH AND TECHNOLOGY DEVELOPMENT

- INCREASE OIL AND GAS RESERVE BASE BY ENHANCED RECOVERY.
- RESEARCH AND DEVELOPMENT TO OBTAIN CLEAN ENERGY FROM COAL.
- MAINTAIN AND ENHANCE STRONG SCIENTIFIC AND TECHNOLOGICAL BASE.
- SOLVE PROBLEMS ARISING DURING R&D STAGES OF SCALE-UP.

MISSIONS OF THE ERCs (CON'T)

PERFORM WORK IN FOSSIL ENERGY TECHNOLOGY AREAS

PROVIDE MEANS TO:

- **MAKE GOVERNMENT A GOOD BUYER.**
- **TRANSFER TECHNOLOGY TO INDUSTRY.**
- **UNDERSTAND AND RESOLVE ENVIRONMENTAL ISSUES.**
- **SUPPORT HEADQUARTERS PLANNING/IMPLEMENTATION.**
- **MANAGE PROJECTS IN THE FIELD.**
- **INTERACT WITH INDUSTRY/ACADEMIC/PUBLIC/OTHER GOVERNMENT AGENCIES.**

the Energy Research Centers have to do to make the government a good buyer.

Regarding the transfer of technology to industry, I want to say that our relationships with industry over the years have been excellent. Somehow or other, industry has never considered the Energy Research Centers as rivals. Some of them have actually sent people who worked at our laboratories. We have had any number of visitors from industry. Our publications have been used by industry. Some time ago we wanted to jazz up our publications from the old, gray Bureau of Mines format, and we heard voices roaring back that said, "For God's sake, that's our bible. Don't put pink and yellow stripes on it, because when we see that gray cover we know we can depend on it."

I'll come back to environmental issues later. The support of headquarters and planning implementation are things that we do constantly, back and forth. We should do these even more thoroughly in the future. I think it was mentioned this morning by Dr. White that he envisages that more projects will be managed in the field.

It's important that you realize that the Energy Research Centers have been sort of a connecting link, you might say, between industry and government. We also have excellent relationships with the universities. We work with other government agencies. Research and technology transfer take place through the Energy Research Centers with ease.

(Slide 6)

About our so-called strategy, I think that the first one listed is very important: to maintain a proper mix of in-house expertise. What do I mean by that? Well, the people that we employ come from the coal industry; they come from the oil industry; they come from the chemical industry; and they come directly out of school. We have a mix of people who have a lot of experience in high pressure technology, in coal and petroleum desulfurization, in the basic chemical science; and we have a mix of chemical engineers, mechanical engineers, chemists, some physicists, and a fair number of mathematicians. This is the basic mix of personnel that we look for, and it's been very successful.

Maintaining the balance between in-house and out-of-house research is a constantly ongoing thing. We're working that out now. We identify and define promising areas of research -- as does everybody, I guess.

We do research which includes special know-how -- and I'll enlarge on that -- and in high-risk areas, which are by definition areas that government people should be in.

I guess now is about as good a time as any to discuss environmental impacts stemming from fossil energy research. We take this area, of course, extremely seriously, as does everybody in this room. In our Energy Research Centers for instance, the process people are responsible for the environmental consequences and health

STRATEGY OF ERCs

- MAINTAIN STRONG IN-HOUSE EXPERTISE WITH PROPER PERSONNEL MIX AND RESOURCES.
- MAINTAIN BALANCE BETWEEN IN-HOUSE RESEARCH AND MANAGING/MONITORING CONTRACT RESEARCH.
- IDENTIFY AND DEFINE PROMISING AREAS OF RESEARCH.
- DO RESEARCH INCLUDING EITHER SPECIAL KNOW-HOW AND EQUIPMENT OR IN HIGH RISK AREAS.
- ASSESS, AND MAKE ACCEPTABLE, ENVIRONMENTAL IMPACTS STEMMING FROM FOSSIL ENERGY R&D.

effects of their process from the time they are initiated. At the same time, at PERC, we have another group, called the Environment and Conservation Division, which looks over the shoulders of the process people, to make sure that they are carrying out their environmental duties. It's too easy to ignore environmental and safety problems when you are trying to get a process on stream. In spite of the fact that you say you're all for the environment, when something comes along that, in your research and development, you just want to get done as soon as possible, the attitude is: "Well, I'll take care of that later," and the problem manages to get swept under the rug. But we have an overseeing group who go around and talk to the process people; in several cases, they've identified potentially harmful environmental problems and pointed them out early in the game. We believe this overseeing group is absolutely necessary.

(Slide 7)

I think this just gives you a flavor of what an Energy Research Center is. It by no means gives you the type of facilities in the Centers. Fred Holzer of the National Laboratories told you this morning all about Laramie; it was a good talk, so I'll omit that.

But we do have high-pressure/high-temperature continuous process units, up to a ton a day. We're building a process development unit for coal liquefaction that will process up to 10 tons of coal per day.

ENERGY RESEARCH CENTERS . . . .

. . . . HAVE SPECIAL FACILITIES, KNOW-HOW AND SKILLED OPERATORS

HIGH-TEMPERATURE, HIGH-PRESSURE CONTINUOUS PROCESS UNITS

LARGE COMBUSTORS

PRESSURIZED GASIFIERS

HIGH-PRESSURE CONTINUOUS CATALYTIC UNITS

ENGINE TESTING FACILITIES

OUTSTANDING ANALYTICAL AND SUPPORTING EQUIPMENT

. . . . PERFORM AND MONITOR LARGE SCALE FIELD TESTS

We have large combustors, one of which is a 500 pound per hour combustor, the largest you'll find outside of a utility. It's an experimental unit.

We have pressurized gasifiers, and the rest you can read from the slide.

The last line on the slide mentions something that's very important. The Energy Research Centers monitor and perform large-scale field tests, especially at Laramie, Morgantown and Bartlesville.

There are huge amounts of Devonian shale in Ohio, Pennsylvania, Kentucky and contiguous states. Much field work is required to obtain gas from this shale. I don't know what percentage of work at the ERCs is actually carried out in the field, but it is large. At Pittsburgh, we have a 75 ton per day coal gasification pilot plant and a supporting process development unit. One of the advantages of having such units near you is that they feed back rather basic problems, problems that couldn't have been foreseen and that you go back to a laboratory and decide, my gosh, I will have to put someone on this right away. Occasionally, the researcher will have to start pretty far back to solve the problem. In science, you always find out that you know less than you think you did.

(Slide 8)

Let me illustrate this. Dr. Mills mentioned the oxy-desulfurization of coal. I bring this up to give you some idea as to how the ERCs do things. That process involves, as somebody said

SOME ACCOMPLISHMENTS FROM BASIC APPLIED RESEARCH

- OXYDESULFURIZATION OF COAL
- SOLUBILIZATION OF COAL (REDUCTIVE ALKYLATION)
- COSTEAM
- HOT CARBONATE GAS CLEANUP PROCESS
- SUPERCRITICAL GAS EXTRACTION

today at the break, the basic elements: earth, air, fire and water. The oxydesulfurization process involves treating coal with water and air, and you get out <u>all</u> of the inorganic sulfur. Ordinary coal cleaning only gets out about half of the inorganic sulfur. In addition, the process may remove up to 40 percent of the organic sulfur.

Now, where did that process come from? Well, if you just read your literature a bit, your organic chemistry, or in fact any chemistry, you will find that the free energies of formation of very stable molecules, like CO_2, CO, NO, water, SO_2, etc. are very favorable, and there is a tendency for these small molecules to form in what is called an extrusion reaction. So we said, let's take dibenzothiophene as a model compound. If you could oxidize that to a sulfone, (the sulfur atom in dibenzothiophene has two oxygens on it), SO_2 should extrude very easily. And so we treated dibenzothiophene sulfone with alkali and got a quantitative yield of 1-phenylphenol. In other words, all the sulfur was removed by this treatment.

We went from this to coal. Now I don't know if that's basic research or not, because the extrusion reaction was known and this is an extrusion to coal. It was an application of basic research to the removal of sulfur from coal.

The second one on the slide was on the solubilization of coal. Nobody has been able to really measure the molecular weight of coal, but we did this by reductively alkylating coal. I won't explain what that is, except to say that it simply adds a long hydrocarbon chain to coal; for instance we added a hexane chain to coal. And we found that when we did, coal became soluble in benzene, and even in hexane. And then we were able to determine the molecular weight of solublized coal.

Another example is the COSTEAM reaction. We said to a researcher one day, -- everybody hydrogenates coal with expensive hydrogen gas -- your job is to go into the laboratory and find a way of hydrogenating coal using some other (preferably cheaper) gas. And don't come back until you've found it.

And he came back with a coal liquefaction process that uses the gas, carbon monoxide, in the presence of water. This led to the COSTEAM process, which is applicable, we found at first, to low rank coals. The Australians, who have lots of low rank coal, as do we, are also very interested in this process.

At first, we thought this process was noncatalytic, but it turns out that the alkali in the low rank coal is a catalyst. Sodium formate is undoubtly the necessary intermediate, and a hydrogen atom from sodium formate is transferred to the coal.

The hot carbonate gas cleanup process (the Benfield process), with some 400 plants now built or building, came out of the simple reaction that's in all the chemistry books; water plus potassium carbonate plus CO_2 gives you $2KHCO_3$. This picks up CO_2. When you heat this solution up, CO_2 is released. The Benfield process also removes hydrogen sulfide. This process certainly stemmed from a basic reaction and is a good example of basic applied research.

Dr. Mills funded this last example on the slide, dealing with supercritical gas extraction. That's something that the British have developed to treat coal with a low-boiling solvent above its critical temperature. In this manner, they get out 20 to 30 percent of low-boiling material. But their process results in a large amount of residue.

You know that one of the big problems in the liquefaction of coal is solids-liquid separation. We have taken the solid-liquid mass after most of the oil has been removed and treated it with toluene under supercritical conditions. We find that we can cleanly remove all the usable oil from the residues with a quantitative recovery of toluene. Our remaining problem is to make this a continuous process, which does not seem at all difficult.

These are just a few examples of how work is conducted in the Energy Research Center.

(Slide 9)

I think I will just let you read this. I've said most everything on it. Next slide, please.

(Slide 10)

The next slide is an important one.

As Dr. White told you, tests are going on in Albany, Georgia, some 40 miles from Plains, on the burning of solvent refined

ERCs ARE FOCAL POINT FOR FOSSIL ENERGY RESEARCH

- EDUCATION AND TRAINING FOR UNIVERSITY, GOVERNMENT, INDUSTRY, FOREIGN SCIENTISTS.
- EXTENSIVE UNIVERSITY CONTACTS AND CONTRACTS.
- FREE ACCESS FOR INDUSTRY, GOVERNMENT, ACADEMIA – U.S. AND INTERNATIONAL.
- ERC EXPERTS SENT TO ALL FIVE CONTINENTS.
- TALKS, LECTURES, MEETINGS – NATIONAL AND INTERNATIONAL.
- 1000's OF PUBLICATIONS CONSTITUTE FOSSIL ENERGY INDUSTRY "BIBLE".

ERCs ARE RESPONSIVE TO CHANGING OPPORTUNITIES, NEEDS, DEMANDS

- SOLVENT-REFINED COAL COMMERICAL COMBUSTION TESTS
- COAL-OIL SLURRY COMBUSTION (NEAR-TERM)
- RE-REFINING OF LUBE OILS
- DEVONIAN SHALE DEVELOPMENT
- NATURAL GAS FROM COAL SEAMS
- FOSSIL ENERGY ENVIRONMENTAL PROBLEMS

coal (SRC). SRC, it turns out, is neither fish nor fowl. It's not a solid, so you can't burn it as you would in an ordinary coal combustor; it's not a liquid, so you can't burn it in an oil-type burner.

The combustion group of the Pittsburgh Energy Research Center, which has been doing basic and applied work in coal combustion, was asked to figure out a way of properly burning SRC. Well, the group devised a satisfactory method to burn SRC in a very short time and this is how the SRC is being burned in Albany, Georgia. Some three weeks ago, we had to send a man to Albany, Georgia to make sure that the SRC burned well. It burned beautifully and the test was a success. It's important to note that the Energy Research Center was ready to respond to this challenge in a short time. We must be and are ready for tasks of this sort.

Take the coal-oil slurry as another example. We were asked if we could get a coal-oil slurry unit set up in a very short time. In less than three months we had one operating at PERC. We found an old Bureau of Mines boiler, set up a coal-oil slurry unit, and furnished all the steam heat for the ERDA installation at Pittsburgh last winter. This unit ran for over 1,000 hours.

We are now building a 700-horsepower unit. This winter, we hope to put several of these coal-oil slurry units into small industries in the mid-Atlantic area.

A very good job has been done recently at BERC on the re-refining of lube oils -- these oils have been tested and they meet all specifications.

Devonian shale has been covered, natural gas from methane seams has been discussed and I have talked about environmental problems. Let's see what's on the next slide.

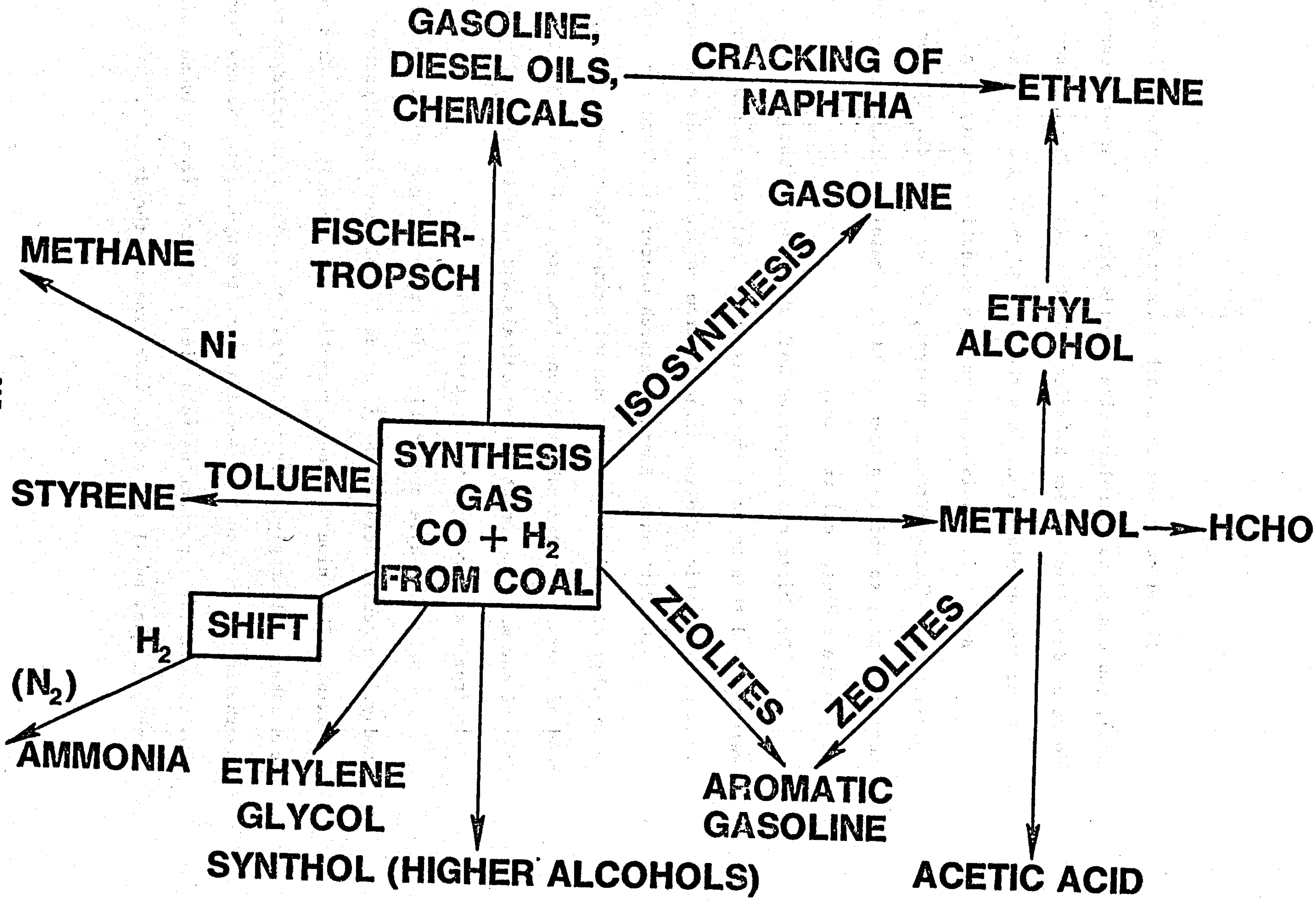
(Slide 11)

Let me talk about this, and then probably end up.

Most of the liquefaction that we have talked about has been hydrogenation of coal, which is something I believe in. In other words, adding hydrogen to coal is a promising route to low-sulfur liquid fuels. But you make a lot of aromatic (benzenoid) and poly-molecular materials during the hydrogenation of coal.

We are advocating a large program on what we call Project PLUS. One of the advantages of Project PLUS (Petroleum-like Liquids Using Synthesis Gas) is that you first gasify the coal to synthesis gas and then convert the gas to petroleum-like (aliphatic) oils. It should be pointed out that, even when you hydrogenate coal directly, about one third of the coal must be gasified to make hydrogen anyhow. In other words, you have to go through the gasification route to make your hydrogen in the first place. We know that in the next couple of years, there are going to be several good pressurized gasifiers. I think a number of people in the audience may know better than I what they are.

PROJECT PLUS



If you start out from carbon monixide and hydrogen (synthesis gas), you can go to petroleum-like liquids via the Fischer-Tropsch route as does Sasol in South Africa. That's fine. They are now building another plant ten times the size of their present plant.

But it is possible, by using a selective catalyst, not necessarily a Fischer-Tropsch catalyst, but an oxide catalyst or a zeolite, etc., to obtain a high yield of a gasoline fraction, or you could make a diesel oil fraction.

Dr. Mills has supported work which shows that you can go to methanol and then to an aromatic gasoline. And work is now going on in making aromatic gasoline directly from carbon monoxide and hydrogen.

The Pittsburgh Energy Research Center has found that you can make ethyl alcohol from methyl alcohol using a homogeneous catalyst. And of course, you can make ethylene from ethyl alcohol. Ethylene is one of our most important petrochemicals and it will eventually be made from coal, probably via synthesis gas.

Formaldehyde and acetic acid are made from methyl alcohol today, the acetic acid synthesis using methyl alcohol and carbon monoxide. The Union Carbide Corporation has recently shown that you can make ethylene glycol from synthesis gas. You make hydrogen from synthesis gas and you make ammonia using the hydrogen. We now know how to make the important petrochemical, styrene, from toluene using synthesis gas, but I won't take your time for the details.

Project PLUS thus gives us an environmentally clean route to gasoline, to diesel oil, and to other fuels and petrochemicals. All the sulfur and all the nitrogen are removed during gasification and the final products are not carcinogenic.

About 33 billion pounds of synthetic ammonia is made in this country every year. Happily, there is work going on transplanting microorganisms, Phizobium species, which grow on the roots of certain nitrogen-fixing plants. It may be possible for these microorganisms to be transplanted to wheat, rye, and oats, etc. It may well be a good idea for ERDA or someone else to support work to make all our ammonia (fertilizer) via microorganisms on the roots of growing plants. It is interesting to note that 100 billion pounds per year of ammonia are fixed naturally in this way each year.

Indeed, why not fix all our nitrogen in this way? If successful, this could pretty much wipe out the ammonia industry. It would be to our advantage to do this. We would save all the fuel necessary to make ammonia. Perhaps, even more importantly, we would be replacing the humus so badly needed in the soil. At present, we must add increasing amounts of fertilizer each year because humus is not replaced. The huge amount of synthetic ammonia results in eutrophication of our rivers with resultant killing of the fish present.

So this is a plan where I advise avoiding the petroleum or fossil energy route altogether. Instead put all your money into agricultural research. If you could get the dollars and will do this, you would not need the ammonia industry and it would be a tremendous boon to agriculture and to the environment.

Thank you.

(Applause.)

DR. PHILLIPS: Thank you. Now, I am going to ask you a question. What was your next slide? Could we see it, please?

DR. WENDER: I have taken up more than my allotted time. The rest of the slides are in my handout.

DR. PHILLIPS: Are there other questions or comments? Yes.

VOICE: What is your ratio between in-house and out-of-house research work?

DR. WENDER: That figure is not in the handout. It's a hard question to answer because most of the out-of-house work is funded from Washington. Bartlesville, for instance, monitors over $100 million worth of outside work. Is that not so Mr. Ball?

MR. BALL: That is right. We have about $7 million worth of in-house work, and $110 million worth of contracts.

DR. WENDER: That's an exceptional example. Morgantown has fluidized bed combustion. We only do direct combustion at the Pittsburgh Energy Research Center. The number you ask for is a hard number to come up with because these are really contracts that emanate from Washington, and we get to be the TPOs of these contracts.

The figure is available, I think, from Dr. White.

DR. PHILLIPS: Other comments or questions?

(No response.)

Very well. Thank you, sir.

We will go on then to our next-to-the-last talk for today's sessions, university research overview by William Reynolds, Stanford University.

DR. REYNOLDS: Thank you very much.

I am delighted to have this opportunity to provide you with information and perspective on the current and potential role of universities in fossil energy research. As Chairman of the Institute for Energy Studies and of the Department of Mechanical Engineering at Stanford I have had the occasion to discuss the ERDA program with many colleagues. In preparing this talk I spoke with several key people at leading universities to get their views on the messages that I should deliver today. I will present my analysis of the situation and interpretation of some widely held views.

My talk is organized in two parts. First, I will put forward a case that the universities have much to contribute to ERDA's fossil energy programs, but that many of the best minds have yet to be directed towards ERDA's research needs; some steps that ERDA might take to involve more of this top talent will be suggested. Second, I will examine the balance between research and development in the ERDA fossil energy program, and point to a serious gap which I perceive exists between the very basic research and the very applied development programs; recommendations will be made for ways in which the universities could assist in bridging this gap. Along the way you will hear a number of things that I hope you will find useful.

Universities have been the primary performers of basic research, not only for the federal government but for the nation as a whole. Table 1 shows the distribution of federal research support for universities, industry, and government laboratories for FY76. Note that universities are involved in both basic research, which is the advancement of knowledge potentially useful in a number of applications, and applied research, which is research for new knowledge undertaken with particular applications in mind. In addition, universities are sometimes involved in development, which is the technical activity concerned with non-routine problems encountered in translating existing knowledge into specific products or processes.

TABLE 1

FEDERAL OBLIGATIONS FOR BASIC RESEARCH, FY76
(Billions of Dollars)

	Basic Research	Applied Research
Universities	1.0	1.0
Industry	0.5*	1.5
Government Labs**	0.3	0.4

*Mostly aerospace
**Including those administered by universities

Source: NSF 75-323

Measures of university strength and productivity pertinent to fossil energy are given in Table 2, which shows the sources of recent publications in two major referred journals reporting research relevant to fossil energy, Combustion and Flame and the Journal of Catalysis. Note that nearly 70 percent of these publications are derived from work conducted at universities. Two pertinent review journals, Progress in Energy and Combustion Science and the Annual Reviews of Fluid Mechanics, use university people to an even greater degree. In the recent elections to the National Academy of Sciences, 80 percent of the new members were from universities. The fact that as many as 37 percent of the members of the National Academy of Engineering are in universities attests to the high concentration of applications-oriented talent in universities.

TABLE 2

MEASURES OF RESEARCH CONCENTRATION

	INDUSTRY	GOVERNMENT (incl. labs)	UNIVERSITIES
Referred Journals			
Combustion & Flame (1/75-6/77)	19%	12%	69%
J. Catalysis (6/75-5/76)	23%	10%	67%
Review Journals			
Prog. Energy & Combustion Sci.	23%	5%	73%
Ann. Reviews of Fluid Mech. (74-77)	2%	11%	87%
Academy Memberships			
Nat. Acad. Sciences (1977 elections)	10%	10%	80%
Nat. Acad. Engrg. (all)	55%	9%	37%

Research is conducted by universities for several reasons; it is the primary vehicle for training advanced students to the cutting-edge in their disciplines; it is one important way for a faculty to stay current and to advance knowledge; it is a way for the organizations and people involved to contribute to the solution of important societal problems. Therefore, research is mutually beneficial to both the sponsoring agencies and the universities.

Although many universities involve Masters level students in research, work at the frontiers requires training beyond the Masters degree. Therefore, while in some instances ERDA may be able to benefit from Masters-level research, the primary contribution to ERDA's high-technology programs will come from universities involved in Ph.D. level research. Hence, the quality of a university's Ph.D. program should be a significant factor in considering ERDA-university interactions.

I would like to dispel any notions that Ph.D. programs simply produce more professors for other institutions. For example, Stanford is a major producer of Ph.D.'s in engineering and the sciences but only about one third of these go to academic institutions, the remainder go to government and industry. If the nation is to maintain a strong position in advanced energy technology, this flow of fresh Ph.D.'s to industry, government, and other universities must be maintained.

There have been many surveys of the quality of graduate education and research in engineering and the sciences. Table 3 shows some results of a recent survey and lists engineering schools by their ranking for the overall quality of graduate education. Note the range of undergraduate-to-graduate enrollment ratio (UG/G), the Ph.D. production per faculty member per year (Ph.D./Fy), and the range of annual research support per faculty member (Res.K$/Fy). Note, however, that the research investment per Ph.D. produced (Res.K$/Ph.D.) at these institutions lies in a narrow range around $100 K per Ph.D.

For a variety of reasons, the engineering and science-oriented schools generally considered to be the strongest were slow, as a group, to become involved with ERDA. To illustrate this fact, let me note that only 11 of 75 universities' research programs mentioned in ERDA 77-33 as providing advanced research to the fossil energy program

TABLE 3

RESEARCH PRODUCTIVITY PARAMETERS FOR LEADING ENGINEERING SCHOOLS

Institution	Faculty	UG/G	Ph.D./Fy	Res. K$/Fy	Res. K$/Ph.D.
A	321	.85	.5	63.9	128
B	212	1.47	.69	57.5	83
C	142	.50	1.11	130.0	117
D	372	2.58	.34	46.2	136
E	--	--	--	--	--
F	270	3.19	.33	36.7	111
G	323	3.78	.33	32.8	99
H	83	2.17	.31	51.8	167
I	214	3.12	.32	31.3	97
J	74	3.62	.47	79.7	169

Source: SUNY-Buffalo Survey, corrected

were placed at universities ranked among the top 20 in this survey. This does not imply that the projects were placed at schools not qualified to do the work, but it does suggest that there is a great deal of top university talent that could be brought on-board the fossil energy program.

Table 4 shows a breakdown of funding, by agency, in the three-top institutions in Table 3, each of which could make significant contributions to the ERDA program. Note the breadth of high-technology agency support and the magnitudes of their annual research budgets; \$60-70 million. These clearly are three very serious technological activities. Note the relatively small fraction of ERDA support in each case (National Laboratories managed by these institutions have not been included in this summary. In the case of institution B, an ERDA laboratory operates predominantly with faculty/Ph.D. student teams, and makes major contributions to the university research program.) Now let's look at the university funding nationwide by these same agencies; Table 5 gives this detail. Excluding DHEW, which is not primarily a high-technology agency, the NSF is the largest supporter of research in universities, followed by the DOD, ERDA, and then NASA. Now consider Table 6, which gives the ratios of ERDA-to-DOD and ERDA-to-NSF support in all universities and in the three we have considered. Note that these ratios for the three top institutions are significantly lower than the national averages. This is a clear indication that these three outstanding institutions, and

TABLE 4

RESEARCH EXPENDITURES* AT THREE LEADING UNIVERSITIES, UFY76

Agency**	Institution A	Institution B	Institution C
DOD	13.2	6.6	7.6
ERDA	2.9	0.9	1.7
NASA	7.0	3.7	5.1
NSF	20.8	14.8	15.4
DHEW	17.3	26.4	34.0
Other Govt.	5.0	7.4	3.2
EPRI	≃.7	≃.4	1.2
	66.9	60.2	68.2

*Industrial funding not included

**Not including federal laboratories managed by the institutions.

Source: Institutional Private Communication

TABLE 5

R&D SUPPORT IN UNIVERSITIES
(Millions of Dollars)

	Outlay FY76	Est FY77	Est FY78
DOD	282	312	353
ERDA	129	152	200
DHEW	1459	1287	1415
NASA	111	116	119
NSF	446	463	512

Source: Special Analysis, Budget of the United States Government, FY1978, OMB.

TABLE 6

COMPARISON OF AGENCY FUNDING IN THE THREE UNIVERSITIES WITH THE HIGHEST-RANKED ENGINEERING SCHOOLS*

	All Universities	A	B	C	A + B + C
ERDA/DOD	0.46	.22	.14	.22	.20
ERDA/NSF	0.29	.14	.06	.11	.11

*FY76

TABLE 7

FEDERAL SUPPORT FOR FIVE MAJOR UNIVERSITY MATERIALS RESEARCH CENTERS (UFY77) (Millions of Dollars)

	A	B	C	Q	R
ERDA	0.05	7	0.5	0	.1
(%)	(3%)	(90%)	(8%)	(0%)	(5%)
Other	1.61	1	6.4	4.1	2.3
	(97%)	(10%)	(92%)	(100%)	(95%)
TOTAL	1.66	8	6.9	4.1	2.4

Source: Institution Private Communications probably many other first-rate institutions, have a great deal of high-technology research talent that could be brought to bear on ERDA problems. Progress in this regard is being made, (An institutional arrangement between ERDA and one of these universities is now bringing more faculty to ERDA's research programs. The University Research Program under the Fossil Energy Program now involves about 150 universities, compared to only 23 in 1976.) but I believe the university potential is just barely being tapped.

Let's examine this hypothesis in a particular research area of direct concern to the fossil energy program; materials. Table 7 shows the division between ERDA support and other federal support at five of the major centers for materials research established at these universities over a decade ago as part of a national "centers of excellence" program. The institutions are designated as in Table 3. Institution A also has other materials research, including a significant amount from ERDA, which is not funded through it's materials center. Center B is part of an ERDA laboratory, and is funded almost entirely by ERDA. However, in both Centers B and C practically all of the investigators are regular faculty at their institutions, and the "workers" are Ph.D. students. Thus, these two are quite similar in structure and capabilities, but one is heavily supported by ERDA and the other only modestly. Institutions Q and R also have good materials programs; one is very close to another ERDA laboratory, but neither is an ERDA laboratory; the ERDA support for each is very small. One can draw two conclusions from these data. First, universities with an in-house ERDA laboratory have been able to switch their efforts to energy research much more rapidly than have those which do not operate ERDA laboratories. Second, there is a great deal of capability in materials research that as yet is not being exercised on ERDA problems.

Let me close this analysis of the Fossil Energy Program with the comment that many university people have perceived (correctly or incorrectly) that the attitude towards university research varies greatly among the Program Divisions. In particular, the Division of Magnetohydrodynamics makes extensive use of several universities, and has given universities responsibility for some very large-scale experiments. In contrast, the Division of Coal Conversion and Utilization makes practically no use of universities, which could make some very important contributions through, say, applied research on combustion in a large-scale combustion research facility. The Division of Materials and Exploratory Research has an excellent and growing university research component, and I have heard a number of compliments about the way their program is being handled (as well as expressions of dismay at the small size of the Division budget!).

I would like now to discuss the special requirements for conducting quality research in the university environment, as these may shed some light on why some of the most highly regarded universities have not become involved with ERDA as rapidly as others.

A <u>critical mass of activity</u> in the general area of the research is most desirable; while there are a few instances of the lone professor and his student doing outstanding work in an isolated situation, the best work seems to come from departments in which there are a number of good people, and good students, working on similar problems, surrounded by good supporting departments.

<u>Flexibility</u> in the details of the work is highly desirable, especially in the most basic research; a research team which keeps the general objectives of the sponsor in mind should have the freedom to make mid-course adjustments in the details of the research if this serves the objectives of the program.

<u>Deadlines</u> should not be too tight. Strict deadlines, which <u>are</u> essential in development programs, are not conducive to good research, and can force the taking of data before an experiment is fully debugged. In the interest of quality research this pressure should be avoided.

A research team should have a <u>support commitment</u> for a period of several years; three-year grants and contracts are most preferable, since this is the length of time that a typical Ph.D. student spends on a research project.

<u>Stability of support</u> is essential. The larger the research team, the more stable the support needs to be. Transfers of support from one agency to another, from one set of contract monitors to another, from one set of long-term objectives to another, which we

have seen in the energy area over the past several years, are very disruptive, often leaving periods of months during which research teams do not have adequate funding. An industrial research organization might absorb such discontinuities by transferring people from one department to another, or by reducing the technical staff, but universities cannot operate this way; universities cannot fire students and faculty one month and hire replacements three months later, or transfer students and faculty from Physics to Electrical Engineering on short notice.

Finally, <u>support must allow for inflation</u> and other appropriate cost increases.

Critical mass in a research area usually requires more than one faculty member, and a number of Ph.D. students. Table 8 shows the total budget for a hypothetical research team consisting of four faculty members, 2 research associates, and 16 Ph.D. students. There would be a continual flow of students in and out of the program at the rate of about 6/year. With funds for salaries, equipment, travel, and the inevitable indirect costs, the total annual research budget for this team might be about $600K. This might be provided by 1 large contract at $200 K/year, 2 medium contracts at $100 K/year each, and 4 small grants at $50 K/year each, perhaps from 4 different funding agencies. The group's research would be in a coherent area, such as high-temperature materials, superconductivity, MHD, combustion, or catalysis, and might span a spectrum from very basic research through applied research, perhaps even including a modest amount of prototype development.

Research activities in many large universities are conducted by teams and sub-teams of this general size. A team working in, say, catalysis could decide to turn some of its attention to problems of special interest in the ERDA fossil energy program. What would induce a team or one of its members to do this? The obvious first thought is a need for funding. But, I have heard repeatedly that the good people at the good institutions are fully committed. They have momentum in their research, and well-developed relationships with their sponsoring agencies. So, an alternative source of equivalent funding would hardly seem sufficient to capture their attention. If ERDA seriously wants to involve the best university minds in fossil energy research, then ERDA will have to present them with funding opportunities and procedures that are at least as attractive as those offered by the other agencies.

With this problem in mind, let's examine the University Program of the Division of Fossil Energy Research. According to ERDA 76-10, most of the university programs involve at least three years of support. This shows excellent sensitivity to one of the most important criteria for good university research, and Dr. Alex Mills and his staff are to be congratulated for this sensitivity. Second, the size of the contracts reflected in ERDA 76-10 shows similar awareness of what good research requires; funding levels range from $25 K/year, which is a bit on the low side, to about $800 K/year, which should be quite adequate for a substantial team effort. For about half the contracts the spending rate is in excess of $80 K/year, and about one-third are at the rate of $150 K/year or more. This general balance seems consistent with the model of Table 8.

TABLE 8

TYPICAL BUDGET FOR A UNIVERSITY RESEARCH TEAM

I.	SALARIES (and Benefits)		
	4 Professors		
	2 Research Associates		$290 K
	16 Ph.D. Students		
	Technical/Secretaries		
II.	TRAVEL, MISCELLANEOUS		10 K
		SUBTOTAL	$300 K
III.	INDIRECT COSTS		150 K
IV.	EQUIPMENT		150 K
		TOTAL	$600 K

Output: Will produce 6 Ph.D.s/year.
Sources of funding: 1 large contract at $200 K/year, 2 medium contracts at $100 K/year each and 4 small grants at $50 K/year each; 4 agencies.

In an attempt to stimulate new fossil energy research in universities, the Division of Fossil Energy Research early this year announced a program of Starter Grants in coal research. Areas of interest mentioned in the program announcement were "research directed toward...converting coal to liquid and gaseous fuels...coal combustion, and...materials...for coal processing equipment." The Starter Grants were limited to $20 K; the program budget was $400 K/year for 2 years.

I believe that the $20 K grant size in this starter program was too small. Grants of this size may be appropriate for the new Professor, just starting to build his research program. But I do not believe that this will prove to be enough to entice many established Professors, perhaps members of productive research teams of the type shown in Table 8, to alter the nature or funding of their research.

However, this program may have received some proposals from good faculty who, for one reason or another, are "between agencies." In reviewing these proposals, ERDA might look carefully for this opportunity. If such cases are detected, ERDA should make a prompt on-site assessment of the capabilities of the group involved, work with them to identify the research that will be conducted, and move swiftly to provide the necessary additional funding to keep the good team together and get them moving on ERDA activities (<u>before</u> the starter work is finished!).

As the work under the rest of the starter program progresses, ERDA will undoubtedly become aware of some special opportunities to help young groups build up productive research teams. When these are identified, ERDA should budget for a phase-up of these activities to a good level of support. It is unlikely that a $40 K grant following a $20 K starter will produce the desired results; the second awards should be closer to $100 K, and should be designed to increase the number of people working in the team. Care must be taken that the program does not expand beyond the supply of good Ph.D. students.

What might ERDA offer to the well-funded, established teams as incentives for participation in ERDA's programs? Opportunities to obtain expensive special equipment, or to upgrade facilities, or to add more supporting staff, might be considered. Let me offer a specific suggestion that I know many "saturated" departments would find attractive; the opportunity to add junior faculty. In the 1950s universities were able to respond to the needs of NASA and the DOD by faculty expansion, but today the faculties of most of our universities have reached steady-state limits imposed by physical and budgetary constraints. Many institutions will not have many retirement vacancies over the next dozen years, but then retirements will begin to come in rapid succession. Then it will be possible to add new faculty who can work in areas of interest to ERDA. It would be a bold step of leadership for ERDA to act <u>now</u> to guide these replacements, say by providing <u>interim</u> funds, on a cost-sharing basis, to support advance replacements. A program to provide $500 K per year for five years would support half of the base salary of 50 new young professors. If allocated to productive institutions, where each professor carries $100 K per year in sponsored research, ERDA would have planted the capacity to handle $5 <u>million</u> annually in university research in areas of ERDA's choosing.

In summary, there are active steps which ERDA could take to bring more of the best university talent "on-board" the ERDA fossil energy program. I believe that steps such as those suggested would strengthen the research base for the program, and that it would be very much in the long-term interests of the program to take these actions now.

I would like now to examine the balance between basic research, applied research, and development in the ERDA fossil energy program. To begin, let's look at the balance in the oil industry (Table 9). The industry spends about half of its R&D budget on research. Industry-wide, approximately 5 percent is devoted to basic research and 44 percent to applied research. The four largest firms together spend considerably more on basic research (almost 9 percent of their total R&D expenditures). Note that the total spent on basic research by the industry is comparable with the high-technology research budgets of single universities.

TABLE 9

R&D EXPENDITURES OF THE OIL COMPANIES
(Millions of Dollars - 1975)

	Basic Research	Applied Research	Development	Total
4 largest firms	24.7 (8.9%)	138.7 (49.8%)	114.8 (41.3%)	278.2 (100%)
all others	8.8 (2.6%)	133.9 (39.1%)	199.5 (58.3%)	342.2 (100%)
industry total	33.5 (5.4%)	272.6 (43.9%)	314.3 (50.7%)	620.4 (100%)

Source: David Teece, Stanford

The basic mission of ERDA is to accelerate the implementation of alternative energy technology. ERDA does this by becoming a partner with industry in major development activities, and by supporting the research needed to provide a sound scientific and engineering base for future technological development. This is not the same as the mission of the oil industry, and so one would not expect the percentages in Table 9 to apply to the ERDA fossil energy program. Economists argue that the social benefits of basic research far outweigh the private benefits, which is a way of saying that industry invests less in basic research than it draws from the national pool of basic research. The larger firms are able to sustain a higher proportion of basic research, as Table 9 shows; but it falls upon the government to be the primary supporter, and the universities to be the primary performer, of the basic research which ultimately supports technological development. Therefore, I would argue that a government agency which matches industry 50-50 for development costs should be spending considerably more than does that industry on basic research. In view of the numbers in Table 9, it would seem appropriate to spend something like 10 percent of the total R&D budget of the fossil energy program on <u>basic</u> research in areas likely to contribute significantly to future fossil energy development. For a $500 million program, this suggests a basic research component of the order of $50 million per year.

The oil industry figures might provide a better guide as to the amount of applied research that is necessary to support future technological development in fossil energy. The oil figures suggest that an agency which matches industry 50-50 for development costs should be spending about as much for applied research as it spends on the development projects. For the fossil energy program, this would translate to about $360 million per year.

My assessment (The FY77 Budget Authorization Legislation document was used as the basis for this compilation. Each project was reviewed and the NSF definitions of each type of activity were applied (these definitions were also applied in Table 9). In the case of the Basic Energy Sciences program, the fraction of each area applicable to fossil energy, as estimated by ERDA, is given in the document. ERDA 76-10 was used in some cases to guide the classification of a project.) of the breakdown in the ERDA fossil fuel program is shown in Table 10. The amount shown under the Basic Energy Sciences program is deceptively large; I have shown the dollar amounts for research which could be applicable to fossil energy. Much of this also could be applicable to solar, geothermal, and other ERDA energy development programs. Therefore, had I instead identified each project in the Basic Energy Sciences program with only one of the ERDA development programs, the basic research total in Table 10 would only be about $12 million as shown in the bottom line of this table. Thus, from an overall agency point of view, the funds allocated to basic research

TABLE 10

ERDA Fossil Energy R&D
FY77 Budget Outlay Estimates
(Millions of Dollars)

	Basic Research	Applied Research	Development
Fossil Energy Program			
Coal	--	43.1	314.9
Petroleum and Natural Gas	0.2	1.6	30.4
In Situ Technology	--	2.3	17.8
Basic Energy Sciences*			
Materials	29.5	--	--
Molecular Sciences	17.2	--	--
Geosciences	2.6	--	--
Math/Comp.	2.1	--	--
Conservation			
Heat Engine System	--	1.0	--
Improved Efficiency	--	4.3	--
Environment and Safety			
Coal	--	1.8	
Oil and Gas	--	1.2	
TOTALS	52.6 (11.2%)	55.3 (11.7%)	363.1 (77.1%)
GRAND TOTAL $471.0			

Based on FY77 Budget Authorization Documents; does not include equipment.

*Non-additive analysis: the additive numbers are tabulated below.

Additive Analysis	12.6 (2.9%)	55.3 (12.6%)	363.1 (84.2%)
GRAND TOTAL $431.0			

in support of the fossil energy program are more like 3 percent than 11 percent of the total fossil energy expenditures. Note that applied research constitutes only about 12 percent of the total program.

These numbers support two opinions that I have heard from many colleagues. The first is that too much emphasis is being placed on development, and not enough on research, in the ERDA program. The second is that there is a "gap" between the basic research programs and the development programs, that applied research is not receiving sufficient emphasis.

There is other evidence to support this position. Table 11 shows the support for basic research in the physical sciences and in the engineering sciences as estimated by the NSF for FY76. Except for the materials area, the ERDA emphasis on basic research clearly has been in the physical sciences. This is due to the fact that ERDA also has responsibility for support of high energy and nuclear physics. In view of this responsibility, it is not inappropriate that ERDA spends more on basic research in the physical sciences than does the NSF. However, in view of ERDA's mission in energy technology, the difference between NSF and ERDA support for basic research in the engineering sciences is alarming.

TABLE 11

SUPPORT FOR BASIC RESEARCH, BY AREA - FY76
(Millions of Dollars)

	Physical Sciences			Engineering Sciences			
	Chemistry	Physics	Other	Chemical Engineering	Mech/Aero Engineering	Materials/ Metallurgy	Other
DOD	10.8	34.5	10.8	1.8	5.4	33.0	35.4
ERDA	63.8	180.8	3.5	0.2	0.0	16.2	3.0
NASA	55.4	193.6	217.7	0.0	22.7	7.7	11.3
NSF	48.2	72.5	36.8	8.5	10.2	16.3	26.9

Source: NSF-75-323

The "gap" is further demonstrated by Table 12, which shows support for applied research in the physical sciences and engineering sciences for FY76, as estimated by the NSF. Note that ERDA, which has a total budget comparable to that of NASA, spent far less on applied research in the engineering sciences. I regard this as very alarming for an agency with a primary mission to implement and advance high-technology energy systems over an extended period of time.

TABLE 12

SUPPORT FOR APPLIED RESEARCH, BY AREA - FY76
(Millions of Dollars)

	Physical Sciences			Engineering Sciences			
	Chemistry	Physics	Other	Chemical Engineering	Mech/Aero Engineering	Materials/ Metallurgy	Other
DOD	32.7	96.5	37.8	26.4	562.7	80.7	519.6
ERDA	30.8	147.0	5.4	38.2	5.1	14.3	43.5
NASA	1.5	5.9	5.1	1.9	495.6	70.7	68.8
NSF	4.3	2.3	0.1	1.1	1.1	4.3	22.8

Source: NSF-75-323

The FY78 ERDA budget proposal includes increases for research in the engineering sciences of combustion, coal chemistry, and fuel-forming catalysis in the Basic Energy Sciences Program. An analytical research chemistry and coal carbonization laboratory is proposed by the Fossil Energy Development program. These are positive signs that the scientists and developers are moving to fill the gap.

What basic and applied research might ERDA be doing that it is not doing now? There have been a number of workshops devoted to identifying critical problems that require research, especially as related to coal. These have led to very detailed recommendations for basic and applied research in materials, coal chemistry, coal combustion, and coal planning analysis, and identified a great deal of needed research in these areas. I think that more might also be done in the area of high-technology underground mining, to name just one other possibility.

There are four areas within my own specific expertise which do not seem to be receiving sufficient attention. Others with different expertise undoubtedly can identify areas that they feel are neglected. My suggestions for additional emphasis are:

1) Basic boundary layer heat and mass transfer in high-temperature systems. This would provide needed information for future systems.

2) Recirculating and separated flows. Low efficiencies in turbomachinery and associated equipment are generally associated with flow separation; recirculation is usually the key to high-performance combustion.

3) Scaling to larger sizes. Problems are always encountered when one scales results obtained in an experimental situation to the much larger sizes associated with commercial devices.

4) Combustion

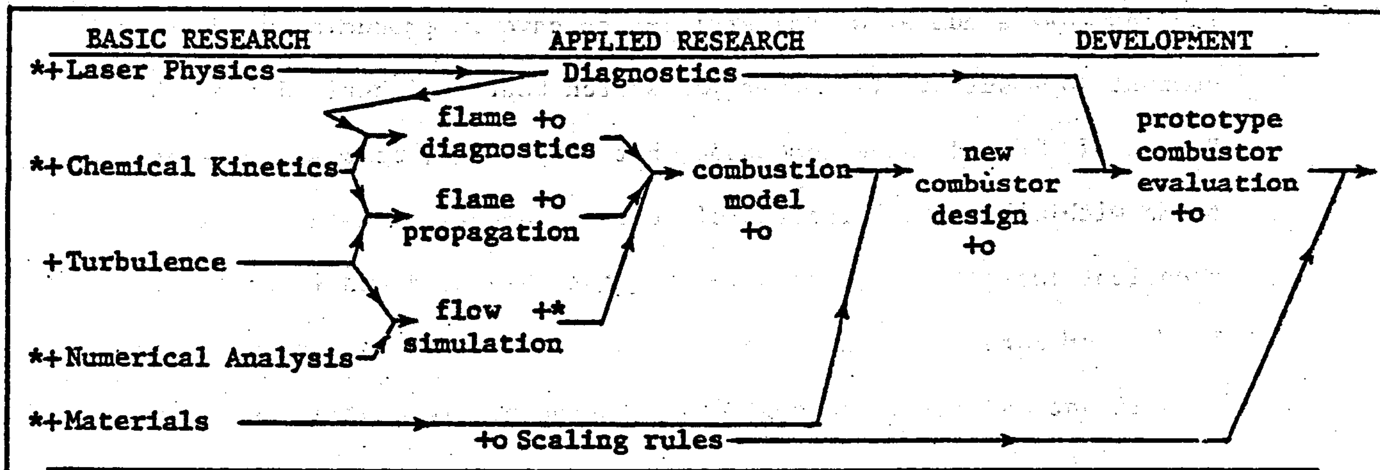
There are a number of universities with engineering departments well-qualified to do research in these four areas, as well as a few industrial research centers, but to the best of my knowledge these areas are not within the special competence of the ERDA laboratories. However, there are special instrumentation and computation capabilities in the ERDA laboratories which could be very useful in an integrated ERDA/university/industry attack on these problems.

Let me now concentrate on the research opportunities in combustion. Certain ERDA laboratories, with their high concentration of scientific talent, have developed some remarkable tools for combustion diagnostics and computational chemistry and fluid mechanics. However, they have not as yet had much experience in practical combustion systems, and, as Table 2 shows, they do not have the track records that a number of universities do have in producing useful combustion results. (The Energy Research Centers inherited from the Bureau of Mines do have some good, but very small, combustion research teams with substantial records of accomplishment.) The labs have excellent tools to apply to problems, but they need considerable input from more experienced combustion groups as to what problems are significant and likely to contribute to the development of new energy technology. Universities, certain Energy Research Centers, and certain industrial concerns, are in a good position to provide this guidance. The mutually beneficial interplay that has recently developed between researchers at the LBL and faculty in the Department of Mechanical Engineering at Berkeley is perhaps a paradigm of the university/agency cooperation that could give ERDA the beginnings of an excellent coordinated program in basic and applied combustion research. Figure 1 shows the spectrum of combustion research and areas in which university laboratories and industry could contribute.

I believe that the ERDA fossil energy program would benefit from a set of carefully-developed research <u>plans</u> and record of ongoing

FIGURE 1

POSSIBLE R&D SPECTRUM IN ONE FOSSIL ENERGY AREA



*ERDA labs have special expertise

+Universities have special expertise

°Industry labs have special expertise

research. These plans should be developed by teams of experts from universities, industry, the ERDA laboratories, and the fossil energy programs. They should be published as a guide to organizations seeking to participate in the program, and updated continually as some research needs are covered and new needs are identified. The plans should include both basic and applied research. In the materials area, many of the elements of such a plan now exist. But plans must be developed in the other areas as well.

In addition to the plans, the groups in ERDA which support these programs should develop competency files, and then seek out the most qualified groups or combinations of groups to work on the problems identified. The ERDA laboratories should have to compete for funding with universities and industrial research laboratories on an equal footing, with the research output, significance, and quality, and not agency budgetary responsibilities, being the primary deciding factors. The ERDA laboratories should be encouraged to team up with university researchers to provide balanced research teams; laboratories strong in basic research should seek cooperation from university people strong in applied research, and vice versa. The universities will have to contribute to such joint efforts from positions of strength; they must be given good financial support, and not merely "bones" tossed by the laboratories.

Each research program area should have an external Technical Advisory Committee consisting of individuals who are capable of evaluating and assessing the research. One would expect that these committees would have good representation from active university researchers in the field. The General Technical Advisory Committee for the Fossil Energy Development Program is an excellent group to provide overall program advice, but is not the best possible group to critique the specific research programs.

The integrated research plan for fossil energy research would not only identify the work that is needed, it would tell how much should be budgeted for basic and applied research. I would not be surprised if the fossil energy research plan showed that the basic research component should run at about $50 million per year and that the applied research component should be about $200 million per year.

Let me close with a suggestion about the administration of research within ERDA. Funding for applied research is at present centered in the development programs. The longer-range character of this research renders it vulnerable to the shorter range urgencies of the development programs. It is natural for those charged with meeting demonstration deadlines to concentrate on the near-term needs at the expense of the longer-term research which is the life-blood of future technological development. Many industrial firms have solved this problem by separating organizationally and budgetarily the research from the development activities. Such a separation may be necessary to redress the balance between basic research, applied research, and development in ERDA's energy program.

With the coming of the Department of Energy, an opportunity exists to take this step. The Moss Amendment to HR 6804 requires the establishment of an Office of Energy Research (OER), the Director of which will administer the Division of Physical Research (DPR) program transferred to DOE from ERDA. The amendment permits the Secretary of Energy to assign the OER Director the responsibility for supervision and support of research activities carried out by any of the Assistant Secretaries. The Director of the OER would report directly to the Secretary of Energy, and therefore could defend the long-range interests of the national energy R&D program before the senior authority. I believe that it might be a very good idea to give the Director of the OER this responsibility and concomitant budgetary control. The Director would then be in the position to administer a coherent, purposeful program of basic and applied research, involving universities, government laboratories, and industry, that is necessary if we are to continue to be the world leader in energy technology development.

To summarize, I believe that the research program that supports fossil energy development in ERDA is seriously underfunded, especially in the area of applied research, particularly in the engineering sciences. There is a gap between the very basic research supported by DPR and the work of development programs, and this gap should be filled now in the interests of future development. With the creation of DOE and OER there are new opportunities for coordinated planning and support of fossil energy research activities; there is much that the universities can contribute to both the planning and conduct of this research.

3. Summary

The major points that I have made today are as follows:

1. Much university expertise could be brought to bear on fossil energy problems.

2. Active steps could speed the rate at which the best university groups are brought on-board the fossil energy program.

3. Research funding levels are insufficient to support the long-term fossil energy program objectives.

4. The gap between basic research and the hardware development projects needs to be filled now by a significant increase in the funding for applied research.

5. A fossil energy research plan is needed to give structure and direction to the programs.

6. Universities can assist in formulating the research plan and in performing much of the basic and applied research required to meet the long-term program objectives, and can assist in some of the development activities.

7. Consideration should be given to the possibility of resting the responsibility for the quality and support of both the basic and applied research programs with the Office of Energy Research in the Department of Energy.

DR. PHILLIPS: Thank you very much. This platform is open for comments and discussion. Dr. Mills?

DR. MILLS: I would like to address two aspects: obviously there were a number of very interesting points you were making.

I must say, in fossil energy, we have struggled hard, and then get the message back that we are not really in tune with the universities.

Just a couple points. ERDA supports on-campus research, $160 million; the largest health and safety; the second largest division of physical research; the third largest in fossil energy; and the on-campus research doesn't include the Montana activity, 22 million.

We are trying to build this up. We are letting contracts for three and four years. We have some of $600,000 or more per year of; M.I.T., Utah, Penn State, Cal Tech, and one or two others.

So we are struggling with universities to come to a mechanism to meet our joint needs and opportunities. And apparently, we are part way there, but far from what is satisfactory. So that's one point, just to put a couple numbers in there.

Now there is another point that I would like to make, and this is perhaps not so pleasant. We are turning down nine out of ten proposals from universities as being inadequate.

One gets back to the situation that coal has not been a very attractive university activity, and therefore, it's taking a long time to attract people to provide interesting activities.

A related question is, where is it best to do basic research? Is it in the industry, is it in the energy research centers, is it in the national labs, or is it in institutes?

I could remind you that many of the big progresses which were made in the past were at the Max Plank Institute; Burgess, Peer, and so on, who were winners--Burgess won a Nobel Prize for his work--were not at a university.

One of the questions is universities versus nonuniversities. And the other is basic research versus non.

You said that funding opportunities are not as attractive to the university community from ERDA as others. I am sure you have some specific points on that as to what it is we should do differently in order to provide this attractiveness.

DR. REYNOLDS: Thank you, Dr. Mills. I am sorry if I sounded critical of your activity. I certainly didn't mean to, only trying to give you some help.

I was trying to reflect a lot of comments that I have heard from colleagues around the country about what they perceive. Now, this may or may not be fact. It's what they perceive.

And this is not particularly fossil fuels, your program. This is a general sort of perception of the agency. It's highly fragmented; the approach to university research in one group is quite different than another group, and the statement has been made to me about the fossil energy program in particular, that you have to know a top guy to get any action on their proposal.

In many cases there are monthly letter reports that are due. These are not characteristics of the agencies that have been supporting most university research.

I would have to get personally specific to cite instances, and I don't think I'd better do that in this forum, but I would be happy to talk with you more about that.

MR. DEVLON: Mark Devlon from Argonne Laboratories.

I think you have a very good point on your last vugraph. Your point 6 was a desire for larger university and laboratory partnership.

My question to you is: Some of the national laboratories are operated by consortia of universities who have boards of directors who have responsibilities for planning. Do you look at that as an adequate or an appropriate way for this partnership to take place, or do you have some other approach?

DR. REYNOLDS: I am thinking more of partnerships at working levels. There is an excellent cooperation now between LBL and the Department of Mechanical Engineering at Berkeley, in the combustion area. I think this is a paradigm of what ought to happen.

There is an exchange of people in the department, Mechanical Engineering Department--they know the applied research needs, they know what combustion research is all about and how to do useful combustion research.

People in the laboratory know how to get good measurements and do good calculations. Putting these two together in a very constructive way; that's more of what I mean.

I would like to see, for example, the proposals that come from the laboratories for support be asked to see if they have the right mix of university support. I would like to see universities be encouraged to go team up with laboratories to get hold of some of the expertise that is there.

DR. PHILLIPS: Any other questions or comments?

DR. BARON: I think we have come here to consider the efficiency of ERDA's research. And I propose that we keep that in mind when we use such words as "basic research" and "applied research" and what not.

There are lots of ways to use them, and I guess all nomenclature is to some extent arbitrary. But when you are asking specifically; is some research efficient or not, I suggest that an entirely different definition of the work "basic" should be applied.

When that is done properly, very great light can be thrown on the efficiency of research.

Let me give a brief illustration. I am in charge of a party of gold prospectors, but I am stuck in Nevada. The commercial objective is to find gold in California. The problem is to get across the Sierras.

By the way, if I were in Hawaii, the problem would be to build a boat. So you can have different problems corresponding to the same objective, depending on where you are.

Now, there are two ways of doing this, one which I would consider corresponding to basic research, and the other to something else called exploratory, or some other way.

The one that would correspond to basic research would be to hire the National Geographic Society and ask them first to make a geological map of the Sierras, then make an elevation map of the Sierras.

And then you hire the National Botanical Society, and they would make a map of vegetation and so on and so forth.

And on the end, you would have all these maps, and you could clearly then find the suitable mountain pass, especially if you had maps of hardness and rock formations, and what not.

Now this corresponds to basic research. In fact, the very word "basic" means that everything you found is already based on some other foundation. That's why basic and fundamental research are the same synonyms of each other.

Now the other way of doing it, which in this case we all would do, I am sure, is to hire Jim Bowie and say find me a mountain pass.

This is exploratory research. The reason that we would do it this way is simply that we all know intuitively that in the first case, we would have to find an awful lot of knowledge which is unrelated to our problem.

So whether you use basic research or not is simply a question of how much of the knowledge that you must discover is related to the problem that you are addressing.

I am submitting to you that it's best to think of basic research as a method competing with other methods of doing it, and at an efficiency and a deficiency of any research program, be it Exxon's or Shell's or ERDA's, should be assessed on the criteria of what part of the total knowledge that is acquired by doing this research in fact addresses itself to the problem.

And only when you do that can you answer, should we do this in a basic way or some other way.

DR. PHILLIPS: Thank you.

Alex Zucker.

DR. ZUCKER: I just can't let that one go. This is great if you know exactly what the future holds.

But let me illustrate something that has come to mind just recently about utilization of research where you have no idea that the problem really even exists.

It turns out that nuclear accelerators have been built, oh, for the past 50 years, with the idea of examining properties of nuclei. It now turns out that they form one of the great foundations for many of the high technology areas of the future.

No one would have accused Cocroft and Walton, or Lawrence of looking at producing energy by fusion. But in point of fact, accelerators seem to offer a way for inertial fusion that could not have been foreseen.

In a similar way the whole accelerator technology is important for the ion implant game, and the production of small calculators.

The whole question of producing fissionable isotopes--breeding fissionable isotopes by accelerators offers a new, nonproliferating nuclear technology.

The situation is such that the basic science uncovers those areas which we cannot predict. Jim Bowie's trip would have been totally useless if it hadn't been for the science of cartography. He could not have come back and told the guy where California is.

So the whole question of measuring in a short term what you are getting is misleading. It would lead, for example, in the 19th century to a great science of pulleys and belts rather than developing electric motors.

And it is just a totally blind alley.

DR. PHILLIPS: I believe this is very exciting and romantic to search for gold in California, and not know where California is and things like that, but I believe it's a little bit off our subject now.

I declare it slightly out of order, although very interesting. Other questions at this time?

MR. SMITH: I wanted to ask Alex Mills a question earlier as a result of Bill Reynolds talk. I am ready to ask him.

One of the curious things I noticed about that map, where you had contracts with universities, was a total absence of dots in the Boston area and the Palo Alto-Berkeley regions. Is there any particular reason for that?

DR. MILLS: We have a large project at M.I.T., which is not in Boston, but Cambridge, if you will accept that.

(Laughter.)

MR. HILL: Let me respond a bit to that. We have been trying for years to subvert bright, university types into coal research.

Ten, fifteen years ago, I think there were three, maybe four universities that had a medium level of effort or a high level of effort.

The Electric Power Research Institute, in cooperation with Alex's shop, prior to that incorporation with NSF-RANN, tried to funnel money into coal research sponsorship, and found the very thing you say is true, Bill, that established research groups with their own pattern looking at dirty, old coal had a very hard time getting excited about it, particularly since there wasn't a format that gave the longevity to contracts.

I can't help mentioning, when I got my first contract with OCR years ago, Bill Cochran, bless his heart, said, "Hey, we've never had any contract with universities before, let me see, if you will, the contracts you've had from other agencies."

Stupidly, I gave him the contract from ONR, AEC and Air Force Office of Scientific Research. And the contracts people, bless their hearts, succeeded in putting together every restriction that each of those contracts had, including monthly reports, permission to talk had to be obtained by getting written permission from the office before you could talk about your research.

Well, that was backed away from. And then when I was here in Washington, we really backed away from it, and I think you've got a good system now.

But the point I'm making is that it has been a case of trying to get people to come into the field from the purer fields. And this requires a lot of effort.

We had to set up a department, a program area, to receive proposals from universities, because everybody wanted to study the kinetic formation of methane. And that wasn't one of the things that EPRI, for example, had interest in.

And so we had to have somebody that would work with the professor and turn his proposal to where it would pass peer review, And in that way--what do you have, 150 different sites that were not doing work before.

And they are not the big ones, because they are already established by and large, except M.I.T.

DR. PHILLIPS: Other questions or comments?

Yes. I think this will have to be the last comment.

MR. CANONICO: Domenic Canonico, Oak Ridge National Labs.

I would just point out something that Dr. Mills said earlier that over almost 50 percent of his unsolicited proposals come from universities. And I would hate to leave us here today with the idea that the universities are not interested in fossil energy research.

DR. PHILLIPS: Very good point.

Very well, we will now go on to our last paper, which will be a short one concerned with production of research manpower in the fossil energy area, by Ricki Kobayashi.

DR. KOBAYASHI: Thank you, Gerry.

On the way back from lunch, you said you would give me five minutes, so if you will push the warning button, I will get started.

DR. PHILLIPS: Go.

DR. KOBAYASHI: There are many comprehensive documents and papers such as:

(1) A Study of NASA University Programs, (NASA SP-185, 1968),

(2) The University and Environmental Quality (Report to the President's Environmental Quality Council, Office of Science and Technology, September, 1969),

(3) Fossil Energy Technical Manpower: Forecasts of Supply and Demand, (Prepared by Bernard S. Friedman for ERDA, October, 1975), and

(4) Engineering College Research and Graduate Study: A Ten Year Statistical Analysis by W. J. Fabrycky and I. D. Moon, Engineering Education 66, 452 (1976).

and similar compilations provide statistical data, both historical and projectional, on U.S. scientific and technical manpower.

Rather than delve into a mass of statistical data, I shall present a few comments regarding manpower needs to meet "national" energy goals.

Although our activities in fossil energy exploration have been international in character for several decades, we have not been engaged in the optimum utilization of oil and gas in foreign lands except perhaps in Canada. The sudden change in proceeding towards a near optimum production and utilization of oil and gas in the OPEC nations could not be capitalized until after the oil embargo in 1973. Since that time scientific back-up and engineering work for and in the OPEC nations have increased several fold. Our ultimate involvement in foreign lands will cover all the fossil energy areas as we develop expertise in shale, tar sand, and coal utilization and advanced recovery methods for oil in the years ahead. Thus, a serious assessment of our manpower needs must include our deep involvement in fossil energy projects throughout the world as well as those designed to improve our fossil energy posture here at home!

As recently as 1974-1975, we actually experienced a rather severe decline in the number of bachelors degrees in engineering awarded. Engineering enrollments increased sharply, however, in 1975-1977, so that enrollment in engineering schools throughout the country has increased drastically in the last two years. The Arab oil embargo followed by the declaration of Project Independence and the general shift towards the pursuit of professional degrees are probably the main reasons. At any rate, a mass shift from the pure science to the applied areas of engineering has taken place. An imbalance of scientists to engineers and of bachelors degree to Ph.D. degree recipients will almost surely occur in the coming years.

The burgeoning enrollment in engineering schools throughout the country is now a fact. Enrollments in the earlier years in engineering schools throughout the country have increased up to a factor of four, depending on the curriculum and the university. This has, however, immediately led to the shortage of qualified personnel to teach them. The teaching problem during the first two years of their careers starts in the physics and chemistry and math departments, particularly in the all important teaching assistantship and tutorial type of relationships. A general laxity in the teaching of the language skills has reversed itself and even there a greater amount of instruction will be needed.

In chemical engineering alone, approximately 100 new faculty positions have sprung open in the last year and a half. Although exact figures are not yet available, probably two to three times that many new faculty positions have become available in all of engineering. Many of the positions, as our own, will have to be filled by temporary instructors, because we are unable to find or competitively bid for candidates possessing the requisite qualifications. The academic demands for Ph.D.'s together with similar increased demands of industry has led to a dearth of new Ph.D.'s in all areas of engineering. The shortage will only be reduced as a result of a combination of the following factors:

(1) the job market tightens for the B.S./M.S. graduates,

(2) a more favorable differential salary scale between the B.S./M.S. engineers and the Ph.D. develops,

(3) substantial infusion of traineeships and research funding becomes available to draw trainees from the swell of undergraduates, and/or

(4) retraining of Ph.D.'s from the scientific disciplines with an applications bias.

The point is that all the agencies: NSF, DOD, NASA, etc., have essentially phased out their support of graduate research simultaneously: In the sixties, the NASA university programs alone were responsible for training over one thousand graduate students per year. In contrast, the Energy Sector, which impacts almost 40 percent of our GNP, has just begun a rather feeble training program.

Disciplines of education are interdependent. The basic disciplines of education: science, literature and the arts, are interdependent. Since the ultimate goal we seek for individual development is interdisciplinary, the symmetry among the various disciplines in our educational institutions should be largely preserved. The weakening of one discipline in relation to another will ultimately lead to weakening of them all.

One of the quickest ways to transmit enthusiasm and ideas to the university campuses would be to provide summer faculty appointments to fossil energy-oriented research facilities at governmental and private research and development centers throughout the country. Existing fossil energy research centers are amongst the most sophisticated research centers in this country. A cooperative program to stimulate faculty members who in turn would transmit new understanding and enthusiasm to students is in order. In some cases appointments up to a year may be advisable, keeping in mind that the university teaching load has increased drastically.

On the occasion of the receipt of the 1972 Redwood Medal of the Institute of Petroleum, Professor Fred Rossini gave an address entitled "Chemical Thermodynamics in the Petroleum Industry" in which he summarized his involvement in the study of the thermodynamics of chemical compounds encountered in the petroleum industry over a period of over three decades. In retrospect, realizing that his studies were closely related to

(1) the production of petroleum,

(2) the transport of petroleum,

(3) the refining of petroleum,

(4) the production of petrochemicals from petroleum, and

(5) the environmental problems associated with the petroleum industry, would we not consider his studies as mission oriented? His work not only represents good basic science but also served to help direct a multitude of successful missions. A corollary observation is that a futuristic view might lead to the conclusion that a given research endeavor was very basic, or abstract, while an historical view of the same endeavor would class it as obviously mission oriented. Many, many similar examples could be made of other "basic studies." The point I wish to make is that we should take heed not to define the work "mission" too narrowly.

In his address to the Columbia University Graduate School of Business in May, 1968, James E. Webb, then administrator of NASA, delivered a series of talks entitled "Goal Setting and Feedback in Large Scale Endeavors." We are, I presume, engaged in a "large scale endeavor" or "endeavors." One of the most important points made by Mr. Webb is that care should be taken in assessing the relationships between the primary goals and the accompanying sub-goals or "sub-missions" in our case. He claims that the second- and third-order effects, good and bad, must be better evaluated to predict the total impact of large endeavors on society. We have seen and are beginning to see some of the secondary effects of the space program on our society. The secondary effects may even become as large as our primary goals in the years ahead.

In concluding my talk, I quote from an address to the Educational Section of the International Congress of Mathematicians in 1912, by A. N. Whitehead, "I recur to the thought of the Benedictines, who saved for mankind the vanishing civilization of the ancient world by linking together knowledge, labor, and moral energy. Our danger is to conceive practical affairs as the kingdom of evil, in which success is only possible by extrusion of ideal aims. I believe that such a conception is a fallacy directly negatived by practical experience. In education this error takes the form of a mean view of technical training. Our forefathers in the dark ages saved themselves by embodying high ideals in great organizations. It is our task, without servile imitation to exercise our creative energies."

DR. PHILLIPS: It is open for discussion. Any comments or discussion?

Dr. White.

DR. WHITE: I want to comment on the question, but I certainly second your enthusiasm for the appointment of faculty people for summer employment in the ERC's. As far as I personally am concerned, I urge my fellow directors to do everything they can within budget limitations. I think that it is not a useful exercise unless it is possible to give that man coming in a really meaningful assignment. And it seems like that should be easy, but if you got 10 or 15, then to go to 20 or 30, it becomes a real challenge in a laboratory which is, as some of them are, relatively small with relatively small supervisory staffs. I just mention that side of that problem. If you feel we are not doing enough, it may be that it is not just money or not willingness, but a conviction that quality is equally important to quantity.

DR. KOBAYASHI: I certainly agree with that.

DR. PHILLIPS: Thank you. Any other questions or comments?

Are there any general comments or discussion anyone wants to give in regard to today's program?

DR. WHITE: I guess we will have a session tomorrow on ideas, but sometimes you have conflicts in times for meeting. I just wanted to mention a thought I had in the shale area.

There were a number of points up there about the engineering aspects of retorting. There are other ways of getting the material out of shale than just retorting. I know back when I was at AMOCO on hydro retorting, also solvents, and these sort of things can be done, and they are in some ways very attractive.

One of the things, for example, the hydro retorting is clear enough so that in order to begin to talk intelligently and listen intelligently about some of the claims, I suggested to one of the fellows, I think it is one kind of thing that might be done in the university.

We had a Fisher-Assay for a pyrolysis step in trying to assay Western shales. We don't have anything equivalent, any hydro retorting step, which is a standardized test procedure that you can say, well, if you treat it by this test, you will get 50 gallons a ton, or 20, or whatever it might be. One of the interesting things is this, Eastern shales, Devonian types, which are no good at all for normal retorting; they don't respond and they are very low Fisher-Assay, but you give them hydro retorting and they produce some very surprisingly high volumes of reasonable liquid yield.

Now, these are the sort of areas that we don't understand, what are the differences, but I know in some of our work, some of the solvents are intriguing. Now that may be entirely impractical to use commercially, but, on the other hand, maybe some further basic work there could give some useful answers.

Another problem that is similar, isn't related at all, sort of in-between the shale and coal, and that is some of our heavy oils. There are some very large amounts of heavy oil deposits, not only in

California, but also in the East--excuse me, in the midcontinent, Missouri and Kansas area, which are not recoverable by any normal technique and it is a real challenge to find a way to get those out. The economics are going to be critical here.

One of the things we are trying to pound into our fellows, any time we are thinking about it is, remember, we do have to face that net energy, no matter what the dollar cost is. You may say, "Some day the cost may rise enough, so even if my method is expensive, it will be worthwhile to get those out, so go ahead and work on the method.

But if you are spending 150 Btu's to get it out, totally, and you are only getting out 100, I don't care what the price is, it's still not going to be very attractive.

DR. BARON: On that point, it is rather amazing, we plan to calculate what amount of oil will be recoverable by using only the criteria that I can't expend more energy than I am getting. I got to 60 billion barrels as opposed to the normal 20, 21 billion barrels that we talked about as being reasonable.

DR. WHITE: I never heard that figure before.

DR. PHILLIPS: I have an interesting number in regard to the geopressured gas, brines. As you know, roughly a month ago it was reported that, I guess it was 17 cubic feet, is that right, Phil, per barrel--

DR. WHITE: 20 to 50. In our current well ERDA is producing, it is running 50 cubic feet a barrel.

DR. PHILLIPS: Okay. Take my number and multiply it by about 3. However, I remember the number, it corresponds to 3.4 cents per barrel. However, that is not the number that interests me. The number that interests me is that of the gravitational energy that would have to be expended to raise the barrel from 10,000 feet to the surface, and then assuming that the second lowest value, it would take at least that much to put it back in the ground, that comes out to almost 75 percent of energy content of the barrel. It seems to me, if anything, that might prove that this is where we need an in situ technology.

We don't want to have to bring it up and put it back down. Are there other comments?

DR. WHITE: There is a real challenge.

DR. PHILLIPS: A real challenge. Very fundamental. Dr. McBride?

DR. MCBRIDE: Frank McBride, Colorado School of Mines. You have asked us to think about the basic science future of your agency, and whether what you are doing is good basic science. And I don't mean it is appropriate at the moment, but it could be improved upon.

It prompts me to ask you whether or not you or anyone else has in your laboratory a group of scientific generalists who do nothing but think about this kind of problem? As I sit here listening to these processes, I am sure that Irving Wender doesn't need my advice about any of the things he is currently doing. I suspect that some of my fellow invitees and all of the participants would say the same thing. But it might be if somebody thought very differently from Irving and had the challenge to think differently from Irving, he might come up with an answer which would surprise all of us. And thinking for only a day and a half about these problems is really not enough. You have to put your feet up on the desk with Dr. Wender and say, "Now, dammit all, if you can do this, what would happen?" That is the kind of talk you need.

I guess my suggestion to you is--it is probably a half-baked suggestion, is that you establish a scientific internal auditor gadfly group that does nothing but go around and put its feet up on the desk and say, "Now, dammit all, why are you doing it this way?" Do you have such a group?

DR. PHILLIPS: That is sort of the purpose of this meeting, as a matter of fact, Doctor.

DR. MCBRIDE: I understand that but I am suggesting to you that this meeting is probably going to be ineffective for that purpose. You need an in-house gadfly.

DR. PHILLIPS: Sure. I think you certainly must be right. However, I think our intention is to get information from the outside.

We certainly want your first cut at it. That is for sure. In fact, in that regard, I think we should close the meeting now. But I would again remind you, if you want to participate in our study groups tomorrow, please let us know by turning in one of these sheets with your name.

To Dr. McBride's discussion, we are mainly concerned with questions of balance. There is a tendency for organizations to become obsessed with the current problems and activities. Once again, that is natural, if counterproductive. When existing problems are frustrating, exhausting, little energy is left for detached appraisal. There may be room for something like a special assistant for devil's advocacy charged with the responsibility of challenges to prevailing concepts.

Through a structurally-recorded position of partial independence, he may be able to save his leader from longer-run slips, arising from every occupation, of the current problem.

Useful dissent, which might otherwise be ground in natural bureaucratic conflict, would have a greater chance to emerge.

(Applause.)

I thank all of you. We will convene again in the morning at 8:30.

(Whereupon, the meeting was adjourned at 5:30 p.m. to reconvene Wednesday, 29 June 1977 at 8:30 a.m.)

MITRE CORPORATION

and the

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

PUBLIC MEETING

on

FOSSIL ENERGY RESEARCH

Quality Inn
415 New Jersey Avenue, N.W.
Federal Ballroom South
Washington, D.C.

Wednesday, 29 June 1977

The meeting in the above-entitled matter was reconvened, pursuant to adjournment, at 8:30 a.m. Dr. R.H. Kropschot, presiding.

PROCEEDINGS

DR. KROPSCHOT: Good morning. May I please call the meeting to order.

We would like to proceed with our presentations, and since in this program the exception is the rule, we are going to deviate slightly from our schedule again. I would like to introduce the second paper on your agenda rather than the first one. The Environmental Safety Research, that is entered under the direction of the Assistant Administrator for Environmental Safety. The Special Assistant to Dr. Liverman, Dr. George Shepherd, will present that work.

DR. SHEPHERD: Thank you. I am coping with a bout of laryngitis. If I fade out in the middle of the talk, those of you who wish to follow my remarks can read my lips. For the rest of it, I tried to make the slides self-explanatory.

(Slide 1)

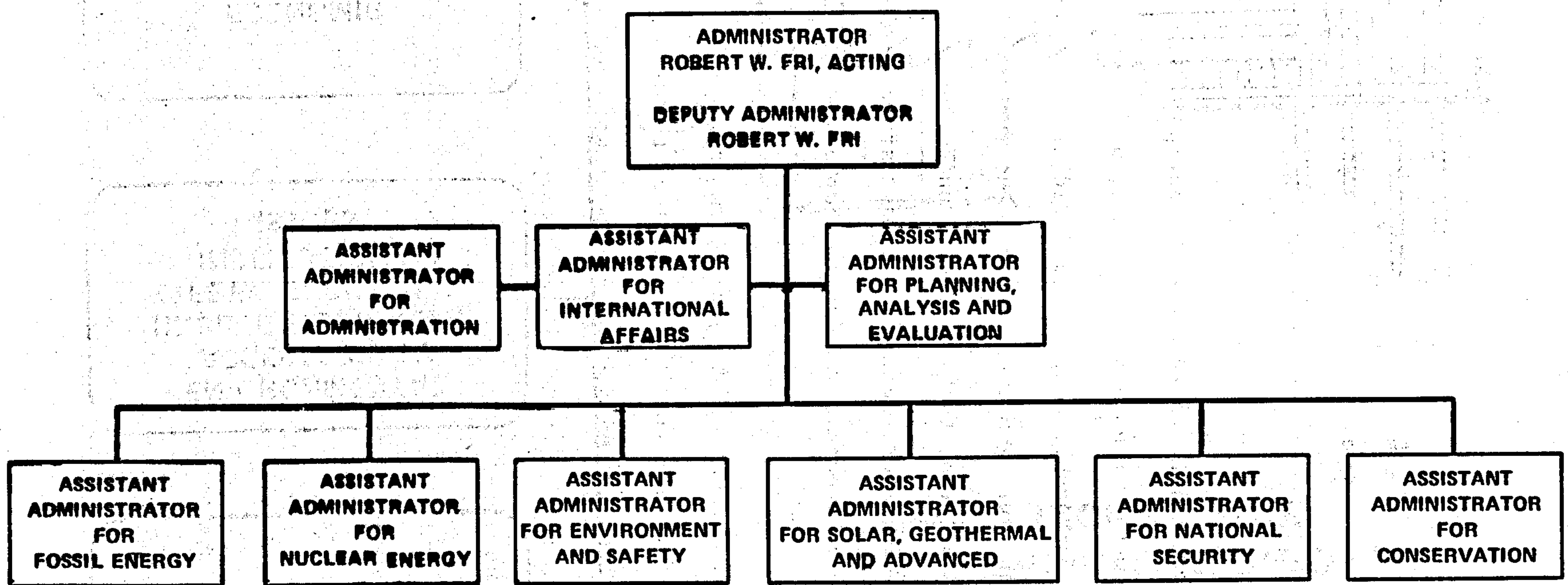
The Office of the Assistant Administrator for Environmental Safety is represented by the third box from the left.

(Slide 2)

Factors influencing the commercialization of an energy technology include technical feasibility, environmental acceptability, and economic marketability. While this is an oversimplification, there is an environmental factor in acceptance of a technology.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ORGANIZATIONAL CHART

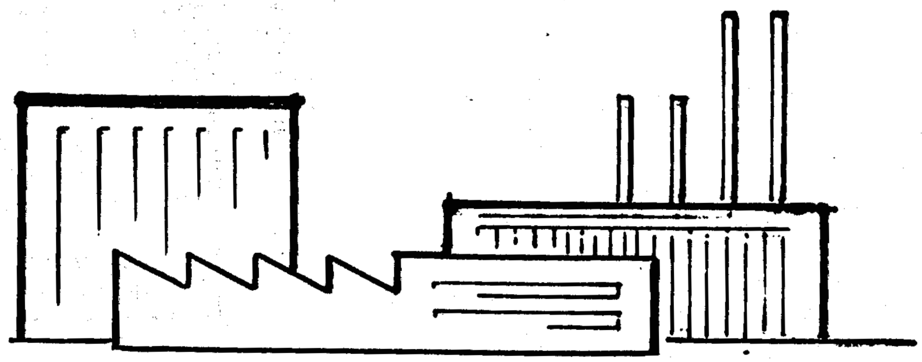


FACTORS INFLUENCING THE COMMERCIALIZATION OF AN ENERGY TECHNOLOGY

TECHNICAL FEASIBILITY

ENVIRONMENTAL ACCEPTABILITY (INCLUDING HEALTH, SAFETY, SOCIETAL & INSTITUTIONAL) ISSUES

ECONOMIC MARKETABILITY



COMMERCIALIZATION

(Slide 3)

The Environment and Safety Program goals are to ensure that energy technologies are developed with adequate considerations for environment, safety and health requirements in our operating facilities and to conduct general life science and medical applications research.

(Slide 4)

The environment and safety program, run by the Assistant Administrator for Environment and Safety, has three major components to it; energy technology, overview and assessment research, and environmental health and safety assurance.

(Slide 5)

The AES Program objectives in research are to assess the health, biological and environmental affects from energy generation; to characterize, measure and monitor energy related pollutants; to conduct studies in general life science missions; and to conduct, within ERDA, the reactor safety research programs of NRC.

(Slide 6)

The AES organization is composed of a number of organizational boxes. We are going to concern ourselves with the bottom 5; Biomedical and Environmental Research, Operational Safety, Control Technology, Safety Research Coordination and Technology Overview.

(Slide 7)

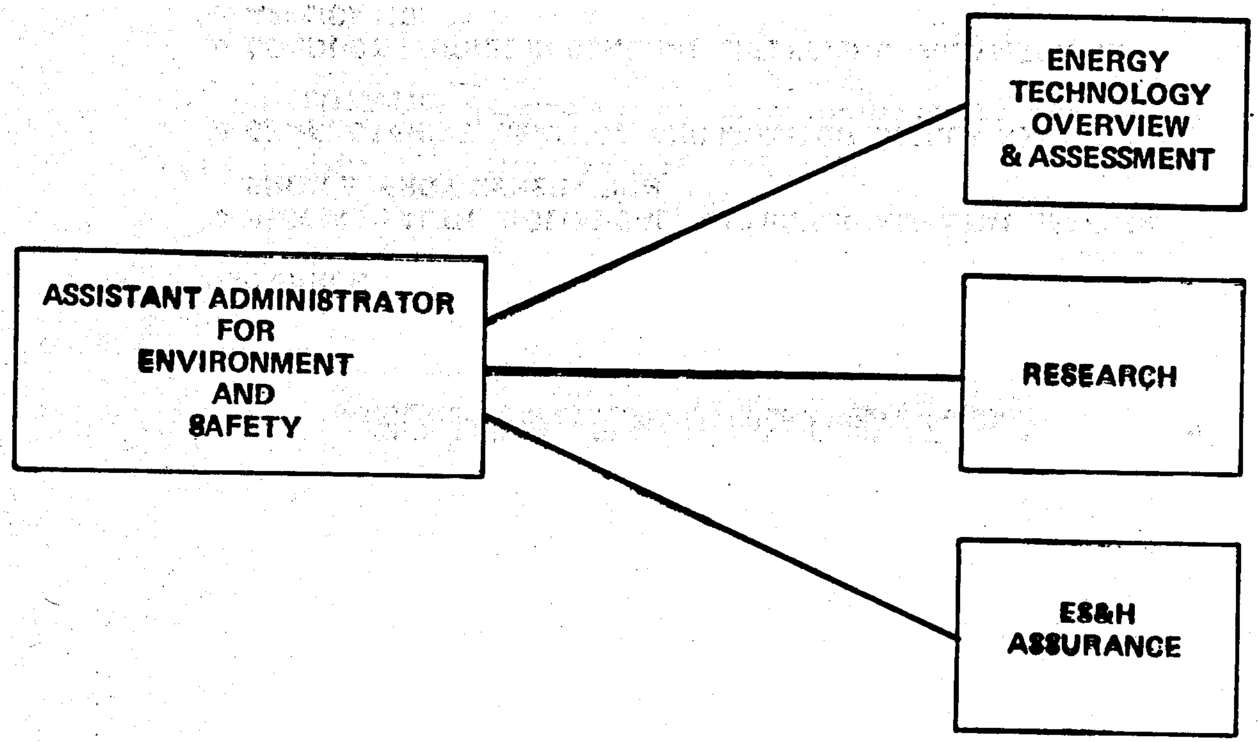
The prime responsibility of the Division of BER, Biomedical and Environmental Research, is research. The Office of Reactor

ENVIRONMENT AND SAFETY PROGRAM

GOALS:

- TO ENSURE THAT ENERGY TECHNOLOGIES ARE DEVELOPED WITH ADEQUATE CONSIDERATION OF ENVIRONMENTAL, SAFETY, AND HEALTH REQUIREMENTS FOR COMMERCIALIZATION.
- TO ENSURE ADEQUATE CONSIDERATION OF ENVIRONMENTAL, SAFETY, AND HEALTH REQUIREMENTS IN ERDA'S OPERATING FACILITIES.
- TO CONDUCT GENERAL LIFE SCIENCE AND MEDICAL APPLICATIONS RESEARCH.

ENVIRONMENT & SAFETY PROGRAM

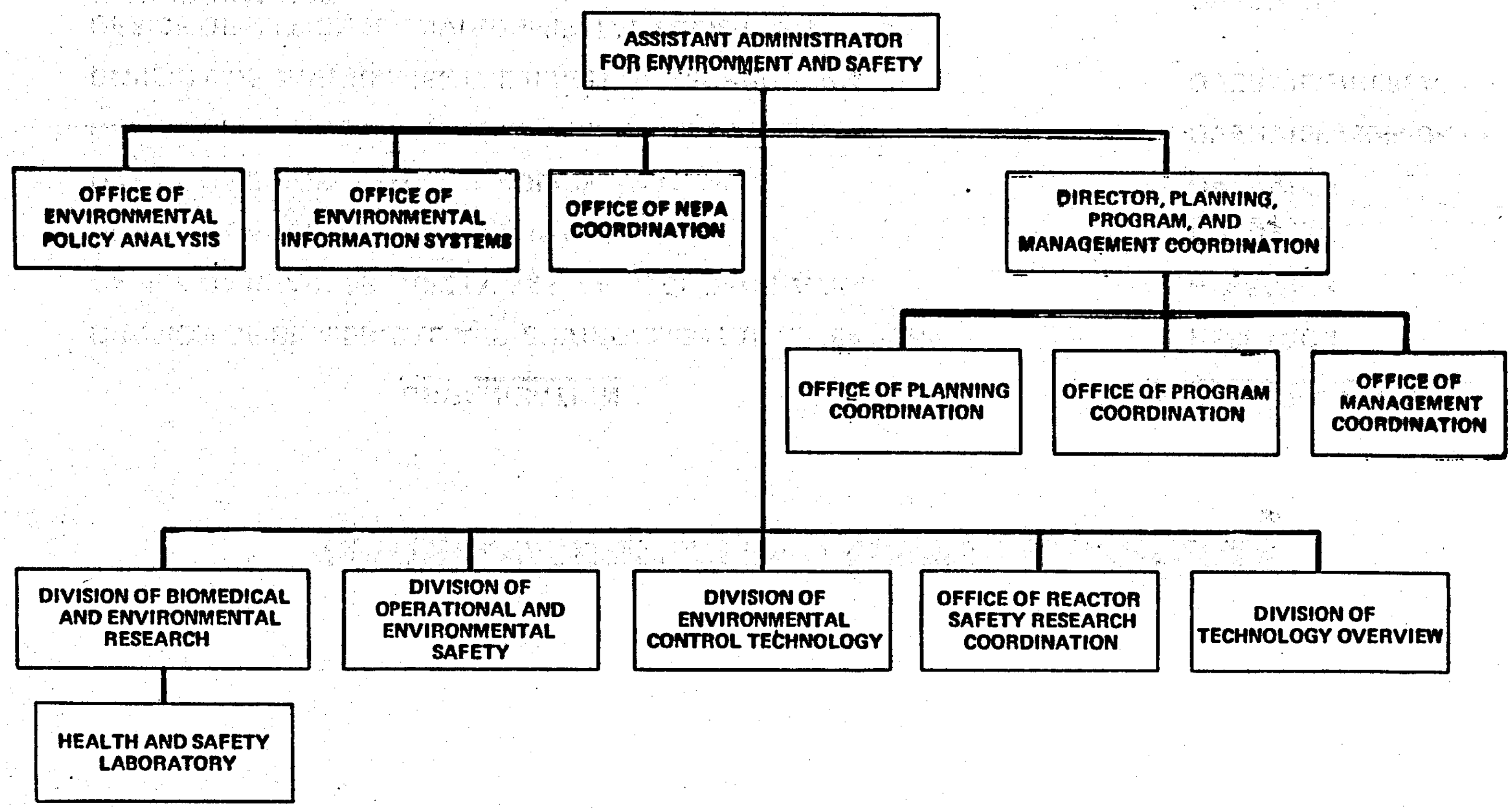


AES PROGRAM OBJECTIVES

RESEARCH

- ASSESS HEALTH, BIOLOGICAL, AND ENVIRONMENTAL EFFECTS FROM ENERGY GENERATION
- CHARACTERIZE, MEASURE, AND MONITOR ENERGY-RELATED POLLUTANTS
- CONDUCT STUDIES IN GENERAL LIFE SCIENCE AND MEDICAL APPLICATIONS
- COORDINATE WITHIN ERDA THE REACTOR SAFETY RESEARCH PROGRAM OF NRC

AES ORGANIZATION



ENVIRONMENT AND SAFETY PROGRAMS

ORGANIZATION	PRIME RESPONSIBILITY
DIVISION OF BIOMEDICAL AND ENVIRONMENTAL RESEARCH	RESEARCH
OFFICE OF REACTOR SAFETY RESEARCH COORDINATION	RESEARCH
DIVISION OF TECHNOLOGY OVERVIEW	OVERVIEW
OFFICE OF ENVIRONMENTAL POLICY ANALYSIS	OVERVIEW
OFFICE OF ENVIRONMENTAL INFORMATION SYSTEMS	OVERVIEW/SUPPORT
DIVISION OF ENVIRONMENTAL CONTROL TECHNOLOGY	OVERVIEW/RESEARCH
OFFICE OF NATIONAL ENVIRONMENTAL POLICY ACT COORDINATION	OVERVIEW
DIVISION OF OPERATIONAL AND ENVIRONMENTAL SAFETY	ES&H ASSURANCE

Safety Research Coordination, has as its prime responsibility, research. The Division of Technology Overview functions as an overview structure; that is, it determines the relevance of research program activities.

The Office of Environmental Policy Analysis is, as its name implies, a policy group which contributes policy statements and concepts to management or research programs. The Office of Environmental Information Systems, again self-explanatory, is concerned with computers, software and data management.

Environmental Control Technology has both overview and research responsibilities, and are concerned with control technology devices and the applications thereof. National Environmental Policy Act Coordination coordinates environmental impact statements operations. And Operational Environmental Safety is concerned with occupational safety and health.

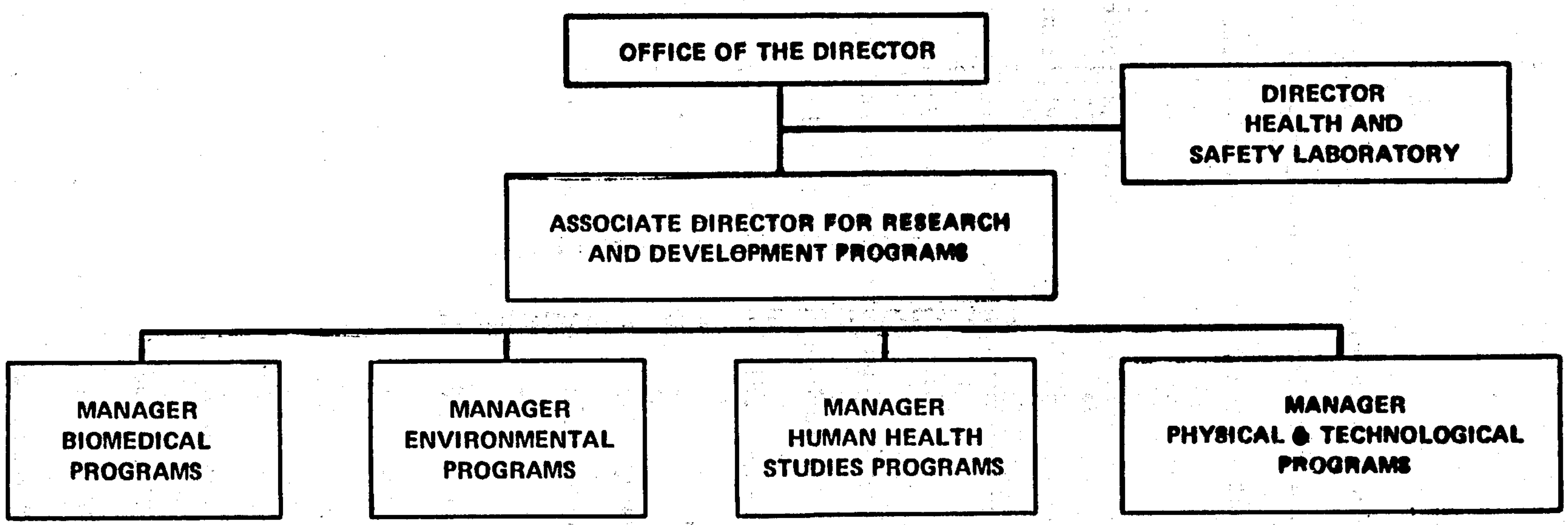
(Slide 8)

The Division of Biomedical and Environmental Research has four programs. Biomedical programs, environmental programs, human health studies, and physical and technological health studies.

(Slide 9)

The summary of the technology breakdowns in dollars for '77 and '78 are as you see here. The category "multitech" includes research programs which are relevant to two or more technologies.

DIVISION OF BIOMEDICAL AND ENVIRONMENTAL RESEARCH



AES FY 1978 BUDGET

OPERATING BUDGET

BIOMEDICAL AND ENVIRONMENTAL RESEARCH: SUMMARY BY TECHNOLOGY

(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
FOSSIL	$ 27.7	$ 34.7
SOLAR	1.2	1.6
GEOTHERMAL	2.8	3.7
CONSERVATION	2.0	1.8
NUCLEAR	54.9	57.8
MULTI TECHNOLOGY	35.3	36.3
TOTAL	$ 123.9	$ 136.0

For example, a program in cadmium toxicity might well relate to more than one technology, since this metal occurs in several Technology Fuel cycles.

(Slide 10)

If we break the fossil line down further, you find that dollars are distributed among human health studies, health effects and biological systems, environmental studies, and physical and technological studies.

(Slide 11)

If we look at environmental, we can break down fossil into extraction, combustion, gasification, liquefaction, oil and gas, and oil shale; but the dollars are as you see here.

(Slide 12)

Health Effects in Biological Systems (Fossil) can be broken down into combustion, gasification, extraction, and shale. The dollars are as you see here, totaling \$10.6 million and 13.5 million for '77 and '78.

(Slide 13)

(Slide 14)

Human Health Studies can be broken down in fossil into these four categories; combustion, liquefaction, oil and gas, and oil shale.

AES FY 1978 BUDGET

OPERATING BUDGET

BIOMEDICAL AND ENVIRONMENTAL RESEARCH: FOSSIL

(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
HUMAN HEALTH STUDIES	$ 2.4	$ 3.4
HEALTH EFFECTS RESEARCH IN BIOLOGICAL SYSTEMS	10.6	13.5
ENVIRONMENTAL STUDIES	12.3	14.5
PHYSICAL AND TECHNOLOGICAL STUDIES	2.4	3.3
TOTAL	$ 27.7	$ 34.7

BIOMEDICAL AND ENVIRONMENTAL RESEARCH
OPERATING BUDGET
ENVIRONMENTAL STUDIES: FOSSIL
(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
COAL EXTRACTION, STORAGE AND PROCESSING	$ 1.2	$ 1.5
COAL COMBUSTION	7.8	8.6
COAL GASIFICATION AND LIQUEFACTION	.7	1.3
OIL AND GAS	1.5	1.7
OIL SHALE	1.1	1.4
TOTAL	$ 12.3	$ 14.5

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

OPERATING BUDGET

HEALTH EFFECTS RESEARCH IN BIOLOGICAL SYSTEMS: FOSSIL

(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
COAL EXTRACTION, STORAGE AND PROCESSING	$ .3	$ .2
COAL COMBUSTION	4.4	5.0
COAL GASIFICATION & LIQUEFACTION	5.1	7.2
OIL SHALE	.8	1.0
TOTAL	$ 10.6	$ 13.5

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

OPERATING BUDGET

PHYSICAL & TECHNOLOGICAL STUDIES: FOSSIL

(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
COAL GASIFICATION & LIQUEFACTION	$ 2.0	$ 2.9
OIL SHALE	.4	.4
TOTAL	$ 2.4	$ 3.3

BIOLOGICAL AND ENVIRONMENTAL RESEARCH
OPERATING BUDGET
HUMAN HEALTH STUDIES: FOSSIL
(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
COAL COMBUSTION	$ .9	$ 1.9
COAL GASIFICATION & LIQUEFACTION	.9	1.4
OIL AND GAS	.5	.1
OIL SHALE	.05	.05
TOTAL	$ 2.4	$ 3.4

(Slide 15)

Environmental Engineering. Again we are talking about the fossil energy, solar, nuclear energy and material transportation. The dollars are as you see here.

(Slide 16)

The environmental energy engineering in the fossil category breaks down into coal, petroleum and gas, and oil shale components.

(Slide 17)

Technology Overview deals with the assessment of health of energy systems, the assessment of environmental and socioeconomic impacts and the assessment of impacts of energy production in local, regional and national scales. I am sure that many of you have come in contact with some of our programs in your respective various regions.

(Slide 18)

If we look at the total funding summary, you will see that Biomedical Environmental Research, ECT, Operational Safety, and so on, have the budget outlays that you see here.

Now, where does this money go?

(Slide 19)

Our ERDA resources, dollars, are going to a variety of places, including universities, other agencies, national laboratories and energy centers. We do have funds going overseas to international

AES ENERGY RESEARCH AND DEVELOPMENT
OPERATING BUDGET
ENVIRONMENTAL ENGINEERING
(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
FOSSIL ENERGY	$ 5.2	$ 6.2
SOLAR, GEOTHERMAL & ENERGY CONSERVATION	1.2	1.3
NUCLEAR ENERGY	1.7	3.5
ENERGY MATERIAL TRANSPORTATION	2.3	3.4
TOTAL	$ 10.4	$ 14.4

AES ENERGY RESEARCH AND DEVELOPMENT

OPERATING BUDGET

ENVIRONMENTAL ENGINEERING

FOSSIL

(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
COAL	$ 3.5	$ 3.6
PETROLEUM AND GAS	1.4	1.9
OIL SHALE	.3	.7
TOTAL	$ 5.2	$ 6.2

AES ENERGY RESEARCH AND DEVELOPMENT
OPERATING BUDGET
TECHNOLOGY OVERVIEW
INTEGRATED ASSESSMENT
(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
ASSESSMENT OF HEALTH OF ENERGY SYSTEMS	$ .5	$ .5
ASSESSMENT OF ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS OF ENERGY SYSTEMS	.4	.4
ASSESSMENT OF IMPACTS OF ENERGY PRODUCTION IN LOCAL, REGIONAL & NATIONAL SCALES	4.4	6.0
TOTAL	$ 5.3	$ 6.9

AES FY 1977-78 FUNDING SUMMARY

(OPERATING EXPENSES)

(IN MILLIONS)

ORGANIZATION	B/O IN MILLIONS FY 77	B/O IN MILLIONS FY 78*
BIOMEDICAL AND ENVIRONMENTAL RESEARCH	164.7	173.0
ENVIRONMENTAL CONTROL TEHCNOLOGY	16.8	27.9
OPERATIONAL AND ENVIRONMENTAL SAFETY	5.9	7.7
OVERVIEW AND ASSESSMENT	18.0	18.0
REACTOR SAFETY RESEARCH COORDINATION	21.0	21.6
	226.4 1/	248.2

*PRESIDENTIAL BUDGET (DOES NOT INCLUDE POSSIBLE CONGRESSIONAL ACTIONS)

1/ INCLUDES RESTORATION OF DEFFERAL FUNDS (8.9M)

ERDA RESOURCES
$

UNIVERSITIES
OTHER AGENCIES
NATIONAL LABS
ENERGY CENTERS
RESEARCH INSTITUTES
COMMERCIAL CONCERNS
STATE ORGANIZATIONS
LOCAL ORGANIZATIONS
PUBLIC INTEREST GROUPS
NATIONAL ACADEMIES
INTERNATIONAL BODIES
OTHER COUNTRIES

ERDA R&D NEEDS

bodies, and we may expand this further through the Agency for International Development.

(Slide 20)

I tried to break down as best I could the distribution of dollars by national laboratories, colleges and universities and others for our entire budget, for research and development. While the National Laboratories are carrying a large part of the load, a fairly good proportion of our resources go into colleges and universities.

Earlier today I was asked how we determine our priorities, how we determine what is relevant and what our needs are, and how we avoid overlapping what people in other agencies are doing?

ERDA conducted in '74, '75, and '76, and is conducting in 1977, a federal inventory of energy-related environmental and safety research. I have here, a copy of our 1976 executive summary. Additional copies are available from the National Technical Information Service. We asked agencies to provide us with descriptions of all of their projects dealing with environment, safety, and health-related energy research. In the next slide, a listing of responses from various agencies may be seen.

(Slide 21)

DR. RAMSEY: Is the response defined as a project?

DR. SHEPHERD: The response is defined by a project. For example, you might find that the Department of Agriculture, where

AES ENERGY RESEARCH AND DEVELOPMENT
OPERATING BUDGET
OPERATING BUDGET

(DOLLARS IN THOUSANDS)

	FY 1977 ESTIMATE	FY 1978 ESTIMATE
NATIONAL LABORATORIES	$ 79.1	$ 87.2
COLLEGES AND UNIVERSITIES	31.8	36.7
OTHER	39.6	50.8
TOTAL	$ 150.5	$ 174.7

INVENTORY OF FEDERAL ENERGY-RELATED ENVIRONMENT AND SAFETY RESEARCH (FY1976)

FEDERAL AGENCY RESPONSES

	NO. OF RESPONSES
DEPARTMENT OF AGRICULTURE (DOA)	7
DEPARTMENT OF COMMERCE (DOC)	93
DEPARTMENT OF DEFENSE (DOD)	3
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (HEW)	263
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD)	1
DEPARTMENT OF INTERIOR (DOI)	80
DEPARTMENT OF TRANSPORTATION (DOT)	9
ENVIRONMENTAL PROTECTION AGENCY (EPA)	305
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (ERDA)	1467
FEDERAL ENERGY ADMINISTRATION (FEA)	20
NATIONAL SCIENCE FOUNDATION (NSF)/RANN	18
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)	5
NUCLEAR REGULATORY COMMISSION (NRC)	200
TENNESSEE VALLEY AUTHORITY (TVA)	65

there were seven projects, also submitted a total input of $7 million. You might find that ERDA, which deals with principal investigators and less with aggregates, in the health area, reported a large number of $10,000 to $50,000 projects.

(Slide 22)

Next, we analyzed these projects according to their individual relevance to R&D needs in environment, safety, and health for fossil energy.

(Slide 23)

Now, if we break down what is going on in the Federal Government in environment and safety research by each of these departments, you will find, for example, that we can break it into fossil, inexhaustible, nuclear and others. This is a fairly recent slide put together yesterday; we just didn't have the data before then. This is going to be available as an ERDA publication sometime in August.

Using this inventory analysis, we can go back and identify each of these programs and find out what a given agency is doing.

(Slide 24)

This information went into a data base at Oak Ridge and is available on an interactive or batch basis. Other agencies are tied in through RECON, and this information is essentially available to the public.

INVENTORY OF FEDERAL ENERGY-RELATED ENVIRONMENT AND SAFETY RESEARCH (FY1976)

SUMMARY OF ANALYSIS

FEDERAL AGENCY	PROJECTS REPORTED		EQUIVALENT PROJECTS	
	No. Proj.	$Millions	No. Proj.	$Millions
DEPARTMENT OF AGRICULTURE (DOA)	7	7.6	18	11.2
DEPARTMENT OF COMMERCE (DOC)	93	41.0	145	50.6
DEPARTMENT OF DEFENSE (DOD)	3	1.4	3	1.4
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (HEW)	263	22.6	426	31.5
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD)	1	(a)	1	(a)
DEPARTMENT OF INTERIOR (DOI)	80	25.9	114	26.4
DEPARTMENT OF TRANSPORTATION (DOT)	9	0.4	9	0.4
ENVIRONMENTAL PROTECTION AGENCY (EPA)	305	63.0	421	68.8
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (ERDA)	1467	197.5	2330	349.4
FEDERAL ENERGY ADMINISTRATION (FEA)	20	1.7	23	1.7
NATIONAL SCIENCE FOUNDATION (NSF)/RANN	18	1.2	13	1.2
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)	5	1.3	14	3.0
NUCLEAR REGULATORY COMMISSION (NRC)	200	77.5	210	84.5
TENNESSEE VALLEY AUTHORITY (TVA)	65	11.8	71	21.4
TOTAL	2536	452.9	3798	651.5

(a) = less than $0.05 Millions

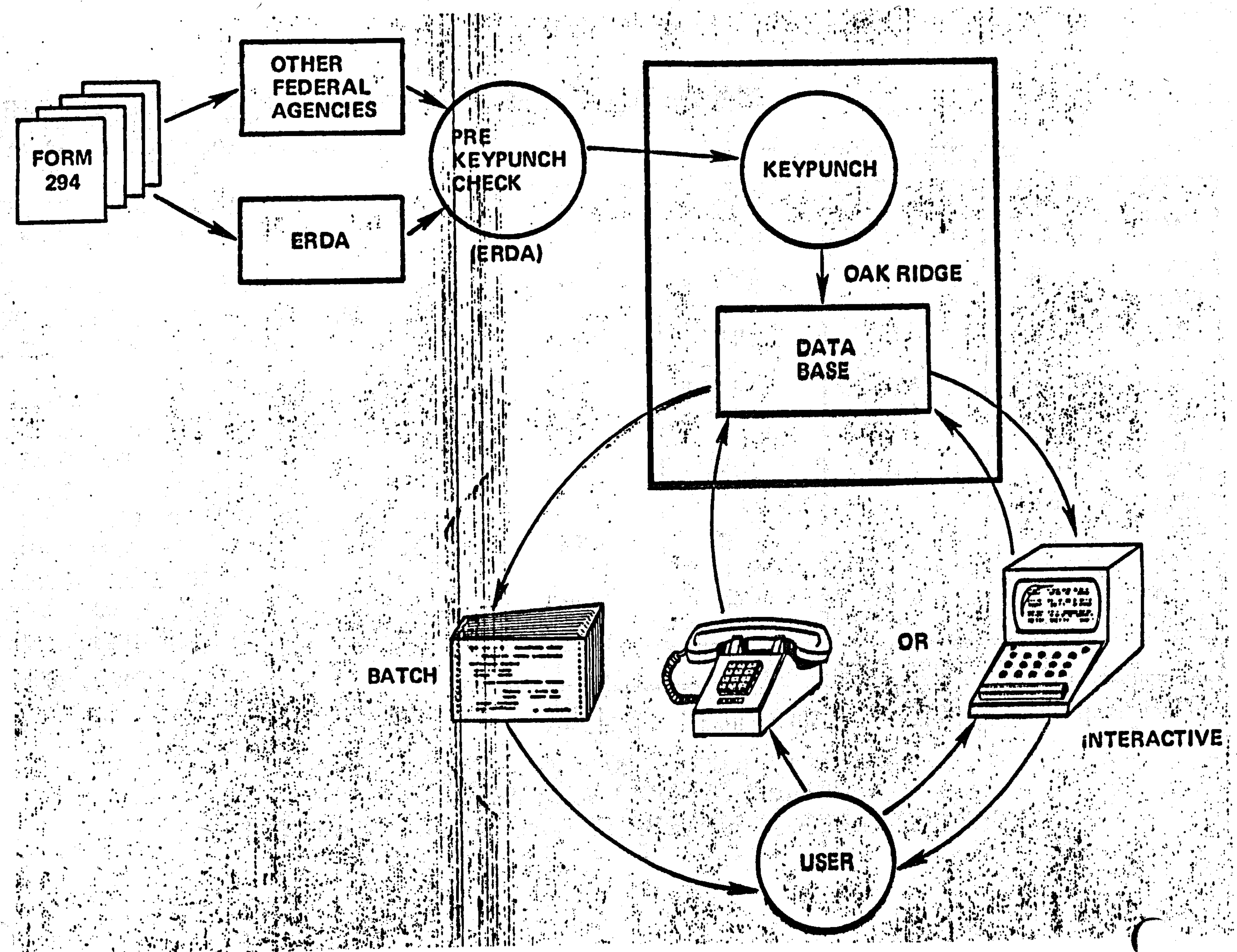
INVENTORY OF FEDERAL ENERGY-RELATED ENVIRONMENT AND SAFETY RESEARCH (FY1976)

SUMMARY OF ANALYSIS BY ENERGY TECHNOLOGY

FEDERAL AGENCY	FOSSIL FUELS[1]	INEXHAUSTIBLE FUELS[2]	NUCLEAR FUELS[3]	OTHER[4]	TOTAL
	(NUMBER PROJECTS/$ MILLIONS)				
DEPARTMENT OF AGRICULTURE (DOA)	16/11.0	-	2/0.2	-	18/11.2
DEPARTMENT OF COMMERCE (DOC)	73/41.0	2/0.1	36/3.8	32/5.8	145/90.6
DEPARTMENT OF DEFENSE (DOD)	1/0.1	2/1.3	-	-	3/1.4
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (HEW)	305/20.8	13/1.0	21/1.5	87/8.2	426/31.5
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD)	-	-	-	1/(a)	1/(a)
DEPARTMENT OF INTERIOR (DOI)	61/12.3	11/1.4	18/4.3	24/8.4	114/26.4
DEPARTMENT OF TRANSPORTATION (DOT)	-	-	-	8/0.3	8/0.3
ENVIRONMENTAL PROTECTION AGENCY (EPA)	288/45.2	28/5.1	30/4.8	75/13.7	421/68.8
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (ERDA)	1119/138.8	175/21.4	710/149.4	326/39.6	2330/349.4
FEDERAL ENERGY ADMINISTRATION (FEA)	9/0.2	5/1.0	1/(a)	8/0.3	23/1.5
NATIONAL SCIENCE FOUNDATION (NSF)/RANN	1/0.2	4/0.2	-	8/0.7	13/1.1
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)	9/2.3	2/0.4	2/0.2	1/0.1	14/3.0
NUCLEAR REGULATORY COMMISSION (NRC)	10/0.8	-	126/28.9	74/54.8	210/84.5
TENNESSEE VALLEY AUTHORITY (TVA)	32/16.7	7/0.9	7/0.3	23/3.5	71/21.4

(a) - LESS THAN $0.05 MILLIONS

(1) COAL OIL & GAS OIL SHALE
(2) SOLAR, GEOTHERMAL, CONSERVATION
(3) FISSION AND MAGNETIC FUSION
(4) GENERAL SCIENCE AND PROJECTS NOT APPLICABLE TO ISSUES AND REQUIREMENTS


FORM 294
OTHER FEDERAL AGENCIES
ERDA
PRE KEYPUNCH CHECK
(ERDA)
KEYPUNCH
OAK RIDGE
DATA BASE
BATCH
OR
INTERACTIVE
USER

(Slide 25)

We can retrieve from this base in a variety of ways. This just gives you one example of a recovery matrix.

(Slide 26)

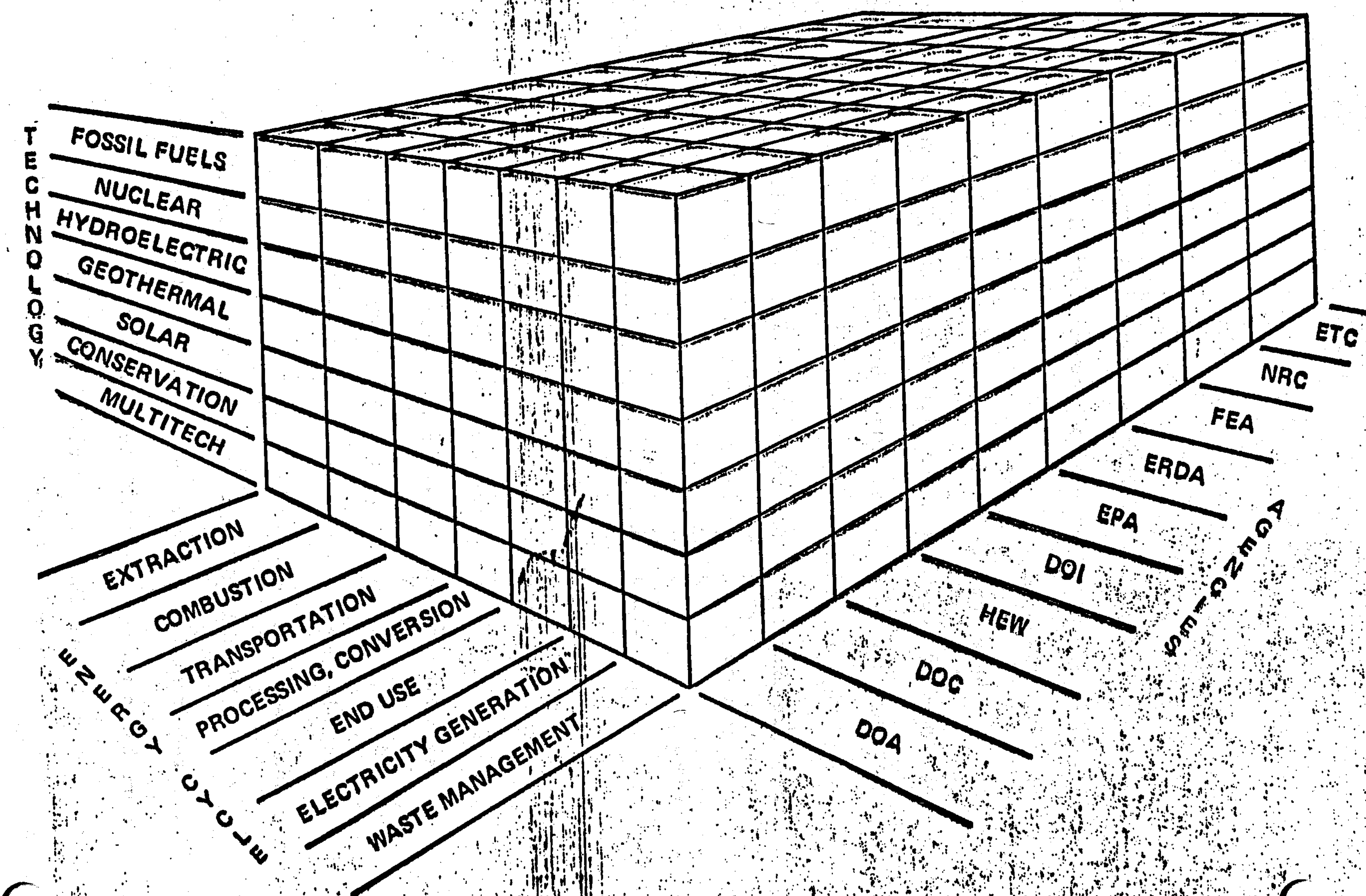
Here are examples of issues for oil shale on the left. The corresponding requirements are listed on the right. The issue is something that concerns us, while the requirements are the sorts of things you need to do in order to satisfy or take care of that issue. These are examples of the tools we are using to ensure that our R&D program activities are relevant and do not overlap those of other agencies.

DR. WHITE: Can you leave that on a second? I am bothered about something there. The issue is degradation of air quality, but I don't see anything in the requirements that says you are going to improve it or lower the release of emissions. You are going to get better standards, you are going to assess the information, base line data maybe, and see what happens after they leave, but in terms of cutting them down, which seems to be the primary requirement of oil, I don't see it there.

DR. SHEPHERD: I am giving you the March 22 list of issues and requirements, which we developed with you people. That requirement has since been added to this list.

DR. WHITE: Yes. Okay.

DATA BASE RETRIEVAL CONCEPT



INVENTORY OF FEDERAL ENERGY-RELATED ENVIRONMENT AND SAFETY RESEARCH (FY 1976)
ANALYSIS OF OIL SHALE RELATED PROJECTS

ISSUES

- DEGRADATION OF AIR QUALITY
- DEGRADATION OF WATER RESOURCES
- EFFECT OF REDUCED AIR/WATER QUALITY ON MAN
- EFFECT OF REDUCED AIR/WATER QUALITY ON ECOLOGICAL SYSTEMS
- LAND RECLAMATION AND ENVIRONMENTAL IMPACT OF PROCESSED SHALE
- OCCUPATIONAL RISKS

ISSUE: DEGRADATION OF AIR QUALITY

REQUIREMENTS

- ASSESS AIR QUALITY INFORMATION FOR SPECIFIC SITES
- DEVELOP IMPROVED STANDARDS FOR POLLUTANT MONITORING
- ACCUMULATE BASELINE DATA NEAR EXPERIMENTAL AND COMMERCIAL FACILITIES
- ANALYZE CHEMICAL CONSTITUENTS RELEASED DURING RETORTING OPERATION
- CHARACTERIZE CHEMICAL TRANSFORMATION OF ATMOSPHERIC RELEASES
- IMPROVE ATMOSPHERIC TRANSPORT AND DISPERSION MODELS
- PROVIDE ADVISORY RESPONSE TO MAJOR ACCIDENTAL RELEASES

DR. SHEPHERD: What we have now is a revised set which has your most recent inputs, as well as those of other Federal agencies. Those are now being put together. They should be ready at the end of this week.

DR. HOLLOWAY: While you are being interrupted, what do you do about the fact that the air quality in Colorado and the oil shale area is already above health requirements.

DR. SHEPHERD: That is a fairly complicated question. We are talking here about research and development, and I think the answer I would give you would have to relate to research and development. Your specific question might require a number of things including monitoring regional air quality. It would require doing research to determine the nature of the material being monitored. If you don't see such activities here, perhaps they should be added.

DR. HOLLOWAY: My point is that the natural conditions already exceed the federal conditions.

DR. SHEPHERD: I understand. In this context, I am afraid I can't give you the answer you are looking for.

DR. WHITE: EPA knows the problem.

DR. SHEPHERD: That's right.

DR. WHITE: And they are wrestling with what to do about it. They have sort of got themselves in a Catch-22 situation, I am afraid.

DR. SHEPHERD: Next slide, please.

(Slide 27)

We have slotted programs against those issues and requirements. We have given examples of ERDA, EPA, Department of Interior, and NSF programs dealing with a particular requirement.

(Slide 28)

Now if we look at the issue, degradation of air quality, and look at the requirements, we can break out for each of the agencies the numbers of projects and the nature of activities for each. Of course it is not sufficient to simply say that we know how many dollars apply to one particular issue or one particular requirement. You must also determine whether or not those projects and those dollars are being applied in a manner which satisfies those requirements.

We have just gone through that process, and we are putting together, if you will, an analysis of the content of the sufficiency of Federal R&D by specific Fuel cycle and the needs of each. The results should be ready by August. This is the means by which we are determining the relevance and the applicability of our R&D programs that we are funding both in universities and national laboratories.

DR. KROPSCHOT: Question or comments?

DR. PHILLIPS: I guess I am interested in knowing what is on the intellectual content of these requirements, how does one critique that? In other words, who are the intellectuals that make the intellectual judgment?

INVENTORY OF FEDERAL ENERGY-RELATED ENVIRONMENT AND SAFETY RESEARCH (FY1976)
ANALYSIS OF OIL SHALE RELATED PROJECTS

ISSUE: DEGRADATION OF AIR QUALITY

(Number Projects / $ Millions)

Requirements	DOA	DOC	DOI	EPA	ERDA	NASA	NRC
• Assess air quality information for specific sites	-	-	-	2/0.7	1/0.2	-	-
• Develop improved standards for pollutant monitoring	1/2.1	1/0.2	-	12/2.3	18/2.1	2/0.6	
• Accumulate baseline data near experimental and commercial facilities	1/0.5	-	-	4/0.9	1/0.2	-	-
• Analyze chemical constituents released during retorting operation	-	-	-	4/0.6	3/0.3	-	-
• Characterize chemical transformation of atmospheric releases	-	-	-	1/(a)	1/0.1	-	-
• Improve atmospheric transport and dispersion models	1/0.5	-	1/(a)	-	8/0.9	-	1/(a)
• Provide advisory response to major accidental releases	-	-	-	-	3/0.1	-	-

(a) - less than $0.05 millions.

INVENTORY OF FEDERAL ENERGY-RELATED ENVIRONMENT AND SAFETY RESEARCH (FY 1976)

ANALYSIS OF OIL SHALE RELATED PROJECTS

ISSUE: DEGREDATION OF WATER RESOURCES

REQUIREMENT: DEVELOP IMPROVED STANDARDS FOR POLLUTANT MONITORING

No. 012003 (NSF)
WATER QUALITY ASSURANCE AND INSTRUMENTATION

No. 054038 (DOI)
ENERGY SUPPORTING RESEARCH, INSTRUMENTATION

No. 070028 (EPA)
GROUNDWATER RESEARCH MONITORING OF – –

No. 087668 (ERDA)
TRACE ELEMENTS IN NATURAL WATERS

AGENCY: ERDA
FY 1976 FUNDS: ERDA $55,000
TECHNOLOGY: MULTITECHNOLOGY
PROJECT DESCRIPTION: TO UNDERSTAND METAL FLUXES IN THE ESTUARINE SYSTEM
APPROACH –
RESULTS –
KEY WORDS –

DR. SHEPHERD: That is a good question. For this last analysis we brought in approximately 40 scientists from the environmental and health science fields from the national laboratories. We also had participants from other agencies. We sat them down in a room with a packet of projects from coal combustion and the issues and requirements for coal combustion, and asked them to (1) slot the projects according to issues and requirements and (2) provide a written analysis of whether or not the projects under a requirement actually satisfy that requirement.

By and large, the projects that we have found are not wholly satisfying the entire spectrum of needs under each requirement. There tends to be fashions in science, as you know, and we tend to find things lumped and aggregated. According to these fashions, we have gaps and we have some overlaps between agencies, in the judgment of these professionally trained people.

Does that satisfy your question?

DR. WENDER: Did they take a vote or did you average them out? How did you get an answer?

DR. SHEPHERD: They sat down and argued these things out among themselves. We had people from our organization sitting in with them, helping to resolve these problems. They argued very strenuously, and in some cases had a majority and a minority opinion.

DR. NELSON: What was the primary opinion from this exercise?

DR. SHEPHERD: The primary inputs from these 40 for thi. exercise were the abstracts as reported in this federal inventory, which represent the SIE.

DR. KROPSCHOT: Could I remind the questioners to identify themselves in asking questions?

DR. HOLLOWAY: I have two questions. The first one, you had a chart that indicated that a project should be technically feasible, economically feasible, and environmentally and healthwise feasible, something to that effect. From the discussion yesterday, I got the impression people in fossil are responsible for the technical feasibility and to some extent, the economic, but you are responsible for environmental and health. Is that the correct impression?

DR. SHEPHERD: Overall that is a correct impression. We share these responsibilities with fossil and we try to work together with them. We do have cooperative programs going, and I think Dr. White would testify that they work very closely together in this area.

Do you want to address the technical aspect?

DR. WHITE: Jim and I have talked about this. And the way we generally tried to divide this is that technical work on pollution control up to the point of leaving the perimeter of the facility is something we have to worry about. Characterizing what is in there, and doing research on how to remove it.

Also the effect that may take place as it gets out into the air stream or the water stream on human health or biological effects or aquatic effects; but they also have the overview of whether we are doing our proper responsibility or our part of the job. And this sometimes leads to a little bit of discussion back and forth, and we kind of work it out.

DR. HOLLOWAY: I didn't see much in there for overview in dollars.

DR. WHITE: There is plenty. They don't need much. They can overview with a few fellows.

DR. HOLLOWAY: The other question I have dealt with, your relationships with other agencies such as EPA and HEW. Let's take, for example, coal combustion. One of the necessary features of combustion might be a stack gas scrubber. Who is responsible for seeing that there are satisfactory scrubbers or new developments in stack gas scrubbers?

DR. SHEPHERD: Again, that is not simple question, and there are two parts to it. Let me address the first part, which is; What are our relationships with EPA, HEW and other agencies? While you are probably speaking of the regulatory end, let me provide you with an example of interaction involving the President's Energy Message and his Environmental Message. The Energy Message said the President was going to appoint a special commission to determine the adverse impacts of increased coal utilization.

The President's Environmental Message directed that HEW, EPA and ERDA work together to determine the adverse environmental impacts of advanced coal technology. The accompanying fact sheet added "as well as the adequacy of federal RD&D." Recently we received a letter from President Carter asking Mr. Fri to take the lead to get the environmental message response moving. We have scheduled meetings with Secretary Califano and with Administrator Costle of EPA and their representatives on July 8 to discuss this matter. The result is a lot of close cooperation going on now.

The responsibility for control technology in this country is split. Phil's fossil energy people have a very real interest in this because it must be part of their technology. They cannot build something that is environmentally safe and socially acceptable if they don't know the environmental control technology options and design for those options.

We in AES have a program which exercises oversight over this activity. I think there is a major responsibility for ECT control technology in EPA for their regulatory purposes and they are developing programs of which you are aware.

Industry, of course, has a major interest in this area and has a fairly large budget for developing different kinds of control technologies. If I were sitting in your chair, I would ask how all these things are going to be put together. I don't have an answer to this problem.

MR. HILL: George Hill. Two questions. One you just touched on. Who decides the jurisdictional disputes where you do have obvious duplication? And second, throughout this whole thing, I haven't seen in the tabulation anywhere what is being done outside of government. There is, I think, quite a bit of overlap and duplication here.

DR. SHEPHERD: Those are two very good points. Who decides jurisdictional disputes when there are overlaps? In government we try to settle our disputes between agencies at the lower, working levels. Disputes which cannot be resolved are referred to higher levels. We have had to settle some problems by reference to the Executive Office of the President, via CEQ and OMB.

I think the other question you asked is a good one. It is something that concerned me, and I would be very happy to have some input from you.

Somebody has the responsibility for determining, I think, whether or not R&D in the entire country, (industrial, academic and federal, as well as state, regional and local) is satisfying the problems that we perceive. We need participation of all these segments of the R&D community in defining needs and in providing the R&D data base for analysis. I think we need to include in our inventory the kinds of projects you are referring to. We are not taking enough cognizance of industrial research in this inventory.

DR. RAMSEY: Since CO_2 is common to essentially all fossil fuel things, are you doing much to look at the possible long-term effects of CO_2?

DR. SHEPHERD: Yes sir. We have a major increase in our program for next year on that particular question, climatological changes, long-range weather changes as a result of increased CO_2 production.

DR. NELSON: Going back to the question of coordination, as you know, there was in the last nine days of OST, a committee for the coordination of environmental health research. That committee was succeeded by a shadow, an effective shadow; the HEW Committee on Toxicology program. As far as I can see it has been most effective. Information has been exchanged at this level.

DR. SHEPHERD: We are members of that Committee.

DR. NELSON: I know you are. I think that is very good. Nevertheless, it has the punch that comes from good will, rather than authority. I think it has been quite effective. There has been urgings on Dr. Press to reestablish, on the broader base, some permanent organization to give oversight and to help chide OMB, which, after all, is the final and most forceful group for determining priorities. And my question is, is there any evidence of life in that push to develop again a government-wide coordinating group which would talk to OMB?

You may not feel just like answering at the moment.

DR. SHEPHERD: It is a good question. It is a touchy one, of course. Let me say, first of all, that one of the options we are considering in our response to the President's Environmental Message is asking Dr. Press's office if they are interested in working with us in putting these things together as an overview group.

As you know, CEQ is staking out a claim in this area. And, as you know, there is soon to be announced a Presidential appointee for the Toxic Substances Control Act, with his entire staff put in place and running. And they will be staking out a fairly major role, perhaps the coordinating role you mentioned. Until this coordinating role is better defined, however, we in ERDA have a responsibility for those toxic substances and impacts of fossil energy and other energy technologies developed by ERDA.

DR. WHITE: I might be able to answer that a little further. There is the rebirth of the Federal Coordinating Council on Science, Engineering and Technology, which was beginning to be reactivated, but with Guy's departure, things are sort of in a holding pattern. I'm on one of those committees, not the environmental one, but the research one -- and waiting for Press to see how he wants it handled. I would guess this would be at least one mechanism that would be used for this coordination purpose, because that is exactly what it is there for.

DR. NELSON: Yes. EPA doesn't want to assume a dictatorial role.

MR. CANONICO: You indicated a major task in the area of reactor safety research coordination. Can you explain?

DR. SHEPHERD: I would like to do this, but am limited in this presentation to fossil research.

MR. CANONICO: I would argue against that because I think that is one of the major problems in the future as far as commercialization of fossil energy, but I think reactor safety is going to be a question we will have to address ourselves to eventually.

DR. SHEPHERD: All I can say is that we do have major programs in reactor safety, and if you are not familiar with them at Oak Ridge, you do have on-site the best library and our program available.

MR. CANONICO: You have the HEC program where the metallurgy program is attached to. I am just wondering where your coordination in that comes through.

DR. SHEPHERD: Generally through Hal Hollister's shop. The Environment and Safety Group, as one part of it, for the occupational safety; and through our reactor safety and research group for the actual physical and mechanical aspects.

DR. KROPSCHOT: One more question.

MR. STANFORD: I was hoping you might give us a little more insight how the CO_2 problem will be addressed.

DR. SHEPHERD: Well, I can give you the name of the person that can give you the specifics. I think that would be the best use of my remaining 30 seconds. Dr. Swinebroad is the Manager of the Environmental Program at ERDA. And he has working with him Dave Slade, who has ERDA's responsibilities for atmospheric, long-term research and CO_2 work.

We are also working with NASA in this area, as you probably know. We do have some satellite and atmospheric monitoring programs which we are going to be getting into.

DR. KROPSCHOT: Thank you very much.

(Applause).

DR. KROPSCHOT: Sorry to have to cut off this very interesting discussion but I would like to now proceed to the next presentation of the programs on fossil energy research being undertaken in the area of conservation under the Assistant Administrator for Conservation with ERDA, and introduce Dr. Karl Bastress.

DR. BASTRESS: Good morning.

My title is Chief of the Combustion and Fuels Technology Branch in the Division of Conservation Research and Technology.

The activity in my program is principally applied research, and I think it is that reason for which I was asked to make this presentation. Also, my part of the conservation research activity is perhaps most closely tied to the interest of fossil energy research.

I am very happy to make this presentation on behalf of the conservation office because of my interest in general in the research activity here at ERDA. I think I would like to start by posing two questions. The first would be: Why am I here, or more specifically, what can I contribute to this meeting on fossil energy research? And secondly: What can this meeting do for the conservation research program?

The answer to the first question: Why am I here?, is rather easy. That is because the conservation program is or can be regarded as complementary to the fossil energy program in many ways. We think of the conservation program as being concerned with the use of fossil fuels, whereas we think of the fossil energy program as primarily concerned with the supply of fossil fuels.

It is difficult to separate the areas of technology in the two programs. In fact, we at the program manager level find it necessary and desirable to coordinate our efforts frequently and closely with our counterparts in the fossil energy office. I must say, that this activity proceeds very satisfactorily. Therefore, I think it is very appropriate for conservation to have a spot on this agenda, since the conservation activity, in a sense, can be regarded as an extension of the general subject of fossil energy research.

The second question, is: What can this meeting do for the conservation program?, I think this can be answered by saying that the conservation research activity also needs to be addressed, as we are addressing the fossil energy research work. We can characterize the conservation research program perhaps in the same way that the fossil energy research program was discussed or described yesterday.

The applied research activity suffers from low funding, and there is a gap, quite perceptible, between the research activities in conservation and the basic research activities in the Division of Basic Energy Sciences. So I would, in answer to the second question, request of both Dr. Phillips and Dr. Kropschot, that the output of this meeting as far as possible be addressed to conservation as well as to fossil energy.

Our conservation program is quite analogous to the fossil energy program in ERDA. We have in the conservation office, six program divisions with a widely varying program of activities. In 20 minutes I cannot begin to describe anywhere near all that goes on in the conservation program. Therefore, to be consistent with the theme of the meeting, I will discuss only the research activities. Therefore, please keep in mind I am addressing a very small fraction of the overall conservation program. You will not hear anything of the major thrusts in the technology development areas of conservation this morning.

(Slide 1)

The overall objective of the conservation effort is the development of improved technology for energy utilization meeting these requirements: Increased efficiency, compatibility with available fuels, and compatibility with the transition to future energy sources.

Conservation RD & D Overall Objective

Develop Technologies
For
Efficient Energy Use
Compatible With Available Fuels
And The
Transition To New Sources

ENERGY EFFICIENCY

Office of Conservation
Energy Research and Development Administration

Now, this term "transition" is used in our conservation office to refer to a period of time, starting more or less at the present and extending into the future to some time when we reach a point where we have stabilized new energy sources.

(Slide 2)

The transition goal is to reduce total energy use in general, and oil and gas use in particular.

The intent here is, as far as possible, to stretch our domestic supplies of oil and gas and to reduce our dependence on imports.

(Slide 3)

We have defined 11 strategic objectives to further focus our conservation program. Seven of these objectives are directed towards what we have defined as the three major energy use sectors; transportation, residential and commercial, which is primarily energy used in buildings, and the industrial sector.

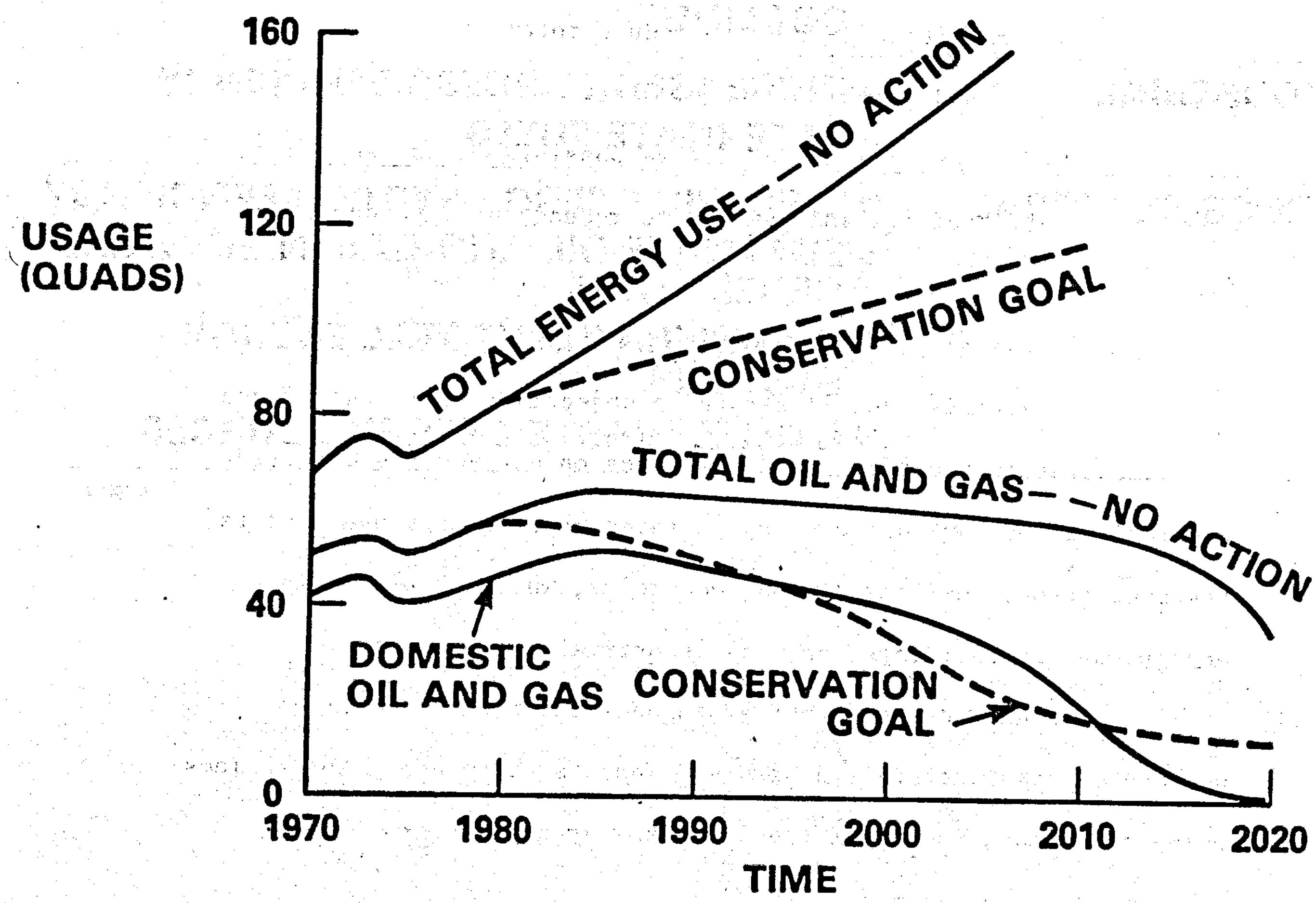
We have defined four additional strategic objectives, which are cross-sectoral in nature. That is, they apply to problems which are common to all of the three energy use sectors.

(Slide 4)

The organization of the conservation office is related to the strategic objectives. We have three program divisions which correspond to the three energy use sectors. Buildings, industry,

[redacted]

THE TRANSITION GOAL



ACCOMPLISHING THE GOAL — THE STRATEGIC OBJECTIVES

TRANSPORTATION	• INCREASED EFFICIENCY • ALTERNATE FUELS
RESIDENTIAL/ COMMERCIAL	• UPGRADE BUILDINGS • INCREASED EFFICIENCY HVAC, APPLIANCES • ALTERNATE SOURCES FOR HEATING/ COOLING
INDUSTRIAL	• INCREASED PROCESS EFFICIENCY • ALTERNATE FUELS
CROSS-SECTORAL	• ELECTRIC ENERGY SYSTEM EFFICIENCY • ELIMINATE OIL AND GAS IN ELECTRIC GENERATION • COGENERATION/TOTAL ENERGY SYSTEMS • UTILIZE WASTE ENERGY SOURCES

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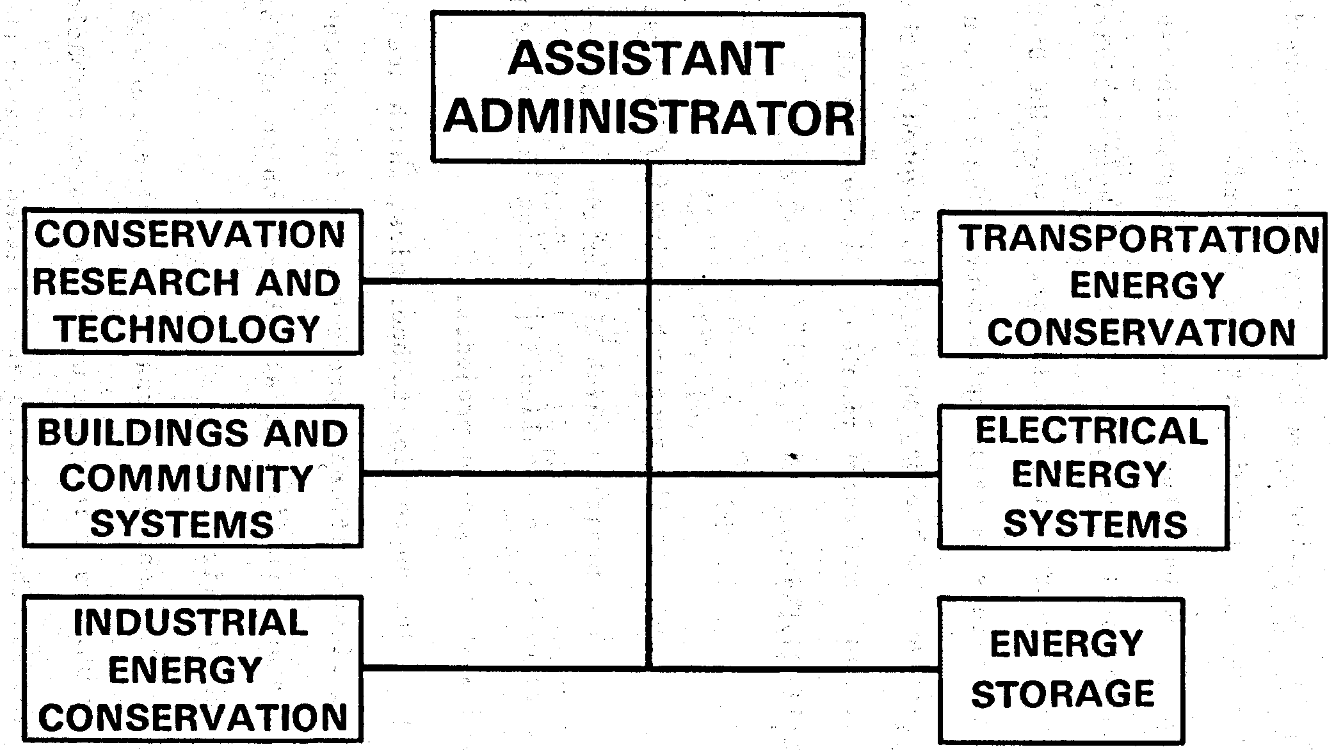
ERDA OFFICE OF CONSERVATION

PROGRAM DIVISIONS



and transportation, and the activities in these divisions are focused on the energy uses within those sectors.

We have three other divisions which can be regarded as cross-sectoral in nature. That is, their activities are focused on the more general problems in energy use. The Division of Electrical Energy Systems is self-explanatory. The Division of Conservation Research and Technology actually is devoted to the area of energy conversion. And then, finally, the Division of Energy Storage again is self-explanatory.

(Slide 5)

Now, to the research activities in conservation.

The projects which are active in conservation fall into two categories: one called supporting technology projects, the other called systems-related projects.

The supporting technologies, which are listed there and consist of six different projects, are independent, applied research projects and are directed at subjects which have broad applications in energy utilization.

In contrast to that, the systems related projects are efforts which are integral with systems or technology development programs and these efforts are directed towards the particular technologies which are being developed under those programs.

Now, I have listed here only a few examples of these systems related projects. In fact, every technology development

Conservation Research Projects

Supporting Technologies

- Aerodynamics
- Combustion
- Fuels Research
- Heat Transfer
- Materials
- Tribology

System-related Projects

- Battery Electrochemistry
- Heat Engine Component Design
- Fuel Cell Electrocatalysis
- Thermionic Power Generation
- Physical Energy Storage
- Chemical Energy Storage
- Thermal Energy Storage

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program in conservation to some degree has a research activity associated with it.

In the next few slides I will focus only on these supporting technology projects for two practical reasons. One is that these are primarily research activities and so they are most appropriate to the subject of the meeting, but secondly, they are more easily defined because the activities there are entirely research and the budgets and scopes of those projects are very clear.

The total effort in these supporting technology projects in FY'77 is $2.1 million. That is slightly more than 1 percent of the total conservation budget. So again, I remind you that I am dealing with a very small fraction of the total conservation effort.

Next slide, please.

(Slide 6)

All of these supporting technology projects are discussed to some degree in the handout which you have. I will only talk about three of them here in order to give examples of the nature of these activities.

The combustion project in conservation is concerned with increased efficiency and fuel switching in four categories of equipment; internal combustion engines, continuous combustion engines, boilers and furnaces, and industrial heaters.

At the present time we've activated efforts in only three areas under this overall project and yet we feel we can point to

Combustion

Objectives:

- Increase Efficiency
- Increase Fuel-switching

Strategy:

- Improve Current Equipment
- Evaluate New Concepts

Status:

- Active IC Engine Projects
  - Lean-burn Engine
  - Direct Injection Stratified Charge
- Active CC Engine Projects
  - Improve Current combustors

some rather significant accomplishments. For example, we have initiated a cooperative research project in the area of direct injection stratified charge engines for automobiles, and this project involves researchers from universities, national laboratories and one of the major automobile manufacturers. The significance of this project, we feel, is that it brings together the research community and the automobile community periodically to review their combined efforts and achieves both a degree of coordination of the work and ready technology transfer.

A second accomplishment in this combustion area is the initiation of a research project under the International Energy Agency, which brings together researchers in the various government agencies in the IEA countries to coordinate their research activities and therefore stretch the research dollars of the various countries as far as possible.

The next slide, please.

(Slide 7)

The combustion project offers many opportunities for additional research in all the areas to which it is addressed. However, we have to be very selective in the activities that we undertake because of our budget limitations.

We estimate that if we were to attempt to pursue all of the new concepts and research opportunities that we have identified, we

Combustion

Additional Research Opportunities:

- IC Engine Research
  - Dual-chamber Stratified Charge
  - Diesel Combustion
- Continuous Combustion Engine Research
  - Premixed, Prevaporized Fuel Injection
  - Catalytic Combustion
- Boiler and Furnace Combustion Research
  - Pulsed Combustion
  - Feedback Control
- Industrial Heater Combustion Research
  - Recovered Heat Utilization
  - Oxygen Enrichment

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would require a budget of the order of $15 million per year. Our budget this year is $650,000.

Next slide, please.

(Slide 8)

The fuels research project is directed towards utilization of two groups of alternate fuels. We speak of principal alternative fuels as those which have been or will be derived from coal or shale. We speak of secondary alternate fuels as biomass and industrial waste materials.

The focus in this project is on the fuels and their combustion properties. That is, what does the designer of combustion equipment need to know about a fuel in order to design his equipment to accommodate new fuels that are coming in the future.

So far, we've activated efforts in this project in areas of hydrocarbon fuels research and we have a rather active program now in the area of wood fuels. I would just comment on that by saying that there is a rapidly growing awareness and interest in utilization of wood residues in certain regions of the country. Obviously not in Arizona, but in areas such as the northeast and the southeast and the northwest. There is a growing awareness that wood residues, I don't mean timber quality wood, but wood residues from various sources can make a significant impact on energy supplies in certain regions.

Next slide, please.

(Slide 9)

Fuels Research

Objective:
- Develop technology base for switching from premium fuels to alternates

Strategy:
- Identify fuel combustion characteristics which influence equipment design and performance
- Measure combustion characteristics of alternate fuels
- Obtain data base for hardware design

Status:
- R&D plans developed
- Project activated in

  Alternate hydrocarbon fuel kinetics

  Industrial wood residue combustion

  Residential fuelwood fire box combustion

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Fuels Research

Additional research opportunities

- Characterization of fuels from
  - Processed biomass
  - Industrial wastes
  - Coal and shale
- Develop criteria for conversion of secondary fuel sources
- Develop design and performance criteria for combustion equipment for alternate fuels

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The fuels research project also offers innumerable research opportunities in such areas as characterization of alternate fuels, definition of desired properties of fuels as they emerge from various conversion processes, and the development of special equipment for combustion of alternate fuels. And again, wood is a good example of that last opportunity.

Next slide, please.

(Slide 10)

The last project area that I'll discuss is heat transfer where in this project the effort is directed primarily towards improved heat exchanger technology to enhance the energy conservation potential in all use sectors and in particular to enhance the potential for the recovery of waste heat. We have efforts in this project activated in four areas which are shown on the slide.

Next slide, please.

(Slide 11)

The heat transfer project, like the others, offers a variety of additional research opportunities. We feel the most dramatic possibilities for improvement lie in heat pipe applications and in enhanced surface heat exchangers. The potential for recovery and utilization of waste heat through unique types of heat transfer equipment is truly very significant.

Next slide, please.

(Slide 12)

Heat Transfer

Strategy:

- Improve Component Effectiveness
- Increase Reliability and Life
- Reduce Costs

Objective:

- Improve Energy Conservation Through Improved Heat Exchanger Technology

Status:

Active Projects in:

- Tube Vibration
- Tublar Ceramics
- Fluid Bed Heat Exchangers
- Ceramic Heat Pipes and Recuperators

Heat Transfer

Additional Research Opportunities:

- Heat Exchanger Fouling and Corrosion
- Low-cost Alloy Fabrication Techniques
- Heat Pipe Materials
- Enhanced Surface Heat Exchangers

Summary

Status of Conservation Research:

- Active Projects in Selected Supporting Technologies
- Active Projects Related to Energy Systems Development

Research Opportunities:

- Improvement of Current Systems
- Development of New Design Concepts
- Utilization of Unused Energy Resources

In summary, let me say that the conservation program includes active research in two general types of projects; supporting technologies, of which I've described three examples, and a wide variety of applied research activities as a part of our systems development projects in areas such as batteries, fuel cells, heat engines and so on.

The budget at the present time, that is in FY '77 and FY '78, for this applied research effort, that is in both types of projects, is approximately 10 percent of the total conservation budget.

The source of that information is clear in the case of the supporting technologies projects because their budgets are spelled out separately. As far as the quantity or the level of research in the systems related projects, that information, which is in your handout, by the way, came from an inventory of research activities conducted approximately a year ago and is based on the program manager's estimate of how much, or what fraction of his program will be devoted to applied or basic research.

I think that the budget estimates for the systems development research projects is perhaps a bit soft or uncertain, but I think the 10 percent estimate is the right order of magnitude.

The second conclusion evident is that research opportunities in conservation are abundant. The pursuit of these opportunities is limited only by the budget. In the meantime, the program managers in conservation are making every effort to stretch the budgets that we have in three ways.

First of all, by assessing the benefits of each potential research project as closely as possible and selecting those which appear to have the greatest benefit at the earliest possible time.

The second method of stretching budget dollars is to initiate cooperative efforts such as the cooperative effort in internal combustion engines which I mentioned we have set up with the automobile industry.

And finally the third mechanism is to coordinate our efforts with other agencies. We're all aware that there is an extensive amount of energy-related work and conservation-related work going on in other agencies in this country and elsewhere. We are making every attempt possible to take advantage of work being done elsewhere and to minimize the duplication of effort.

Can I have the slide off, please?

I'd like to make a few closing remarks in the form of good news and bad news. The good news I think you've heard. That is, conservation, in the context of this meeting, has initiated some independent research projects and the budgets for these projects are likely to increase in FY'78.

I personally feel that conservation should be commended for this effort. Here is an area of independent research activity in support primarily of the overall conservation effort.

Then the bad news. It is my opinion that these research activities will not survive. Two weeks ago I attended a meeting here in Washington sponsored by the AAAS which some of you also may have attended. The subject was funding of R&D in the federal budget.

A variety of messages came from that meeting. But one which was very clear is that research budgets are controllable. Controllable is a euphemism meaning vulnerable to cost-cutting. Unfortunately, we have an immediate example of that in our own program.

Rumor has it that our supporting technology activity, which you have heard described here, has been cut by the House-Senate Conference Appropriations Committee by $5.4 million for FY '78. That is more than half of the intended budget for that activity.

Because of this sort of experience, the supporting technology activity will not appear in the conservation budget as an explicit item after FY '78. We don't feel we make ourselves vulnerable to budget cutting by having applied research activities appear explicitly in the budget.

That doesn't mean the activities will be gone, but they will be buried for budget purposes. However, it's likely that they will be buried organizationally and ultimately they will disappear.

My conclusion is that the outlook is not bright for applied research in the conservation program. And I don't think the outlook will improve until some mechanism for research support is provided.

In the words that were spoken yesterday, I don't think the outlook will improve until the career of some assistant administrator or division director is tied to the quality of research in the conservation program.

Thank you.

(Applause.)

DR. PHILLIPS: Questions or comments?

MR. OETERMANN: Oetermann, General Electric. I note that you do not address cogeneration. Is that because you don't believe there is research required in that, or is it out of your organizational component?

DR. BASTRESS: I did not explicitly address cogeneration because it happens we don't have an applied research project in conservation which is specifically directed to that subject.

However, cogeneration is a substantial activity in conservation. As you can see, it was one of our 11 strategic objectives and it is supported by the activities of several different branches and programs. The combinations of cogeneration are numerous--they can involve either heat engines or fuel cells and a wide variety of heat recovery devices, bottoming cycles, topping cycles and so on.

So it's a broad area which permeates several of the divisions in conservation with coordination at the top. So I would say in the context of this discussion, which is applied research, cogeneration is addressed specifically in those subjects such as heat transfer and combustion as well as certain systems related projects such as heat engines and fuel cells, but we don't have a research activity labelled cogeneration.

Personally, I don't think it really fits in a generic way along with things such as materials, aerodynamics and so on. It doesn't mean we're not doing it. It's very important activity in conservation.

DR. PHILLIPS: Could you use the microphone, please. The reporter tells me he can't pick up the voices.

MR. GUINAN: Guinan, Pullman-Kellogg.

I was just wondering how this bad news will affect your fuel cell program?

DR. BASTRESS: The bad news applied only to applied research. That is, the independent research programs in conservation. My understanding is that the overall conservation budget is likely to increase rather than decrease and in particular the fuel cell program is strong and healthy.

DR. RAMSEY: I first heard of the virtues of the stratified fuel injection with Dick Arwin's study about seven years or so ago. It sounded in about the same state as reported here and I wondered why things were that slow in securing a high level push at that time and is it making much progress since; or how long before we get results?

DR. BASTRESS: You're not asking why are we working on it. We get that question frequently. I'm driving a stratified charge engine made in Japan; why is ERDA worrying about this?

That same question could be addressed to many types of technology. There's room for improvement in nearly everything, but that doesn't answer your question, however.

DR. RAMSEY: My question is the reverse --

DR. BASTRESS: The question is are we making any progress?

DR. RAMSEY: Why does it take so long?

DR. BASTRESS: I can only respond to that in a rather unsatisfactory way by saying it's a very difficult problem. The particular concept which we're pushing here is the direct combustion stratified charge engine which has certain advantages in efficiency if we can make it work.

But the problems of trying to achieve high efficiency and controlled pollutant emissions over the full operating range of an automobile is a difficult one and our approach is to try to understand what is really happening in the fuel injection process and the subsequent processes of air and fuel mixing. We're not actually, with our limited budget, as you might imagine, developing new engines. We're leaving that to Detroit.

But our role, we feel, is to focus the talents of universities and national laboratories with their resources in instrumentation and mathematical modeling and the understanding of these processes, on that one combustion concept, to try to elucidate the problems for the benefit of Detroit so that they can move a little faster in their engine development activity.

I should point out that even though these projects are labelled with hardware sounding names, the nature of the work is primarily fundamental. The work that we are supporting here is primarily in the national laboratories and universities or the research organizations of industry and we are focusing the work, as far as possible, on the fundamental understanding of problems in combustion, in fuel chemistry, in heat transfer and in the other areas to provide a stronger technical base for the engineers in industry.

MR. KELLER: Lou Keller, Oak Ridge.

Yesterday a rather interesting question about the practicality of the return to coal for residential heating came up. I wonder if that's an appropriate question for your group.

DR. BASTRESS: Well, we have discussed the various applications of coal burning with our counterparts in fossil energy and we have defined for ourselves a rather indistinct boundary between our jurisdiction and theirs which primarily says that coal applications are primarily a fossil energy responsibility. However, we are concerned about that subject because the areas do overlap.

I'm going to have to agree with the comments made yesterday about coal burning in residential applications. My view is that the development of improved combustion equipment is a relatively easy problem compared to the problems of logistics of coal supply and the control of sulfur emissions and particulate emissions.

I think you could just as well ask the same question about wood burning, which we have taken on as our responsibility. There I think that there are environmental questions and supply questions which need to be addressed, and we are addressing these. We don't think that the environmental questions are quite as difficult with wood as they are with coal and that's why we're proceeding with the development of improved technology for wood burning in residential applications.

DR. KROPSCHOT: Thank you very much.

(Applause.)

DR. KROPSCHOT: I would like to proceed now with the next two papers which describe work in research and fossil energy, the area of the Assistant Administrator for Solar, Geothermal and Advanced Energy Systems; and to lead off with these two papers, I'd like to introduce Dr. James Kane, who is the Division Director, in this case for the Division of Basic Energy Sciences.

Jim.

DR. KANE: I'm sure you must be dreadfully confused by now why a person who's in the solar, geothermal and advanced energy group is standing up here at a fossil energy meeting. I'll try to explain that to you.

The basic research that existed when ERDA was formed was largely in the old AEC and it was transferred almost intact into ERDA. The ERDA organizers looked around for a logical place to put it; they couldn't find one, so they put it somewhere anyway. And it wound up in solar, geothermal and advanced energy systems.

So the actual charter for long range, more fundamental research in ERDA resides within the Administration for Solar, Geothermal and Advanced Energy Systems. It's a very major undertaking and I'm not going to talk about all of it today. But I will allude to it just to put it in the proper framework, as other speakers have done this.

The total research program, long range, basic, exploratory, whatever you choose to call it, includes high energy and nuclear physics, which I'm not going to talk about today. That is indeed a major undertaking and as someone said yesterday, OMB and the President's office have clearly indicated that we are responsible for the high energy physics program of the United States; the executive agent for it.

We do not have that same statutory assignment for the nuclear physics program, but de facto we have much the same status. We are the major supporter of nuclear physics in the United States.

I really am convinced that it is good for all of us to have those in a package within the Agency. There are two things that have been alluded to so far in this meeting--I won't dredge up any new arguments--and I'll point out that each was the development of one of these two technologies.

The very large magnet that's been mentioned a number of times in the MHD Program was clearly an outgrowth of the high energy physics program, which has been the driving force for the superconducting industry in the United States. Now, all such magnets aren't necessarily made by the laboratories. They are designed there, but the industry has been really stimulated by high energy physics. And if we have an industry in superconductivity today, it's a result of the high energy physics program.

The second, somebody showed a picture yesterday of data which I think was X-ray fluorescence. That very beautifully resolved data was an outgrowth of the nuclear physics program. The lithium drifted detector and all of its ancillary equipment was developed under the nuclear physics program. So my point is not to boast about these--I had nothing to do with either one of them--but to point out that a sharp eye for fallout in some of these things is a good idea, that some of the products of these two very large undertakings in research are highly applicable to the type of questions that this group is talking about.

Now, from now on I'm going to talk only of the work in what we call basic energy sciences. I'm going to tell you what it is; how much we spend on it; and describe its "flavor". Then I'm

I'm going to talk more specifically about some of our research within the chemical areas. And after I'm through, Dr. Donald Stevens is going to talk about materials science. These are both in the research program.

In 1977, the amount of money in this basic energy sciences program in terms of outlays, which excludes equipment purchases and capital construction, was $121 million. In 1978, the President has requested from Congress $138 million.

First I'll tell you the charter and then how those expenditures are divided in categories. Our charter is to carry out a program of basic research in the physical sciences--that's an important point--only the physical sciences, which is supportive of all the ERDA energy technologies, both the production and efficient use of energy. That's our charter.

ERDA is a mission agency. That's the first thing to remember. We are not the NSF, and our work, therefore, must be clearly justifiable on the basis that it's relevant to the Agency's long range goals.

We do mostly basic or exploratory research. We do almost no development or directly programmatic applied science.

I'll give you an example. In material sciences, Don will talk about the extensive work we're doing on steels, for instance. Corrosion of steels, fracture of steels, the deformation properties of steels, and yet even if there's clearly an indicated need for a new steel in one of the technologies, we do not develop that new steel.

Now, let me depart a minute. I personally was responsible for a project one time which required that a new steel be fabricated in industry, and it had different properties from 316 in terms of its ability to contain hydrogen, high pressure hydrogen. And it took about 10 years before a specialty steel maker was able to turn that product out in reliable quantities.

My only point in mentioning this is that if there are requirements for new steels that, say, are able to resist grain boundary attack by a specific pollutant in coal, to pick an example, we are not doing that. We may ferret out the problems that pollutants would give. We may try to understand the mechanism by which the damage is caused, but we will not develop a new steel in terms of putting one in production.

I want to make this jurisdiction thing quite clear, because I made the point yesterday that the programs are responsible for the applied science that is required for them to accomplish their mission.

All right, how do we spend that money? We have--well, I guess one more specialized role. I'm not getting to the main part of my talk. I keep departing from it.

A role that's becoming increasingly important is the building and support for the national use of specialized facilities which are too expensive, dangerous or elaborate to logically expect at a single smaller location, such as university campus.

I'll give you examples of these, and these are all operated on what we term a user basis. One of our jobs is to build and operate facilities which are then made available to the scientific community and the scientific community organizes user groups which often controls the use of these.

This mode of operation has long been the trend in high energy physics where people talk about the big "government" accelerators and indeed are they built by the government, but the experimenters on them are largely, (usually 70 to 80 percent) university researchers who have a large say in how these facilities are operated.

And I want to point to a few of the kinds of facilities that we operate. For instance, we have fallen heir to almost all the high power reactors, steady state nuclear reactors in the United States. Experimental, of course, not power producing.

So if there's neutron diffraction done, or if there is neutron activation done that requires high beam intensity, a lot of this can be done on smaller university-size reactors, but we have reactors that have, you know, far greater beam power than anything you could locate conveniently on a university campus. And we have fallen heir to this type of thing and one of our jobs is to operate these for the benefit of the scientific community.

We have two projects now that are, three actually, under way now that are in this same category. A large synchrotron radiation source, a light source which I think will open up immense opportunities in studies all the way from molecules, clear down into the solid state and polymers; biological research. It is essentially a very large and continuous spectrum light source in which the light is generated by circulating electrons.

We fell heir to one of these, not by accident at all, but by design when the big accelerator at Stanford was built, the circular electron storage ring; it is by its nature the most powerful emitter of synchrotron radiation in the world.

We have another of these under construction at Brookhaven. It will be a user facility in which experimenters can come from universities and if we can get some of the proprietary aspects ironed out, from industry. I don't need to tell you the benefits of this kind of thing, besides basic research, if you stop and think a minute what limits the packing density of electronic components used for solid state applications like computers, where packing density is important--it's the defraction limit of light, because the masks used to fabricate the tiny elements are prepared by photolithography. By using a short wavelength, extremely intense source, we think it will be possible to reduce the dimensions of solid state components in computer microcircuitry.

So these things have tremendous practical applications.

Two more; I'll get through these quickly. I'm taking too much time on this overview.

We're starting a combustion facility. We are starting this at the Sandia Laboratory. Again, it will be user facility and we hope we can entice all sorts of people to come and use that facility to advance understanding of the processes of combustion.

And finally in joint venture with NSF, we're starting something totally different and that is a national facility for computations in chemistry. Many research projects in modern chemistry could certainly use convenient access to large, very large in this case, computers, capabilites of the class 6 type, and those are not available in general, hardly ever available except at national laboratories.

So we have a joint venture with the National Science Foundation which will again make the very large computer complex, not just the number crunching part, but the peripheral item, graphics, the remote access and all these very desirable attributes of the big systems available to the general scientific community.

Okay. Enough of that. Now, let me talk about our organization.

We have four major groups to which we allocate money. The first of these is nuclear sciences. And the budget this next year will be about $25 million. I'm not going to talk about that other than to tell you it's there. We do the cross-section measurements, for instance, of interest to fission and fusion. We do isotope preparation. We are the proprietors of the largest isotope store in the world, I think. If the medial establishment wants stable isotopes that are not provided by industry; we will supply them.

We also are the suppliers of heavy elements. And that's an interesting thing. All the isotope-using neutron generators used by the oil exploration business depend on my program. That seems a kind of surprising place for it. We're suppliers of the americium-241, for instance, that is used as the alpha source for neutron generators.

That's the nuclear science program.

Materials science program, $58 million, roughly, for next year is going to be described quite thoroughly by the subsequent speaker. My personal background is material science and I guess it's not just my prejudice, but if I had to identify a single subject in which the problems are spread almost uniformly across all of ERDA, I cannot name one that is more ubiquitous than material sciences.

The third, and the one I'm going to talk about today, is called chemical sciences; about $42 million in our budget next fiscal year. This is truly chemistry. It is atomic and molecular physics, chemical processes and chemical instrumentation. Now, there are a few things I've probably missed, but that's predominantly what's in there.

Finally, we have mathematics and geosciences. These are two very small programs. The total is $11 million between them. The math program contains very little of what mathematicians would call pure mathematics. It is mostly leaning towards numerical sciences; how we can better use our enormous array of computers, for example.

Some of you may not know this, but ERDA has the largest computational capability in the free world in terms of instructions per second or some measure of very large computation capability.

So most of our effort goes into applied math. We support the Courant Institute quite heavily, for instance, on how we can do better numerical calculations.

Geosciences is a technology that cuts across this entire Agency. The nuclear people are very concerned about making sure they can put their waste in a spot that is going to be inaccessible on geological time scales. They are interested in siting their facilities in places that are seismically satisfactory and so forth.

By the way, the uranium people need to know how much resource is out there. If there is certainly a critical problem in nuclear power in the United States, it's how much uranium oxide is out there at a certain price. That's a major question; the need and timing of the breeder reactor kind of hinges on that.

As I move across the ERDA organization chart, almost every technology has need for geosciences. I don't have to tell you about the importance to geological understanding for fossil energy.

CHEMICAL SCIENCES

TECHNOLOGY RELATED—%

	FY 73	FY 75	FY 77
FOSSIL	0.5	7	13
GEOTHERMAL	0	0.1	0.4
SOLAR	2	4	7
FISSION	18	13	8
FUSION	1	3	5
CONSERVATION	0.5	4.9	5.6
ENVIRONMENT & SAFETY	4	4	5
IMPORTANT TO MANY ENERGY TECHNOLOGIES	7	9	9
IMPORTANT TO LONG-TERM ADVANCEMENT OF ENERGY SCIENCES	67	55	47
	100.0%	100.0%	100.0%

Okay. Who are the performers? The performers are largely universities, national labs and to a much smaller extent industrial labs. How much industrial participation? In the past, it's been small. We have some interaction with the not-for-profits and the high technology kinds of corporations. We have really a relatively small interaction with the big industrial corporations that do the ongoing bulk of really good industrial research. We don't have many connections with them, although we talk a lot to some of them.

There's lots of reasons that we don't. I don't want to go through them here, but I don't want you to be discouraged by the fact that the numbers appear small.

Now to the fossil energy basic research program. Could I have the first slide, please?

(Slide 1)

I told you we were responsible for all technologies and I thought you would be interested in understanding just how we spend our money. The slide shows two-year intervals. You see it's fiscal '73, '75 and '77. Those are percentage numbers. Research has not grown in proportion to the rest of the Agency and that's due, of course, to the Agency focusing on short-term problems. I'm not taking issue with that. I just want you to understand that our program has grown at a rate of about the cost of living plus a few percent.

So in order to achieve the growths you see there, we've had to cut into some of the other areas. And you can see we cut back on fission quite appreciably and we've had to make some pretty hard decisions on what areas we'd get into.

Now, the two at the bottom, those really could be lumped together in some ways. I'll give you an example of a problem that is important to many technologies, and that could be, for instance, hydrogen embrittlement.

You see the rather large category of important to long-term advancement of energy sciences--let me just pick an example off the top of my head. Molecular beam work that tries to understand what the cross-section for reaction between a molecule in a particular energy state. You'd have a hard time attributing that to one of those technologies above. Certainly if you choose a molecule that's in combustion gases, why then you can say that's combustion. But we don't usually do our research that focused in those kinds of things. The molecular beam research looks at what is convenient and gives the most basic information.

I could give you many such examples. I won't.

Could I have the second slide, please?

(Slide 2)

I have it in my notes that you were supposed to notice the rate of change. There was a large rate of change in fossil energy. There was a decrease in these unspecified things.

Here is the major component of our program in fossil energy; the chemical sciences.

CHEMICAL SCIENCES

FOSSIL ENERGY RELATED RESEARCH

	FY 73	FY 75	FY 77
CHEMICAL SCIENCES	$0.4	$2.1	$5.6
CATALYSIS* (HETEROGENEOUS)	0.1	0.3	1.6
COAL CHEMISTRY (CHARACTERIZATION, ORGANIC CHEM., REACTION KINETICS, MECHANISMS)	0.2	1.2	2.2
ANALYTICAL CHEMISTRY (MASS & OPTICAL SPECTROSCOPY, CHROMAT.)	0.1	0.3	0.5
COMBUSTION	0	0.3	1.3

* DOES NOT INCLUDE MATERIALS SCIENCE RESEARCH ON CATALYSTS.

M$ B/O

You can see in FY77 it's $5.6 million. We think it's truly fossil energy-related, and we can point to it as highly relevant.

And by the way, most of our research in fossil energy does have a habit of being related to specific problems--it's far easier to tie it to specific goals. I'll get to those in a few minutes. You can read as well as I can, and I don't imagine you're surprised by a single item on that list.

This program is well integrated. The first two topics with fossil energy--Alex Mills's program and others. In the last topic, combustion--we have a three-way organization going. Karl Bastress, the speaker you heard this morning from Conservation, Andre Macek who works for Alex Mills, and one of my people responsible for combustion, coordinate an overall combustion program.

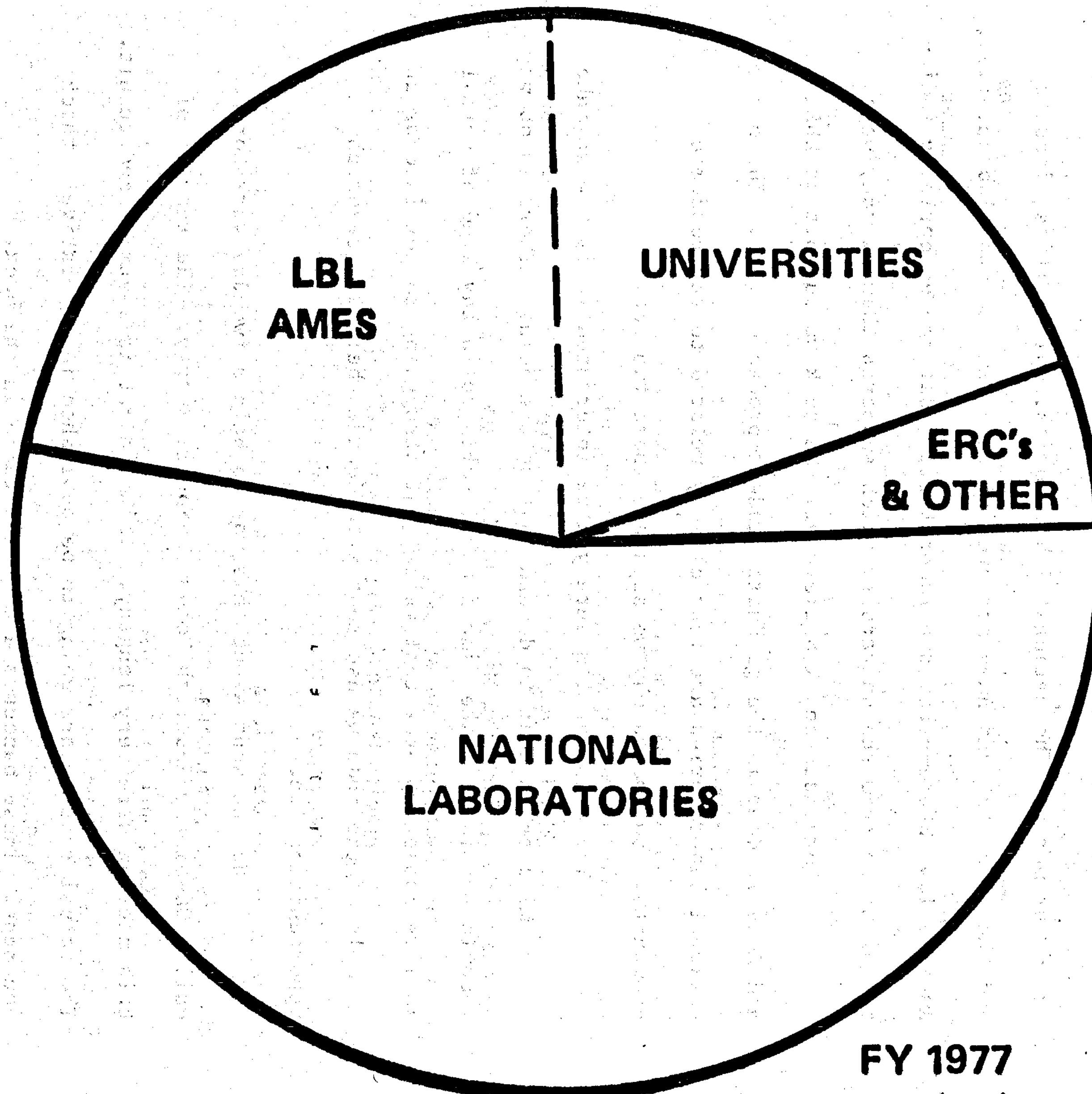
My people are interested in the molecular level interaction part of it: the cross section of the individual reactions, the kinetics of the reactions, and in the fundamental understanding of the turbulence phenomena.

Karl and Andre, the other two people, are more interested in relating combustion research to real world situations like the stratified charged engine or like a fluidized bed combustor or like a MHD burner.

Okay, the next slide, please.

(Slide 3)

CHEMICAL SCIENCES
FOSSIL ENERGY RELATED RESEARCH



FY 1977
5.6 M$ B/O

Who does it? This slide shows a breakdown of where we spend our money. The national laboratories, universities, industry and the ERCs, LBL and Ames are special cases in national laboratories, Ames is Iowa State--they are laboratories that are essentially indistinguishable from the university which supports them in many ways.

For instance, I believe all the work we support at LBL and Ames is done in the graduate student-professor mode. The other national laboratories are less closely related to the academic community. So that's why we separate those two out.

The question I'm sure you're interested in is how we make up our mind as to what to do and what we are doing. There is no way I could possibly in the time I have, tell you in any kind of detail, so I've chosen an area that we're just struggling to get into as an example of the mode we use to try to decide where the research opportunities lie.

How we went about this was to hold a two-day workshop, called Chemistry Research Needs in Fossil Energy. The results of this meeting were very lengthy. This handout is a summarized result. The actual results are going to be published in a relatively thick document. These handouts are on the table in the back.

The handout contains what we found out by sponsoring this two-day workshop. We invited people. I don't have a breakdown here in front of me, but it was universities, national labs, with the energy research centers represented. Those are really our link into the business.

You understand that a lot of our effort has been to redirect some of the national lab work into ways that are productive for the fossil energy problems. And the national labs, as you've heard, are very good for some things and at other things they are totally inexperienced. So if we do use them, we have to make sure we're using them for things that are productive.

The point of the workshop was to find out what things in the opinion of the community were needed and what should we settle on. And it turned out that the participants--it was a rather extensive meeting; it lasted two days and there were 30 or 40 participants --settled again on areas which I'm sure won't surprise you. They're in the next slide.

(Slide 4)

The handout that you can pick up describes these three areas. Can we really understand coal and the primary decomposition products of coal, the asphaltenes, the other fractions that come off when you degrade it in various ways? How can this be related to the other properties that are observed?

Somebody yesterday, I believe it was Alex, showed a very elaborate coal molecule, a polycyclic, aromatic molecule of some kind, and he pointed out that it would be of great benefit if you could cleave it selectively in certain places. I'm sure this has occured

CHEMICAL SCIENCES

CHEMISTRY RESEARCH NEEDS IN FOSSIL ENERGY

CHARACTERIZATION OF COAL AND COAL DERIVED SUBSTANCES

CHEMICAL REACTIVITY AND MECHANISMS

CATALYSIS

to everybody that's studied coal for the last 100 years, and some of you coal experts are probably chuckling at my presumptiveness here. But if you could cleave them in certain places, you would leave a very large residue having a favorable carbon to hydrogen ratio.

So rather than take it apart with a sledge hammer, if you could really learn what the sensitive points of attack are in this complicated system, there would be a big payoff.

And finally, catalysis, for reasons which again I'm sure are totally familiar to this group. I think the reasons were probably best brought out in Alex's slides of yesterday in which he pointed out the effect of capital cost on product cost. I think he even had a slide in which he showed what the price of the product would be if you could put twice as much through the same plant.

Of course, it was a dramatic effect, obtained by increasing throughput.

May we have slide 5, please?

(Slide 5)

These are some examples of things we're doing. I'll leave it for you to gaze at a minute and go into another topic, which is, problems carrying out the program. I really haven't told you much about it yet, but let me tell you a couple of our problems. First, as mentioned yesterday, there really aren't that many performers that are anxious to get into those particular areas we've pointed out.

CHEMICAL SCIENCES

EXAMPLES OF FOSSIL ENERGY RELATED RESEARCH

- CHEMICAL STRUCTURE OF COAL BY CHEMICAL OXIDATION TECHNIQUES USING GCMS. ANL
- ANGLE-RESOLVED PHOTOELECTRON SPECTROSCOPY OF ADSORBED SPECIES ON CATALYTIC SURFACES. LBL
- LABILE SO_2 COMPLEXES FOR REVERSIBLE SCAVENGING OF SO_2 FROM GAS STREAMS. LASL
- MULTIPLE PULSE, MAGIC ANGLE SPINNING NMR OF HYDROCARBON SOLIDS. AMES
- CATALYST POISONING MECHANISMS BY AUGER CHARACTERIZED SURFACE REACTION STUDIES. DELAWARE, NBS

Now that may surprise a lot of you, not that we have great amounts of money, and we do have a lot of proposals we turn down. So I may be overdoing this point. But how are we going to entice the really top-notch young scientist who is very much these days enamored with figuring out polymers and DNA and all that sort of thing? How are we going to entice them into the coal business, because I'm convinced until we get that type of intellect working on this problem, we're just wasting our time.

So there is a big problem in doing this. One of my people who works with proposers and talks to the proposers and discusses research with them, told me that he thinks that it's going to be an evolutionary process, that we're not going to be able to get the established generation of scientists. They've already made their mark in one of these other fields that has a high glamor coefficient. He thinks it's going to be the young people just getting out of school that are really going to plunge into this whole business of coal, understanding it from a very much more basic viewpoint than it has been understood in the past.

The other problem, of course, is budget. Again, this is not a plea. My budget in fossil related research is one of my highest priority areas and I'm going to double it again next year. It's been doubling about every year and that can't go on forever, but we really are very concerned, and we'll do this at the sacrifice of other areas, if necessary, to get more money into fossil energy.

Let me give you a few examples. I picked several of these to show you how we are being selective in some of the uses of the national labs. They have, in some cases, extraordinary capabilities which were built for other reasons, but are very well suited to fossil energy research.

Now that first title sounds rather pallid because it's a gas chromatography-mass spectrometry combined and I'm sure there are many of those instruments, but this one is unique. I guess Argonne has one of the finest mass spectrometry setups that I know of in the United States.

What they're trying to do is to focus their attention on what molecules come off when coal is degraded by a variety of degradation means and what information you get out of this.

The second one is a very interesting one. In fact, that particular piece of work was done on the SPEAR facility because they couldn't get photons in sufficient intensity and at the right wavelength anywhere else to do that photoelectron spectroscopy. For the first time, I believe, they were able to actually prove that carbon monoxide sitting down on the surface of the catalyst was sitting with one end down. Well, now, I forget which end.

VOICE: The carbon end.

DR. KANE: The carbon end was sitting down and precessing around, and they could get its dynamics on the surface using synchrotron radiation. Now, I don't know what's going to come of that, but I'm sure that that kind of knowledge is going to be useful to us.

The third one is one that grew out of LASL, as you probably know. I'm not sure it even came this way, but I'll use it as an example and I hope I'm right. LASL has for years been interested in chelating complexes, the whole heavy element business; separation of heavy elements has been highly dependent on chelating compounds.

Now, obviously you want a chelater that grabs the SO_2 and then releases it again, and that means that it's got to have a certain heat of binding, obviously, to make that happen. So if you had to develop chelating compounds, which are big organic molecules, can you characterize the heat of bonding in some simple measurement without actually measuring it reversibly?

LASL thinks they may have developed a technique whereby they can by infrared measurements of the molecule infer the heat of bonding to SO_2. This would greatly reduce the effort needed to develop chelating agents.

This is again just a gleam. It's not proven technology.

The fourth one represents research by Professor Gerstein at Ames, who is really an outstanding pulsed NMR scientist, and he's turned his efforts toward coal. Now, Ames is an interesting spot. Iowa's got a lot of coal in it. The whole State of Iowa's getting very coal-conscious. I think you're going to see a transition of that Ames Laboratory, at least to some extent into the coal business. They will approach it through the university and I have great confidence that they'll do it in a very basic sort of way.

Finally, a project we have on catalysis poisoning. I'm over my time. I know I've run over and there'll probably be questions. Why don't I just stop right there.

I'll point out that one meeting we had in which we tried. There was a similar meeting to get these fossil energy research needs held on heterogeneous catalysis last fall. And those results are available, too. Not here today, but if you want to contact me, I'll see that you get a copy.

Thank you very much.

(Applause.)

Dr. KROPSCHOT: Questions:

DR. REYNOLDS: Jim, you mentioned that your charge is to deal with the physical sciences, and I think you meant probably exclusive things like life sciences. Where do engineering sciences fit into the picture?

DR. KANE: I have recently reorganized, and one of the new boxes on my organization chart is engineering sciences--that doesn't mean engineering development--it means engineering sciences.

I have a few little pets that I put in that, but I don't think I'm smart enough to say what ought to be there. We're now in the process of developing what things ought to be in there, whether it's modern, say, process control; that might be an example. Or I could think of a great number of engineering sciences topics.

I think ERDA, and particularly we, have been very deficient in ignoring this subject and we're hoping to make amends, but all I can give you is promises right now. We're looking at that.

DR. HOLLOWAY: Jim, I want to ask you a mean question.

Suppose one of the distinguished universities came to ERDA with a proposition for some work on fundamental combustion and they said look, we'd like to do some theoretical work. We'd like to do some modeling work and we would like to do some experimental work in this area.

And ERDA came back and said well, the theoretical work's fine, the modeling work is fine, but thank you on the experimental work, we'll do that in the national laboratories.

What would you think of that?

DR. KANE: I hope we wouldn't do that, Dr. Holloway.

DR. HOLLOWAY: You did.

(Laughter.)

DR. KANE: Did we do it?

What can I say?

(Laughter.)

DR. KANE: That was a mean question.

Let me spend a minute on that. We probably did. In fact, if you say so, I'm sure we did.

I think I would like to clear up what we're trying to do at Sandia, because I think if there's any one thing that's gotten me a bad reputation with the universities, it's been what I did at Sandia. I was largely responsible for that.

Sandia, because of weapons requirements, starting about, oh, eight or nine years ago, developed a very sophisticated dynamic gas analysis technology, not aimed toward combustion at all, analyzing the mixture of gases in a very short time, schlieren and pulsed laser diagnostics and so on. They, over the period of years, acquired some, I think, extremely competent people in combustion and convinced me that we should have a combustion diagnostics facility in which we centralized the development of the very expensive pulsed lasers that it will take to do this.

That meant that we gave, in my opinion, a disproportionate amount of our experimental attention to Sandia. That probably was the reason we did what you said we did.

If we did it, well, maybe we had a right to. Maybe we knew that somebody else was doing it better. I think the answer "because we'll do it in our national labs" would be very poor. If we could have said we are already doing that work somewhere else that would have been a better answer. I hope we said it that way.

MR. HILL: George Hill.

The concern you expressed about getting bright young men and women into the field: I don't see how in the national laboratories you can develop a mechanism that matches quite the university matrix mechanism.

Are you going to shift more to university center support like you have with Ames and so forth, where the post-docs generally spend their time?

DR. KANE: George, I guess I don't know the answer to that right now. I have no plans for a dramatic shift to the universities. I've been thinking of an experiment and that would be to get a couple of Jerry Phillips and Dick Kropschots to come from outside ERDA and look at that question for me and help me on it during the next year.

But I don't envision a dramatic shift. In a constant budget arrangement which is what I'm sure I'm faced with, it's a very difficult thing to make major moves into the universities. We could place our support in bigger chunks than we have though.

MR. SCOTT: Paul Scott.

What's your success ratio for new proposals from universities? Can you give us an idea if somebody comes in new with a proposal, say fossil energy-related? For instance, catalysis, what is it?

DR. KANE: There's a couple of people in the audience I think could better answer. I think our gross rejection rate is, like 7 to 8 out of 10.

Now, there's lots of duplication in the system. People mail them to both us and NSF, so maybe it's not quite as bad as it sounds.

How about Elliot Pierce? Could Elliot give a quick answer to that?

Could you go to a microphone, please, so everybody will hear you, Elliot?

DR. PIERCE: Overall success rate of university proposals in the chemical sciences is on the order of 8 to 10 percent.

MR. SCOTT: 8 to 10. That's other than renewals?

DR. PIERCE: That's right.

DR. REYNOLDS: I just want to remind folks that there was a program that the National Science Foundation had a couple of years ago where they put out a forgivable loan program and the students were paid for going to school and getting an education, and if they went into teaching, the loan was forgiven.

Maybe you could do something like this to get people into the labs in coal.

DR. KROPSCHOT: I will set the clock for 15 minutes for a coffee break and be back then.

(Recess.)

DR. KROPSCHOT: We would like to proceed with a description of the program in material sciences that is being conducted in the Division of Basic Energy Sciences, and I would like to introduce the assistant director for the Materials Sciences Program, Dr. Donald Stevens.

DR. STEVENS: Dr. Kane has given a fairly complete description of the mission of the Division of Basic Energy Sciences, so I will not go into great depth on that.

May we have the first slide, please?

(Slide 1)

But I would like to show you the goals of the Materials Sciences Program. It is a program to develop the understanding of materials properties and phenomena as a basis for the development programs, to chart a better course, to provide information to anticipate materials problems and to help when the unanticipated materials problem comes along in the future. Invariable, in high technology, as advanced technology systems development, we will have materials surprises. That has been classic throughout all systems development for the past 20 to 25 years.

We do not develop materials. We develop understanding of materials.

The program supports research in the areas of metallurgy, ceramics, solid state physics, chemistry and chemical engineering as they apply to materials problems. We have six permanent staff members. And, fortunately, we have two people from universities with us on sabbatical who have played a very important part in an activity that I'll describe later on.

What is the composition of the materials science program?

(Slide 2)

This is a pie chart that shows in one way how the subject content of the program can be broken down. Of course, one can go into phenomena, one can go into materials classes, one can go into

MATERIALS SCIENCES

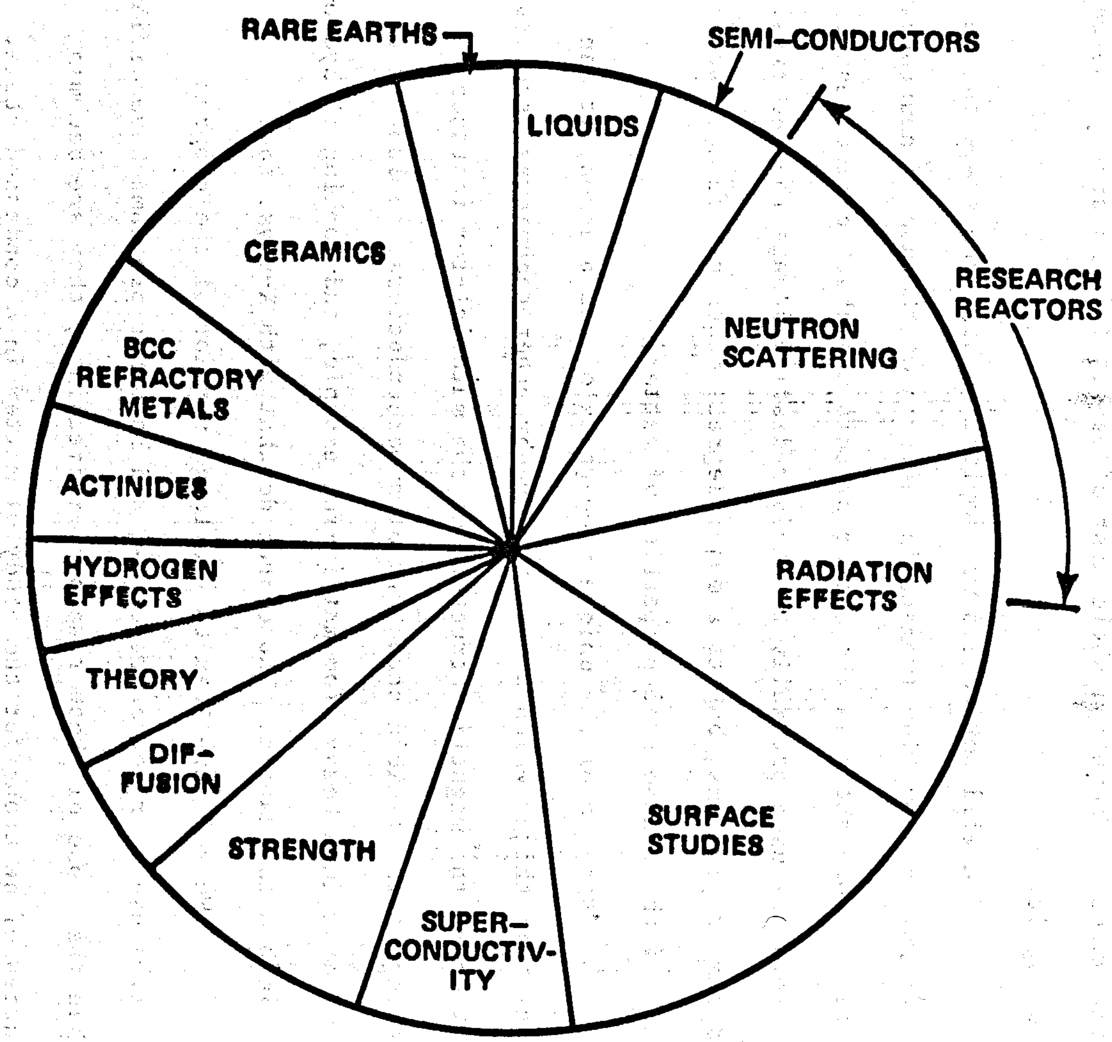
GOALS

- TO ADVANCE THE UNDERSTANDING OF BASIC STRUCTURES AND MECHANISMS GOVERNING PROPERTIES AND BEHAVIOR OF MATTER IN THE CONDENSED STATE.

- TO PROVIDE A FOUNDATION FOR MATERIALS TECHNOLOGY THROUGH THE DEVELOPMENT OF BASIC KNOWLEDGE IN MATERIALS-RELATED ENERGY PROBLEM AREAS OF INTEREST TO ERDA.

- TO EXPLOIT THE UNIQUE CAPABILITIES AND FACILITIES EXISTING IN ERDA LABORATORIES FOR CONDUCTING NATIONAL MATERIALS SCIENCES PROGRAMS.

MATERIALS SCIENCES FY 1977 FUNDING BY TOPICAL AREA



OPERATING BUDGET (CONG APPROP) – $52.8M

environments. There's a whole host of ways. This is simply one way of doing it.

You will notice, as was implied in Dr. Kane's speech, we have a rather heavy involvement in the area of the use of neutrons. Those neutrons shown in the sector of this pie chart called research reactors are used partially to study radiation damage for the fission and fusion programs, but to a major degree, neutrons are used as a probe of the fundamental properties of matter.

Because of the unique properties of the neutron, it can do certain things which cannot be done by other techniques, such as looking at the magnetic structure of the material-for instance, looking at the fluxoid structure of superconductors, to look at a light atom in a heavy atom matrix-for example, and looking at hydrogen in a metal matrix. You cannot do that with X-rays, too.

We see here then that a large portion of the program involves use of research reactors, and as other programs have diminished their use of these reactors, increasingly they are becoming sources of neutrons for the study of matter in a condensed state.

We have a large program in surface properties and ceramics. These programs have grown considerably, particularly since the formation of ERDA.

As Jim pointed out, we were part of the AEC program and when ERDA became operational, our responsibilities greatly broadened from basic research pertaining to the nuclear technologies to basic research to all energy technologies.

So surface and ceramics research particularly have grown in these past several years; also hydrogen effects, work in the BCC area and, of course, in the semiconductor area as it relates to the solar problems.

The budget for the Fiscal '77 is $52.8 million, and as Dr. Kane pointed out in the request before Congress there is $58.45 million requested for the Materials Science Program.

Where is the work performed at the present time?

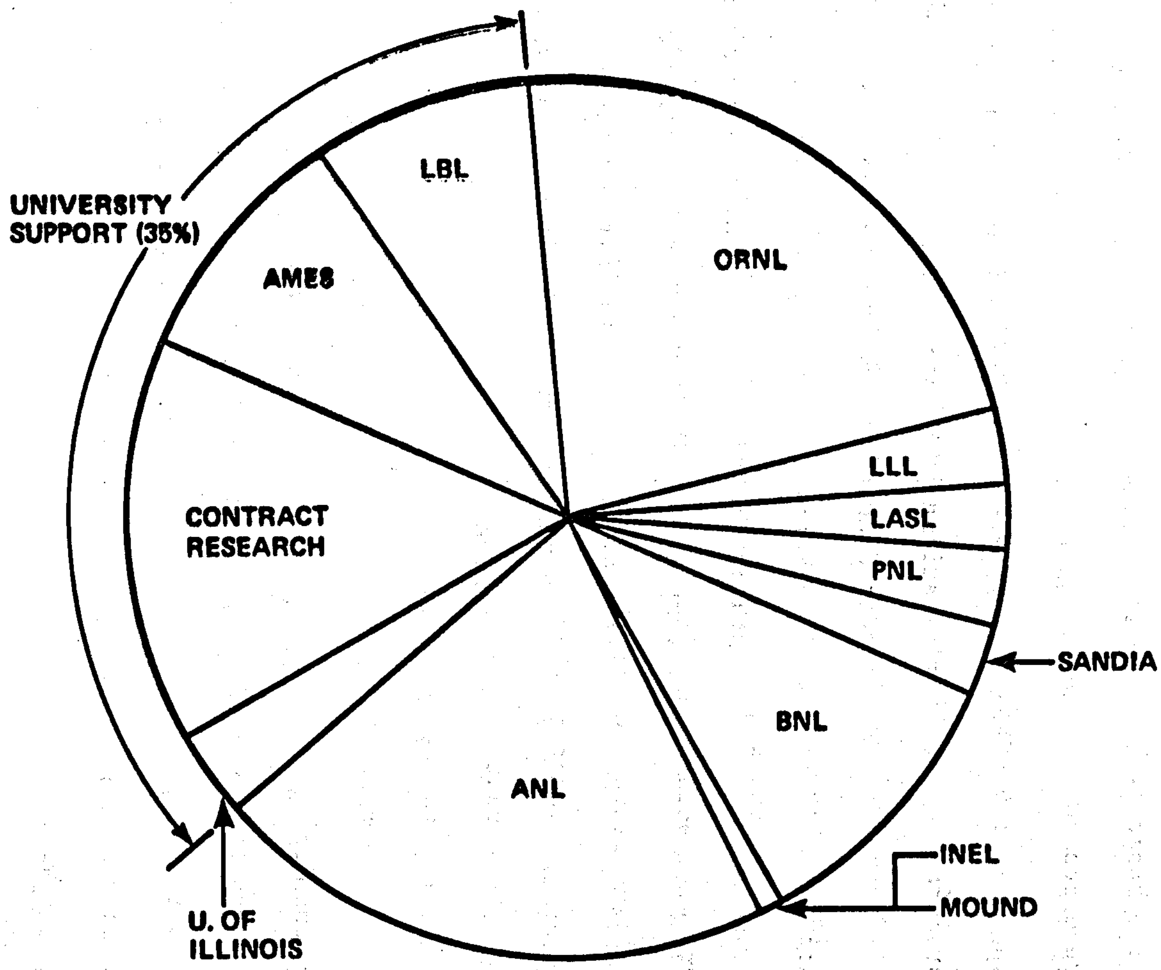
Next slide, please.

(Slide 3)

This pie chart shows, as Jim pointed out in his talk on chemical sciences, that a large portion takes place directly in universities including the Ames and Berkely Laboratories, where the work is carried out primarily by professors and graduate students. We have a large program at the University of Illinois. This is part of the Federal Interdisciplinary Materials Laboratory Program started in the early '60s, when there was heavy involvement at universities by the Department of Defense and the AEC. Subsequently, those large DOD projects have been transferred over to the National Science Foundation.

So about 35 percent of our funds go to the support of professors, post-docs and graduate students, directly in universities.

MATERIALS SCIENCES DISTRIBUTION OF RESEARCH BY LABORATORY & APPROXIMATE PERCENTAGE OF BUDGET



FY 77 OPERATING BUDGET (CONG APPROP)—$52.8M

And there is a heavy involvement in the national laboratory programs by students who come to do their research and professors who come and spend summers and, further, there are graduate thesis advisors of students coming to the national laboratories.

The two largest contractors, as you can see, are the Argonne and the Oak Ridge National Laboratories. This is partially historical, because both of those laboratories have very large metallurgy programs, very large solid state physics programs and very large chemistry programs, all sited contiguously. Because of this interdisciplinary mix, the research that can be conducted at these laboratories can be of a more complex, a more involved nature than is possible, say, with a $40,000 contract at a university.

The contact research program constitutes about 15 percent of the program, and is carried out at universities. I say "primarily," because out of that pot of money also comes the support of workshops, symposia, and things like that, of general broad interest to the scientific community, which are also important to ERDA. There are a few contracts with private industry and not-for-profit institutions in that section, but they constitute just a small portion that I expect will grow in the future.

The next question is what are our program interactions? How do we plan our program? Where do we get the input?

Next slide, please.

(Slide 4)

MATERIALS SCIENCES

PROGRAM INTERACTIONS

- ERDA MATERIALS COORDINATING COMMITTEE
- TOPICAL WORKSHOPS INVOLVING TECHNOLOGY REPRESENTATIVES AND BASIC RESEARCHERS
- CO-SITING OF APPLIED AND BASIC RESEARCH

    EROSION (ANL, LBL)
    HYDROGEN ATTACK (AMES)
    CORROSION (ORNL, LLL)

- ATTENDANCE AT ERDA TECHNOLOGY PROGRAM REVIEWS/WORKSHOPS

    STRUCTURAL CERAMICS
    FAILURE PREVENTION IN COAL CONVERSION SYSTEMS

- PARTICIPATION IN COMAT

    MATERIALS FOR ENERGY STUDY
    MATERIALS R&D INVENTORY

Immediately after ERDA was activated on the initiative of the Materials Science Program, there was set up within ERDA, the ERDA Materials Coordinating Committee. This committee consists of members from each division or majority entity in ERDA that has an involvement in materials R&D with their senior man sitting on this coordinating committee.

The Committee meets once a month, and information about program content, problems which are arising, new directions, budgetary matters, et cetera, are exchanged around the table. Problems of common interest and sources of assistance for the solution of specific problems are identified.

So, number one, at the ERDA Headquarters level, there is the coordinating committee where information is exchanged about problem areas.

Number two, there are topical workshops which are set up both by the Materials Science Program and by the applied programs. For instance, in our program we set up a workshop on stress corrosion cracking which involved scientists from the technologies and scientists from the industrial contractor community. We sat down for three days and analyzed the problem and decided where best to go and who should be doing what. There was then heavy fossil energy involvement in this workshop. It has led to a further activity of the ERDA Materials Coordinating Committee--a continuing subcommittee has been set up to further develop the plans of the agency as a whole.

The third area of interaction is down at the site where the work is done. Perhaps the best coordination, the best program development, takes place down at the working level, where to the extent possible we try to collocate basic research contiguous to applied research. This facilitates the flow of information to the basic people, what the applied problems are, and it facilitates the flow of the new information from the research community as a whole into the applied program.

We have many cases where that is taking place at the present time. It's growing, of course. There is erosion work going on at Argonne and Lawrence Berkeley Laboratory, which is supported both by us and by the Fossil Energy Program; hydrogen attack at Ames; corrosion at Oak Ridge and Lawrence Livermore.

I would like to site a recent specific example of this close interaction. The Ames Laboratory at Iowa State University, with our support, has come upon an economic means of recovery of aluminum oxide from flyash. A patent has been applied for, and very recently, the Fossil Energy Program has come in and put in some money beside ours to further that effort.

Participation of COMAT (COMAT is the Committee on Materials of the Federal Council for Science and Technology) is the high level materials coordinating committee of the Federal Government consisting of high level representatives from each agency having an interest in materials R&D. COMAT has carried out two studies of interest to their audience. One is materials for energy. This was a very exhaustive study, which looked at the materials aspects of the energy technologies, both in the short-term and the long-term. The reports of this very extensive study are just becoming available.

Another study carried out by COMAT is an inventory of the total federal expenditures in FY-1976 for materials research and development. That inventory has been completed. The activity was headed by the Department of Interior with Battelle Columbus as its contractor. COMAT is now going to attempt the horrendous task of attempting to make an inventory of all materials R&D that's going on in the private sector. I wish them luck on that one.

But some interesting things did come out of the Federal materials R&D inventory. The Materials Science Program was deeply involved in this one. We, and all programs, of course, were involved in the general study on materials for energy.

If I may have the next slide.

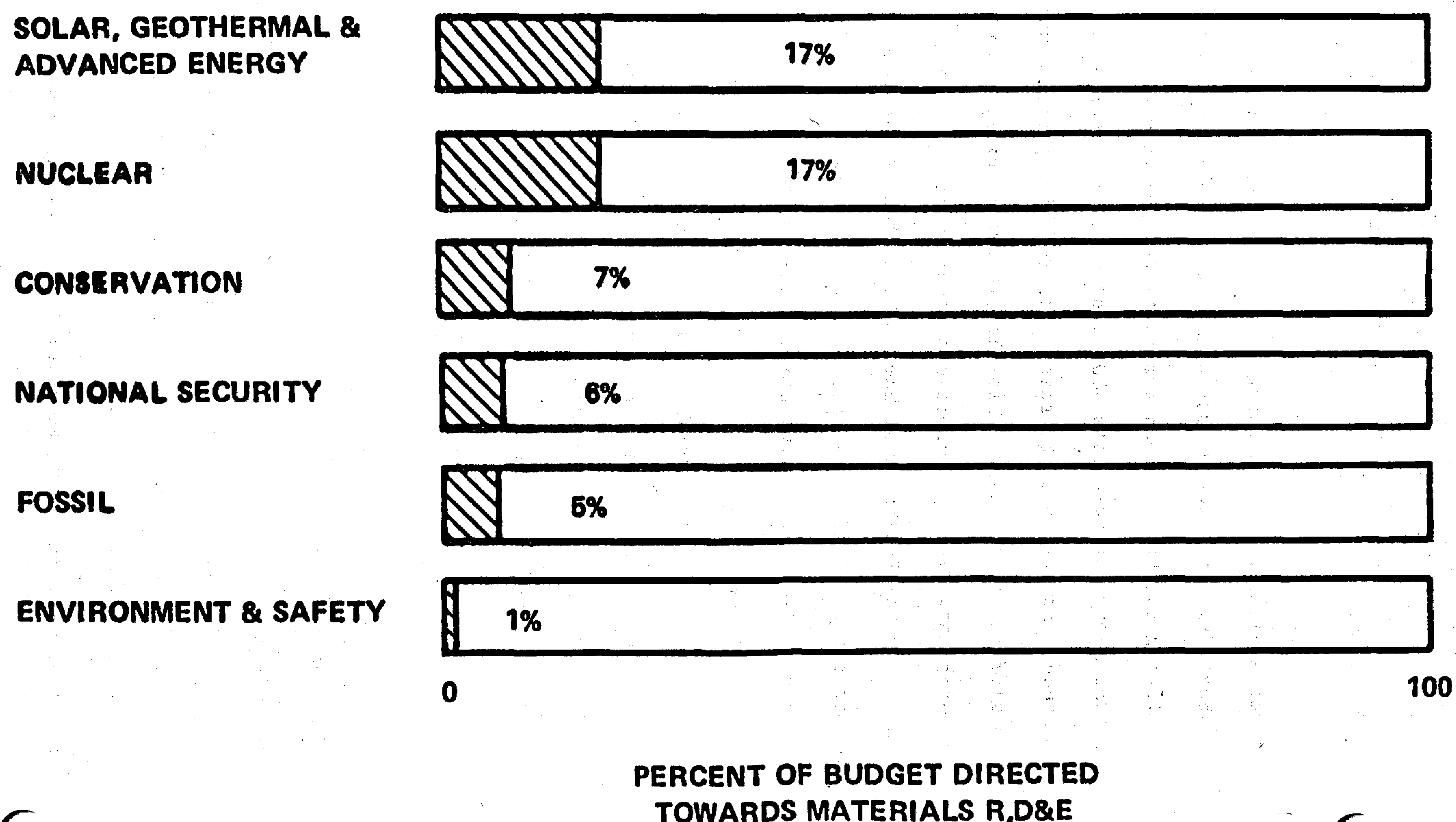
(Slide 5)

As a result of that inventory, we developed information that the total expenditure in 1976 for materials R&D by ERDA was approximately $314 million.

If we then look at the various program areas within ERDA, we find that in the Solar, Geothermal, and Advanced Energy Systems area, 17 percent of the funds available for that program, or those programs, was used for materials R&D. This was the sum total of the

MATERIALS R,D&E IN ERDA

REFERENCE: COMAT INVENTORY OF MATERIALS R&D IN THE FEDERAL GOVERNMENT FY 1976



money spent in Basic Energy Sciences Magnetic Fusion Energy, in Solar, and Geothermal for materials R&D. In the nuclear area, about 17 percent of the funds available for development of fission energy was spent for materials R&D; conservation, seven percent; national security, six percent; fossil energy, five percent; environment and safety, one percent. This then shows generally how the expenditures of $314 million were spread throughout the agency.

Let's look at how the Materials Science Program has changed over the past four years.

If I may have the next slide.

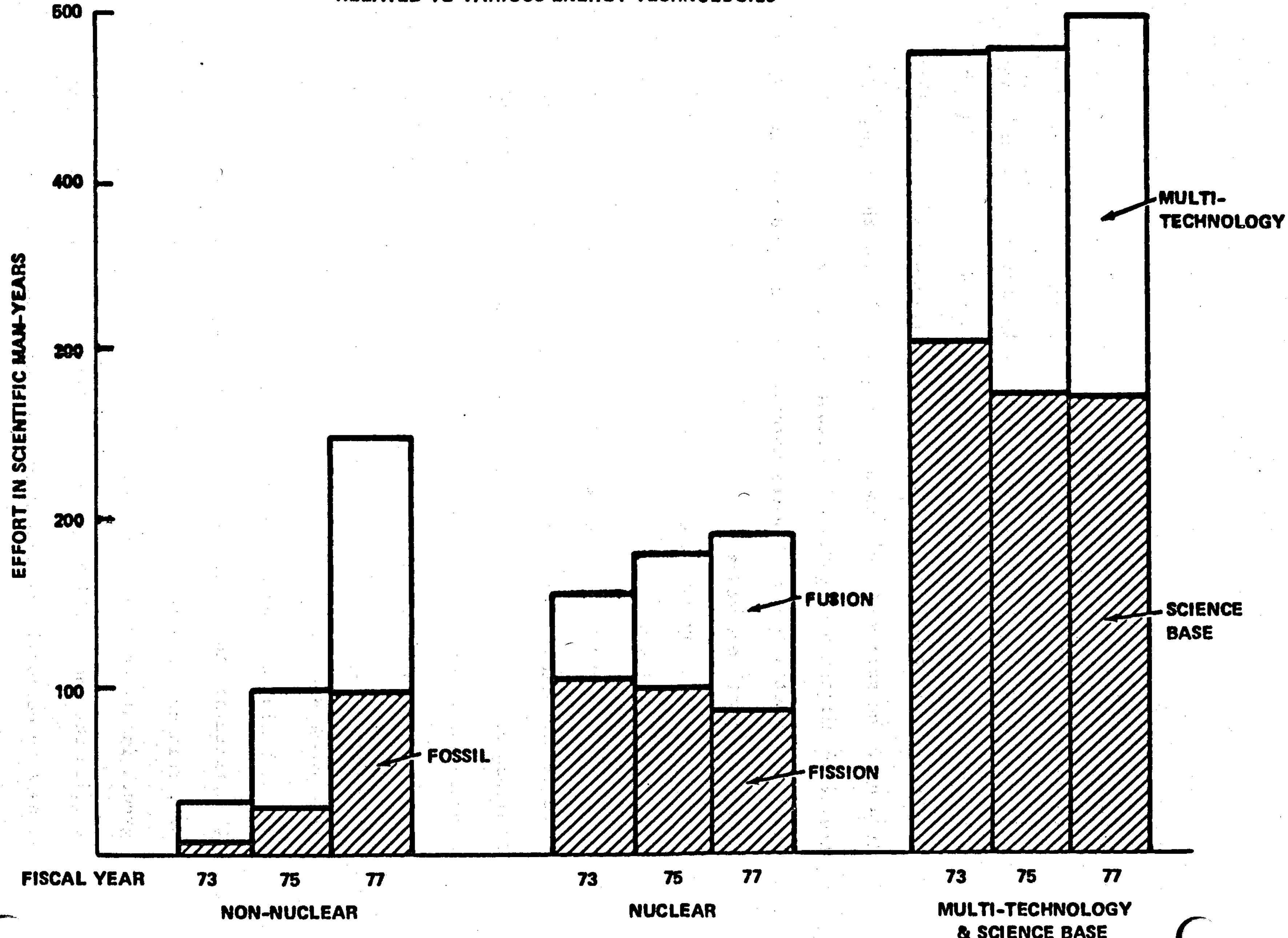
(Slide 6)

We are nearing the end of an exhaustive study calling upon the laboratories to provide us raw data, to analyze the Basic Energy Science Program, in terms of how it has changed from before ERDA, at the beginning of ERDA, and as we are in 1977.

This slide shows the raw data which was just put together this past week on how the Materials Science Program has changed in this four-year period.

You can see that there was very little research going on that pertained to the nonnuclear technologies in 1973. As you can see, this area of research has grown faster by far than the total growth in all other sectors, and one sees in the crosshatched section the amount which is clearly related to fossil energy. One sees a reduction in the amount of research related to fission

MATERIALS SCIENCES PROGRAM EFFORT
RELATED TO VARIOUS ENERGY TECHNOLOGIES



energy, an increase, small increase in the amount of research related to fusion energy.

And then one goes over to the bar charts on the right. I'd like to explain those briefly. By multi-technology research we mean research that has application or pertinence to several technologies. It doesn't make sense then to signify it as totally for one or for the other. Superconductivity is a good example of this. The Math Sciences Program is a major supporter of basic research in superconductivity. We are spending on the order of $4 million on it this year. This research pertains to fusion, to MHD, to energy transmission, and it pertains also to some advanced concepts in exploration-squid devices which I will briefly mention. It really doesn't make sense then to break superconductivity and say so much of it is for fossil, and so much for this, or so much for that. That's what we mean by multi-technology research.

"Basic science" is research which is not clearly discernible as closely related to any given technology. An example of that might be the use of neutrons to study the magnetic structure of, say, the ferroelectrics. It isn't clear that the structure of ferroelectrics is significantly important to any technology. It's that type of research, then, whose purpose is to increase our general understanding of materials, and which provides the basis for our understanding the unexpected when it comes along in the course of technology development.

One sees in this four-year period the amount of "Science base" research has gone down. The amount of multi-technology research has gone up slightly. But, clearly, the areas of greatest growth have been in the area related to the nonnuclear technologies and, specifically, the fossil energy program.

(Slide 7)

The next slide lists research that we are carrying out, which has, we feel, a direct relationship to the fossil energy program. Under coal characterization, we are looking at the physical properties of coal, using, for example, the electron microscope. One finds that coal is a very porous material, and in each of these pores -- they look like wormholes -- there is a small piece of something which apparently is a natural catalyst. I think Dr. Mills mentioned in his comments yesterday about minerals having catalytic properties.

On sulfur effects, we have several things going on. Some recent work at the Argonne National Laboratory has shown that Western oil shale can serve as an absorbent for sulfur dioxide released in its combustion in a fluidized bed. It isn't completely clear why, but it is better than dolomite -- possibly because of its porosity. This information has been turned over to the Morgantown Energy Research Center for further investigation and to see what the useful aspects of that might be.

I will show another example of sulfur effects, in a succeeding slide.

MATERIALS SCIENCES

SUBJECT AREAS OF INTEREST TO FOSSIL ENERGY

	FY 1977 (K$)
COAL CHARACTERIZATION	280
SULFUR EFFECTS	650
CATALYSTS	1,560
EROSION/CORROSION	1,660
MHD MATERIALS	560
HYDROGEN ATTACK & EMBRITTLEMENT, STRESS CORROSION CRACKING	760
CERAMICS	330
	5,800

Dr. Kane mentioned catalysis in his talk. We are concerned with the solid. We are concerned with the structure of the surface and how and why the structure of the surface, is catalytically active. Whereas, in the chemical science program, they utilize the catalytic activity to study reactions and to further the development of catalysts.

Erosion and corrosion is clearly an area we have gotten into, because of the fossil energy program. Erosion was of no significant interest to the Atomic Energy Commission. Erosion is a major problem in the fossil energy area. It's a major problem for topping cycles. It's a major problem for geothermal.

We started early in the game when ERDA was being planned, to set up erosion and corrosion research. There is coal related work on erosion at Argonne and Berkeley. I'll show you an example of this research in a subsequent slide also.

MHD materials, ceramic materials, high temperature materials, and further hydrogen attack and embrittlement, stress corrosion cracking.

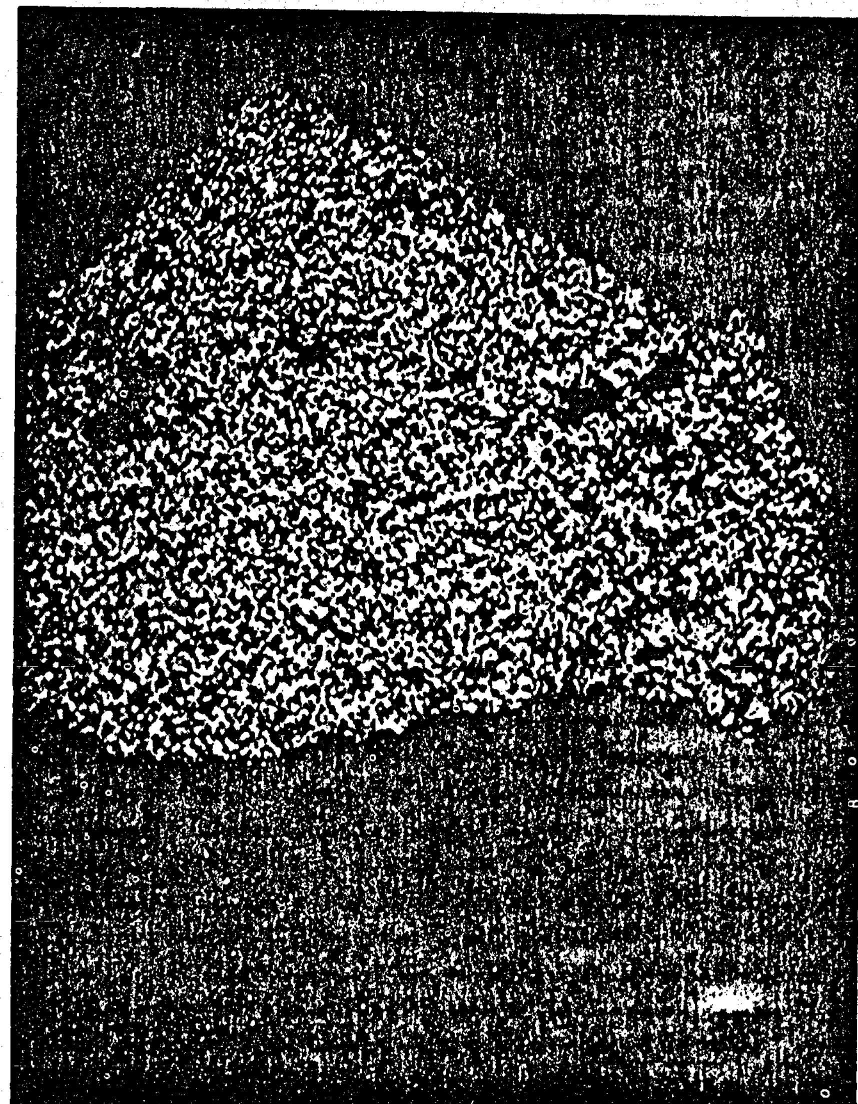
These are examples of research supported by the Materials Sciences Program directly related to fossil energy problems.

If I may have the next slide.

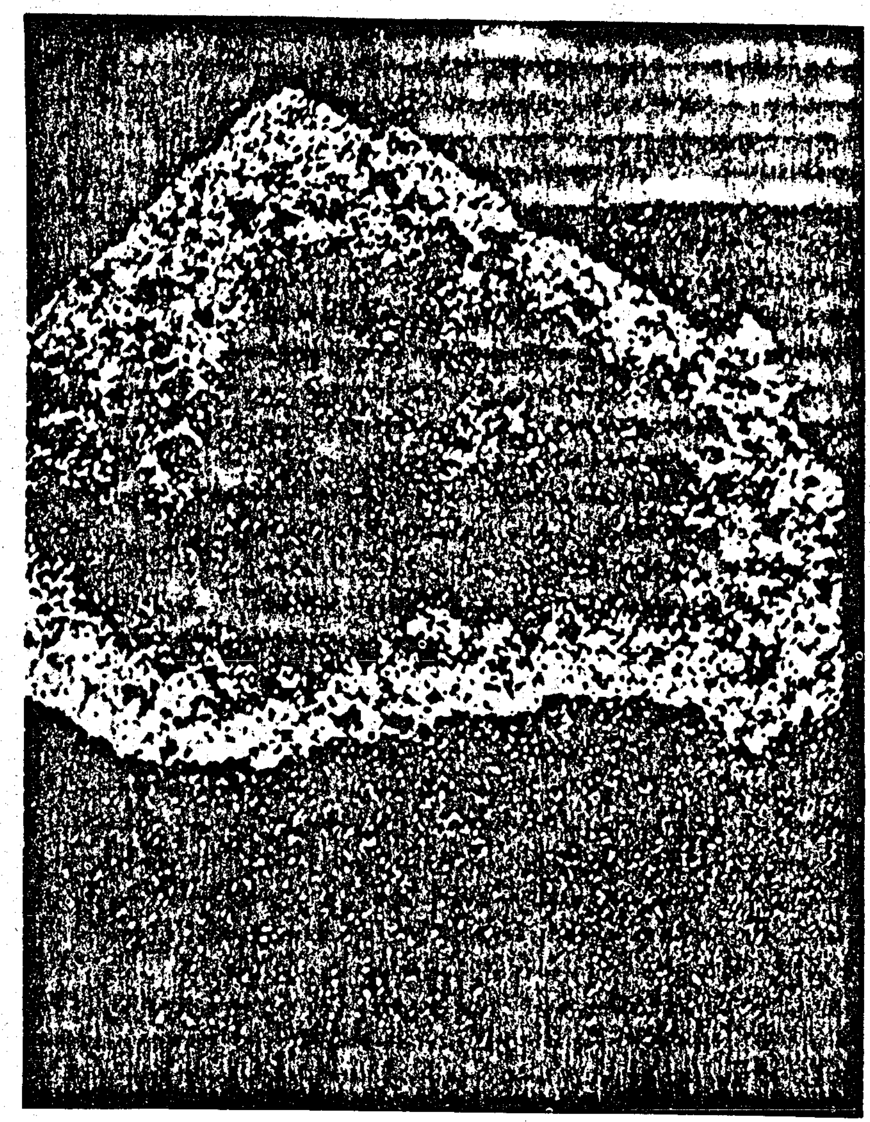
(Slide 8)

This slide shows results of research at Argonne, where people in the Chemical Engineering Division were looking at the use

SO_2 REMOVAL FROM FOSSIL FUEL



FRESH DOLOMITE
Ca, Mg (CO_3)



PARTIALLY SULFATED DOLOMITE

of dolomite to scrub SO_2. They got together with their colleagues in the Materials Science Division and applied materials science techniques to this chemical engineering problem. What they found from these studies are shown on these two micrographs. The one on the left is unreacted dolomite. After it has been partially reacted, one finds that the crystallite has a sulfated region around it, which impedes the flow of CO_2 out and impedes the flow of SO_2 in -- thus slowing down its reaction and reducing the efficiency of dolomite as an SO_2 scrubber. The study shows that it is as much a solid state problem as it is a chemical program. It has to do with diffusion. It has to do with impeding of diffusion and effusion.

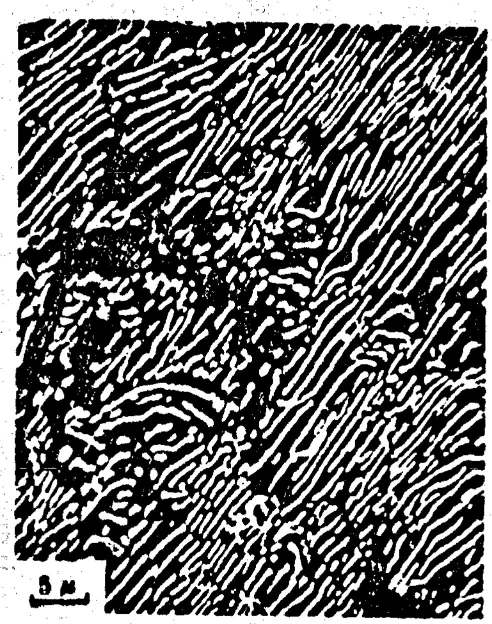
The next slide is an example of research that we're supporting in the area of erosion.

(Slide 9)

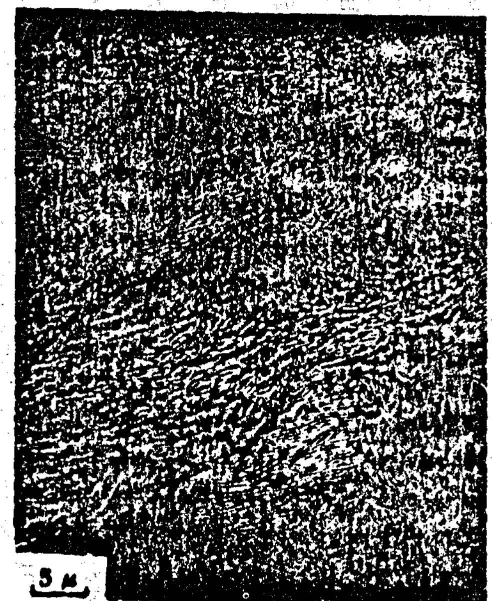
At the Berkeley Laboratory they have set up a very substantial program in erosion and have developed some extremely sensitive equipment costing in excess of $200,000.

In this series of vugraphs, we're looking at 1075-steel. One finds that on the left, in coarse pearlite, the erosion rate is 3.06 times 10^{-4}. If you go over to the far right, and fine pearlite, one has an increase of something like 17 percent in the erosion rate simply as a result of a different microstructure of the material. We don't understand the reason for this but are trying to find the answer. It's a real effect -- the equipment is that good.

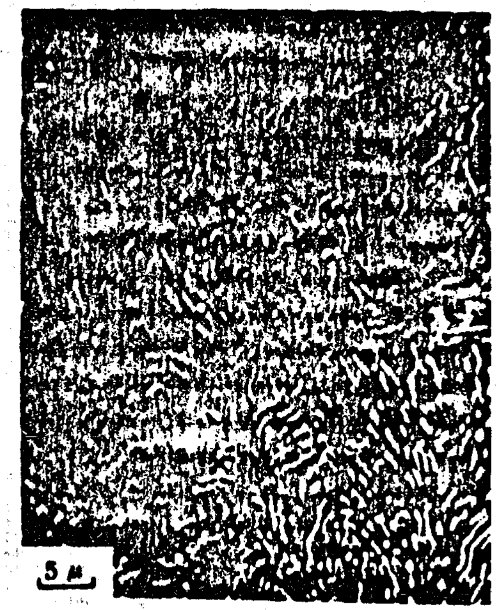
EROSION OF 1075 STEEL



COARSE PEARLITE
Erosion Rate - 3.06 X 10^{-4} gm/gm
Hardness - R_B 90
Lamillar Spacing ~ 1 μm



FINE PEARLITE
Erosion Rate - 3.18 X 10^{-4} gm/gm
Hardness - R_B 99 (R_C 20)
Lamillar Spacing ~ 0.25 μm



SPHEROIDIZED
Erosion Rate - 3.56 X 10^{-4} gm/gm
Hardness - R_B 88
Sphere Diameter ~ 1.25 μm

Impacting Particle: SiC
Impacting Particle Size: 88 μm
Angle of Impingement: 15°
Velocity of Impacting Particle: 366 ft/sec

Next slide, please.

(Slide 10)

Where is the Materials Sciences Program going? As I mentioned, we have a lot of input from technology workshops, our own workshops, topical workshops, from COMAT, from ERDA coordinating committee studies, etc.

We have just completed a series of overview workshops, wherein we have attempted to break out the entire field of materials science into nine tropical areas. The major objective has been to identify and assign priorities within the area of material science.

The two individuals that I mentioned who are with us for this past year from the universities were given the responsibility to manage this study, so that it wouldn't be a rubber stamp of what we're doing, but, hopefully, as an objective study as possible, to find out what we ought to be doing, where the scientific opportunities lie, and where the problems are.

Nine workshops were set up. There were 380 attendees. There were multiple attendees in certain cases. So there were 360 different individuals, whom we consider were the cream of the scientific crop in this country.

Thirty-seven percent of those attendees were from the national laboratories, thirty-three percent from universities, and fifteen percent from industry.

MATERIALS SCIENCES

WORKSHOP SERIES

- **MAJOR OBJECTIVE:** TO IDENTIFY AND ASSIGN PRIORITY TO AREAS IN MATERIALS SCIENCES WHICH WILL HAVE SCIENTIFIC AND TECHNOLOGICAL IMPORTANCE TO ERDA

- **NINE WORKSHOPS:**
  - ELECTRON PROPERTIES
  - SURFACE SCIENCE
  - LOW TEMPERATURE RESEARCH
  - NEUTRON SCATTERING
  - PHASE TRANSFORMATIONS
  - DEFECTS AND DIFFUSION
  - ENGINEERING MATERIALS SCIENCE
  - MECHANICAL PROPERTIES
  - THERMODYNAMICS AND ELECTROCHEMISTRY

- **MAKEUP:** 380 ATTENDEES
  - 37% NATIONAL LABORATORIES
  - 33% UNIVERSITIES
  - 15% INDUSTRY
  - 8% ERDA
  - 7% OTHER

- **RESULTS:**
  - MEETING—PRESENTATION OF WORKSHOP OVERVIEWS
  - COMPENDIUM OF WORKSHOP REPORTS
  - EXECUTIVE SUMMARY

At each of these workshops overviews were given by the technologies to lay out what their problems were and where they foresaw their problems. Then the workshops were broken up into subpanels to analyze those problems in the scientific field. We had a meeting in early June, wherein, technical people from the technologies, people from other agencies, and people from the community as a whole were invited to come to listen to summaries of each of these workshops.

We have a deadline for the complete report of July 15th. We expect to have these reports printed by August 15th or September 1st - a complete compendium of the full reports and an executive summary.

Now, again, like everything else, when you get a bunch of scientists together, they have difficulty in doing what the administrator has to do, that is, establish priorities. A scientist is more interested in what he is doing, and often he's unable to appreciate what somebody else is doing, as compared to his own work. So we're going to end up with a great compendium of recommendations, and it will be part of our job to boil these down into a reasonable set of priorities. But to give you an idea of some of the things which have emerged, may I have the next slide.

(Slide 11)

We have a new program in engineering materials science. This will hit areas of welding and joining, nondestructive evaluation, engineering corrosion, and advanced materials.

MATERIALS SCIENCES

FUTURE EMPHASIS

- **ENGINEERING MATERIALS SCIENCES**

  WELDING & JOINING
  NONDESTRUCTIVE EVALUATION
  ENGINEERING CORROSION
  ADVANCED MATERIALS (COMPOSITES, POLYMERS, AMORPHOUS ALLOYS, ETC.)
  SQUID DEVICES

- **HIGH TEMPERATURE MATERIALS**

  LABORATORY–INTERDISCIPLINARY
  CERAMICS, COATINGS, ALLOYS

- **SURFACE & INTERFACE PHENOMENA**

  CORROSION, EROSION
  CATALYSIS
  SYNCHROTRON LIGHT SOURCE
  ATOMIC RESOLUTION MICROSCOPY

- **THEORY–MODELLING**

  ELECTRICAL & ELECTRONIC PHENOMENA
  FRACTURE & DEFORMATION

One of the things which came out in the summary reports is the need for ERDA to develop the capability to produce and characterize advanced materials, which will be used within the scientific and technical community for materials research and development.

In the area of high temperature materials, while we have work going on in this area, additional research on the thermodynamics of high temperature materials and on the engineering properties of materials at high temperatures are required.

In this regard, we have under consideration a proposal from the Oak Ridge National Laboratory to set up an interdisciplinary laboratory, which will be a high temperature materials laboratory and which will be staffed by chemists, physicists, metallurgists, ceramists, working together to apply their combined talents. The facilities will be available to the entire research community, and there will be work supported by the applied programs. So, again, there will be an interchange between the basic and the applied -- where the problems are and where the new information is.

In the area of surface phenomena and interface phenomena, for example, we don't know anything about erosion. We all know you can sandblast a building, and you know erosion wears away the blades in a high temperature turbine, but actually what the mechanisms involved are, we don't know.

So, again, this is an area where it's been stressed that we expand our efforts.

Obviously, doing more work in catalysis is very important, because this is a high payoff area. Dr. Kane mentioned the synchrotron light source that is in our '78 budget before Congress. The $24 million facility will be available to the entire scientific community and will provide extensive opportunities for surface research.

And, further, in our workshops, it was pointed that we have to get down to the atomic level, electron microscopy. We have provided high voltage electron microscopes to Argonne, Oak Ridge, and the Lawrence Berkeley Laboratory for research on thick samples and high atomic weight elements. Now the technology has progressed to the point where we should be able to see individual atoms. We should actually be able to see atoms in a grain boundary, how they move around, and atoms on a surface. The technique will have a profound impact on the field of materials science. A major recommendation of the workshops was that we do something about that particular area.

And a major recommendation, also, was the need to increase the amount of theoretical support that goes on with the experimental work. If one has a theorist working closely with an experimentalist, to show him how, if he could change his experimental conditions slightly or change his sample a little bit, he could provide some additional information which would be crucial to the evolution of theory, it would be possible to make significant advances.

As I say, there were a large number of individual recommendations which we have to boil down and put in context, so it would be rather senseless for me to read you off a half an hour of recommendations. But, believe me, these workshops were a profound experience. For each, we named a host laboratory, and an individual at the host laboratory was named as cochairman. We then selected, with him, a person who had no connection with ERDA, to be cochairman of each of these workshops. These people, then, in conjunction with the staff managers in my office, worked out what the subpanel distribution should be, and who should be on them.

And there were a tremendous number of people, if you recall, from the university sector and from industry that didn't have a penny of our money, who came in and worked themselves into a lather to provide input to help us in our job to do what we have for the entire ERDA.

With that, I will close my remarks and be anxious to answer any questions that you might have.

(Applause.)

DR. KROPSCHOT: Questions or comments for Professor Stevens?

DR. RAMSEY: If I understand your bar chart correctly it looks as if the materials research stimulated by the fusion project is rather a larger expenditure than the materials research stimulated by fossil fuels.

But in view of the fact that the fossil fuel deficiencies are largely materials limited, as far as I can imagine, and in view of the more immediacy of those and the inevitable long-term problem of the fusion one and even uncertainties on it, I am a little surprised that this distribution is equal.

Now, maybe it is because the industrial research more than makes up for it. I don't know.

DR. STEVENS: Well, that comes about for two reasons, Dr. Ramsey.

Number one, as shown on that chart, we're just newly into the fossil area, and that area is growing rapidly.

DR. RAMSEY: So also is the fusion.

DR. STEVENS: Yes, but I think not quite as fast. Part of the problem is that the fusion materials problems are substantial when one looks at them in detail. We do not anticipate that the fusion portion of our program will grow in the future nearly to the extent that the research related to the fossil technologies, solar technologies, and so on.

MR. HILL: I am wearing my industry hat now, and I was a little alarmed that only 15 percent of people in these meetings were from industry. It sounds almost as if you have a closed fraternity doing some great and marvelous things, tying theoretical to experimental, but I didn't hear you say tying experimental to the real world. Where does that interface take place? Where do you get the input, where do you learn what kinds of things are really rate-determining in the growth of the industrial processes which you are trying to establish.

DR. STEVENS: Well, the participation by industry, industrial representatives, clearly was not as great as it perhaps would have been desirable to have.

The industrial input came primarily from people who were working in the technologies. This was a good share of the input from industry, but then there were, indeed, people from the General Electric Research, Bell Labs, IBM, Westinghouse, Atomics International, General Atomic and industries like that.

Again, one has to remember that we were trying to analyze the scientific opportunities, the basic research opportunities. We wanted input to tell us where the problems are, or foreseen. But the primary emphasis was to analyze those problems into where the scientific opportunities lie.

MR. HILL: Let me just carry it one more step.

DR. STEVENS: I might also say that EPRI was involved.

MR. HILL: I know we were involved there, but the point I want to make is, we had an overview of how much materials work we should do at the Electric Power Research Institute, and the feeling was expressed by the top management, who were relating closely to the utilities, that you can almost spend an infinite amount of money, if you please, on materials research.

Of course, this is a concept, to this extent. This is why I bring it up. You can spend an infinite amount of money on materials research. And great restraints were put on our materials work to be sure that it really was attacking problems that need answers. This is the image abroad. I am merely suggesting it might pay to pay some heed to the impression in industry of what materials work is doing and what it's not doing, and perhaps some lack of support is evident on the industry side.

DR. STEVENS: One area again that showed up -- I alluded to it in my comments. It was shown that a very large impediment to progress in the materials area, was the lack of really well-evaluated engineering and thermodynamic data. This whole area, for instance, Hansen's work on phase diagrams, and thermodynamic analysis of that sort, is no longer in existence in this country. So researchers, who, for example, are trying to investigate the strengthening mechanisms in materials, which often involve the relative stability of one phase versus another, need essential thermodynamic data. There is a major insufficiency of work going on to either generate the data or to critically evaluate it.

There is the National Standard Reference Data Program at the National Bureau of Standards but, unfortunately, it has not gotten the backing that it should have. Materials science and engineering is deeply dependent upon the NBS activities in this important area. And I think -- I may let the cat out of the bag -- this is one of the areas that Drs. Kropschot and Phillips have identified that this agency must look into.

DR. KROPSCHOT: Comments or questions?

(No response)

Thank you very much. We appreciate your participation.

I would like now for a summary session, to introduce my colleague, Dr. Gerry Phillips. We've tried to develop thoughts on how to bring the meeting into perspective and set the tone for the next series of inputs from you.

DR. PHILLIPS: As we told you at the outset of this meeting, the purpose of the meeting is to present to you the status of research in the fossil energy area, as we are doing research within the ERDA agency. And after having presented this to you, then to seek your response to a set of questions.

Now, you will recall that in your meeting the first morning (with competition from various people over on the Hill), we nevertheless got through, I think, a very interesting summary of what the whole agency, ERDA, is all about. And, in particular, what the Division of Fossil Energy has as its mission, its goals and its programs.

And then yesterday afternoon, and here this morning, you've heard a succession of talks on research topics in the fossil energy research areas. These were not all given, please understand, by people in the Fossil Energy Division, but were also given as papers from the Conservation Division, from the Environment and Safety

Division, and from the Division of Physical Research or the Basic Energy Sciences.

So, now, you've had your crash course in what fossil energy research is all about within our agency, and we come to the conclusion, then, by trying to summarize the sort of information that we'd like to have from you and, in particular, what we'd like for you to focus your attention upon this afternoon when you meet in four working group sessions.

We have for those of you that asked us to, put you on one of four lists, each one of which is roughly 10 to 13 people.

They should be small enough groups so that you can talk things over and address yourself to the questions that we now want to present to you.

To aid you in running each of these groups, there will be two cochairmen, one of them will be an ERDA person, and one of them will be a person from our contractor, The MITRE Corporation, and they will introduce themselves to you and try to lead you in your discussions.

Now, the main thing that we're concerned with here is the quality of the research or the adequacy of the research that's going on within ERDA.

(Slide 1)

This is the charge that the administrator gave to Dr. Kane; and Dr. Kropschot and I walked in the door at the wrong time and said we wanted to help out, so we got the job.

QUANTITY OPTIONS

PRESENT ERDA FOSSIL ENERGY PROGRAM

INCREASE

TOO LITTLE RESEARCH

- o TECHNOLOGY NOT COST EFFECTIVE
- o & NEED EVOLUTIONARY RESEARCH
- o & NOVEL, REVOLUTIONARY ADVANCES POSSIBLE
- o & RESOURCES AVAILABLE TO EXPAND RESEARCH
- o & RESOURCES EXPANSION NEEDED

STEADY

PROPER BALANCE OF RESEARCH

- o TECHNOLOGY NEARLY COST EFFECTIVE
- o & EVOLUTIONARY, UNDERWAY, RESEARCH OK
- o & NO REVOLUTIONARY RESEARCH NEEDED
- o & PRESENT RESOURCES ADEQUATE

DECREASE

TOO MUCH RESEARCH

- o TECHNOLOGY IS COST EFFECTIVE
- o OR NO NOVEL ADVANCES POSSIBLE
- o OR NO RESOURCES AVAILABLE

SCOPE - $

TIME

So, let me now talk about our study of this subject in the following context.

If we say that we have a present ERDA fossil energy research program, that you had described to you, and we asked the question: What should we do with that program? Should we increase its scope (which is a quality concept) or should we increase its quantity (which, in fact, is a dollar -- a budgetary concept)?

We really have three overall possibilities. We can say we should decrease it, leave it more or less steady, or increase it.

Now, going from the bottom to the top of this logic diagram (Slide 1), we might argue that there is too much research, and there are people within the ERDA agency that believe that; sincerely believe it.

Their arguments, perhaps, would be something like this: The technology that we have today; The technology of coal liquefaction; The technology of coal gasification; The underground in situ technology; All of the various things that we've been talking about as the supporting technologies, the crosscutting technologies, such as materials sciences, such as instrumentation, et cetera; That all of these are adequate and they are, in fact, cost - and environmentally-effective.

On the other hand, one could also argue that you don't need any research, if there are no new novel advances possible.

If no one has any possibly good new idea, then why bother to have research?

Or there are no resources available, there are not people, there are not institutions that want to propose to do new research.

It is very intersting that the logic in that bottom box is or-logic. Any one or the other of those three reasons is sufficient reason to not do research.

Now, as you go up in the diagram to the next box, we might argue that we have a good program right now, we should leave it steady, we should improve it where we can, add on here, take away there. But more or less leave it on its present course.

There we would argue to justify that viewpoint: That our technology that we have now is directed toward ERDA's mission of obtaining fossil energy, in a useful cost-effective and environmentally-attractive form; that we have that nearly available to us now, and that all we need is evolutionary sort of research to improve it. That type of research is perhaps already under way or could be brought under way. And that we don't really need any revolutionary improvements in our technology.

And, furthermore, the present resources that we have for carrying out the present sort of research are totally adequate to our needs.

And, finally, coming up to the top box, where one would have to argue for an increase, both in scope and quantity of research, we could argue that the technology is perhaps not cost-effective, and not environmentally-effective, and that you need evolutionary research to drive it in the direction of being cost- and environmentally-effective, and that you need, if you can possibly find them, novel and revolutionary advances to cut the cost and to solve the environmental control problems. You have resources available to start this program at the present time, and you probably have to expand those resources of personnel and institutions of the future.

DR. RAMSEY: Gerry, can I ask a question?

DR. PHILLIPS: Yes, Norman.

DR. RAMSEY: I don't quite understand why if the technology is cost-effective, do you have to have less research, and if it's not cost-effective, then you need more research. I can imagine the technology is cost-effective.

The technology is useful, but obviously it can be made better.

DR. PHILLIPS: Right.

DR. RAMSEY: So I don't understand that.

DR. PHILLIPS: Well, okay, I will accept your quibble. You can always certainly argue.

(Laughter)

DR. PHILLIPS: And I think it is a quibble, really, because you could -- if right now, just to be concrete about it -- if right now, we had a technology that would liquify coal, to provide good liquid fuel, gasoline, fuel oils and what not, and we could do this at, let's take a number, let's say $10 a barrel, while our friends in Arabia want more like $13 to $15, if we had that, then it would be very hard to justify a large research program.

You might, if you had some really good idea that would knock the price down to $2, that would really be very convincing.

DR. RAMSEY: But I mean, we do have a technology for burning coal which does produce power.

DR. PHILLIPS: Yes, but we don't have --

DR. RAMSEY: I think we could have a lot of other things, such as liquified --

DR. PHILLIPS: Well, let me come along. That's my next topic, as a matter of fact.

Okay, now this is a logic for us, perhaps, to consider the scope of our research efforts in fossil energy and the quantity of our research and, therefore, the budget.

Let me have the next slide, please, Dick.

(Slide 2)

All right. Now, then, let's turn to the present synfuel technologies. We heard a paper by Chris Knudsen, and we have other inputs during the course of the meeting here, I guess, from Alex Mills, as well, about whether or not the present technologies are cost-effective on the one hand and we've heard discussion also about, whether they are environmentally-effective, on the other hand.

ARE PRESENT SYNFUEL TECHNOLOGIES

o **COST EFFECTIVE ?**

- SYNLIQUIDS ~ 30^+ \$/BBL
- SYNGAS ~ 5^+ \$/10^6 BTU
- DIRECT UTILIZATION WITH CLEAN UP.

AND o **ENVIRONMENTALLY EFFECTIVE ?**

- STRIP MINING
- WASTE DISPOSAL
- WATER RESOURCES/POLLUTION
- SULPHUR
- NO_x
- CO_2
- CARCENOGENIC

From now on, all of my slides and all of my comments are going to be addressed to you as questions in the logic of that first slide.

So we are asking the question now: are our technologies, as they stand at the moment, cost-effective and environmentally-effective?

Well, the numbers that Chris Knudsen quoted, for example, were numbers like 30-plus dollars per barrel and 5-plus dollars per million Btu for gas.

I think that Dr. Mills has quoted similar sorts of numbers.

It was interesting in Knudsen's talk that he said all of the engineering experiences they had in terms of the two parameters that he discussed, namely, the sophistication of experimental knowledge of the processes, on the one hand, and the detail to which engineering studies of costs have been worked out. Those things, in general, historically drive estimated prices upwards, as one goes to more complexity and to more sophistication.

On that basis, these numbers of 30 and 5 conceivably might be lower limits, rather than upper limits.

On the other hand, we believe that evolutionary research in materials science, for example, might very well bring those numbers down.

On the other hand, I guess the engineering experience that's been discussed with me, is that those numbers would never be expected to come down from that sort of research, evolutionary research, more than perhaps 10 to 25 percent.

Therefore, there may be something like a factor of three to five of the synthetic fuel cost prices in excess of what we're experiencing right now.

That's the discussion so far at the meeting.

Now, in regard to the environmental effectiveness of our technologies, we have not had a lot of discussion of that. I simply list here some of the topics that have come up in various of the research papers.

Some of them, it seems to me, are topics that we know very little about. We've heard a lot of interesting possibilities, for example, about the removal of sulfur from fossil fuel, but not a great deal seems to be known, although there seem to be interesting opportunities.

The concerns about the oxides of nitrogen and, perhaps, a rather terrifying concern about the carbon dioxide burdens in the atmosphere; both of those are in many ways unknown.

And, finally, the very worrisome thing about carcinogenic agents that might come from the use of any of these fossil fuels, certainly has to be in our thinking.

(Slide 3)

The next slide, then, asks the question, do we need evolutionary research. Well, a large number of the talks at this

IS EVOLUTIONARY RESEARCH NEEDED ?

(LOW RISK / SMALL IMPROVEMENTS)

- TO PROVIDE COST EFFECTIVENESS TO PILOT DEMOS ?
- TO SOLVE ENVIRONMENTAL PROBLEMS ?
- IS SUCH RESEARCH SUFFICIENT ?
- RESEARCH PRIORITIES FOR :
  - -- MINING
  - -- SYN FUELS PROCESSES
  - -- MATERIALS
  - -- COMBUSTORS
  - -- ENERGY CONVERTERS
  - -- CATALYSIS
  - -- SCRUBBERS
  - -- COMPONENTS
  - -- INSTRUMENTATION / PROCESS CONTROL, ETC.

meeting were concerned with that type of research, where one is basically interested in trying to improve some extant process, some extant device, some extant concept aid, thereby, to improve its cost and environmental effectiveness.

The demonstration plants that we heard discussed yesterday morning, certainly could be improved, no doubt, by this sort of research.

Perhaps the environmental problems could be helped.

And then one has to wonder, is this sort of thing sufficient. In other words, if the price is still too high, there's not real cost-effectiveness, then perhaps that sort of improvement that might perhaps only be 15, 25 percent, perhaps that's not enough. Perhaps the fixes that one has for improving the environmental effectiveness might not be sufficient.

So what is needed for evolutionary research, is to discuss and, within ERDA, arrive at, a set of priorities for those sort of topics, some of which I list right there.

For example, all though the meeting we've talked about combustors and the totality of the ERDA-wide budget for combustion research is under $6 million; I believe each of the speakers involved pointed to these numbers. For example, Kane pointed to -- about $1.5 million. Bastress pointed to something like $1.5, and so forth.

The whole program is, if you will, rather miniscule. And, yet, certainly this must be of some importance to ERDA in its planning of its research program.

The next slide, please.

(Slide 4)

Now, the next question that we want to ask of you is: Should we judge that there are innovative or, if you will, revolutionary possibilities in the way of research? Are there concepts, either spoken to here at this meeting, or that you're familiar with, or you in your own thinking can conceive of, that would provide us with innovations that would help us significantly in our efforts to develop fossil energy in a cost-effective way and in an environmentally-acceptable way?

For example, are new facilities, such as the use of synchrotron radiation to study the detailed properties of surfaces, and how molecules actually are oriented on surfaces; is this of sufficient potential that we should be investing in things of that sort, in the hopes of having, for example, really new basic fundamental understanding of how catalysis works, so that we might then more intelligently design certain types of catalysts?

After all, you know, in modern technology we've made remarkable progress in the lifetimes of all of us here in this room.

It seems to me, one of the things I like to think about is how astounding it is in color photography, which didn't exist when I was a young guy, and now-a-days these people design molecules -- you know, they really design a molecule just like you design a car.

ARE THERE INNOVATIVE RESEARCH OPPORTUNITIES ?

(HIGH RISK / HIGH POTENTIAL PAYOFF)

- o NEW FACILITIES: (E.G., SYNCHROTRON RADIATION, SURFACES) ?
- o FUNDAMENTALS: (E.G., COAL CHEMISTRY) ?
- o APPLIED AREAS: (E.G.)
  - -- MATERIAL: (CORROSION, ERROSION, CRACKING)
  - -- COMBUSTION: (MIXING, MATHEMATICAL MODELING, LASER)
  - -- INSTRUMENTATION: (TRANSDUCERS, ON LINE N.T.D.)

Well, can we come to that stage, perhaps, someday in the design of catalysts?

At the fundamental level, are there real break-throughs that we might expect to have? I believe Dr. Mills mentioned the idea; here is this big coal molecule, and that one can go to it with some sort of scissors and snip it here and there, in a very clever sort of way, which, in principle, takes almost no energy to do, since the bonds are very, very low-energy bonds.

Then you might end up with something where you don't have to add a lot of hydrogen to, and it doesn't take a lot of energy to perform this, and it doesn't jack the entropy way up and then pump the entropy way back down again.

So are there new fundamental approaches to what we might do, for example, with coal?

In applied areas, I've listed materials, combustion and instrumentation, as areas where it's possible that there could be really new breakthroughs that could enable us to improve the cost and environmental effectiveness in a very significant sort of way, not by 15 or 20 percent, but perhaps by factors of two or five or something of that sort.

The next one, please.

(Slide 5)

Here I tried to make a matrix in which I discuss this old hobgloblin that we have of the different kinds of research; basic, applied, and technology development.

IF ERDA NEEDS RESEARCH, WHAT ARE THE PRIORITIES FOR:

CROSS-CUTTING SCIENCE/TECH	INNOVATIVE (HIGH RISK AND LEVERAGE) BASIC	APPLIED	TECHNOLOGICAL DEV	EVOLUTIONARY (LOW RISK & IMPROVEMENT) TECHNOLOGICAL IMPROVEMENT
MATERIALS	SOLID STATE PHYS/CHEM	CORROSION, EROSION, CRACK.	ALLOYS, CERAMICS	COMPONENTS LIFE TESTS
SYNFUELS	COAL CHEM	EARLY H_2 OF COALS	NEW PROCESSES	BETTER PROCESS DESIGN
COMBUSTION	CHEMICAL KINETICS	LASER DIAGNOSTICS	NEW BURNERS	OPTIMIZE FLUIDIZED BEDS
EMISSION CONTROL	COAL SULPHUR NO_x	OXY-DESULPHURI-ZATION	NEW DEVICES	SCRUBBERS
INSTRUMENTATION	NEW TRANSDUCER	IN-SITU	ON-LINE D. N. T.	ON-LINE PROCESS CONTROL
CATALYSIS	SURFACES: SYNC. RAD.	ROLE OF TRACE METALS	NEW CATALYSISTS	OPTIMIZE REJUVENATION
GEOSCIENCES				

Over on the right-hand side I have a column that I call technology improvement, or it could be called engineering. I don't know exactly how to call this. Let's not be too confused by the names, but one has a continuity, in principle, from the most basic and fundamental on the left, towards real useful technologies on the right.

Over here as an ordinate in the vertical direction, I list what we might call crosscutting sciences or technologies. Such things as materials science, and synfuel development, combustion, emission control, instrumentation, et cetera.

One can come up with a list of perhaps 100 such topics, and so this is only an example.

Across this diagram I have tried to write down some of the new things that were discussed at this meeting, and I will not go through it in any detail wtih you; but, for example, in the basic column there, the synchrotron radiation facilities applied to catalysis, is a possible revolutionary new advance.

In the applied column under emission control, the oxide-sulfurization of coals, as was mentioned by Alex Mills, is potentially, to my mind, a revolutionary step ahead.

Over under technology development, under instrumentation, any number of speakers at this meeting talked about nondestructive testing. If one had really good on-line, that is real time, nondestructive testing, so that he knew exactly before a boiler is going to fail or before a high-pressure, high-temperature reactor is going to fail, if you had warning of it, then this might be a very, very important thing in these modern front line technologies.

Now, in the right-hand column, I have tried to put in that same context some technological improvements, and these are things that are going on right now, that ERDA had under way. So this tries to give us within this matrix a picture of the spectrum of our research in these two dimensions.

(Slide 6)

Now, I turn to another of the questions that we're also asking you: Are resources available?

Are there institutions available? Are there people that could carry out these efforts? Could they carry them out now, and can they carry them out in the future?

And what is the balance that ERDA should seek in the utilization, for example, of the energy research centers, the national labs, the universities, and industry?

This topic of balance amongst these different groups, of their various strengths and weaknesses, comes up time after time in nearly all of the talks that we've had.

Other places where ERDA must seek balance in and, in fact, is required by the federal statutes, if you will, that created this and its predecessor agencies, is that we're supposed to be concerned with the time span of your work and seek a balance there. Do we have

ARE RESOURCES AVAILABLE ?

- o NOW ?
  - -- ERC's / NATIONAL LABS / UNIVERSITIES / INDUSTRY ?
  - -- HOW TO BALANCE IN: TIMESPAN, GOALS, SCOPE, BUDGETS, SCIENCE & TECHNOLOGY TRANSFER

- o FOR THE FUTURE ?
  - -- WHAT SHOULD BE BALANCE ?
  - -- WHAT SHOULD BE ERDA's ROLE IN MANPOWER TRAINING ?
  - -- IF BALANCE CHANGES, HOW TO DISTRIBUTE ACROSS RESOURCES ?

a proper balance between our near-term goals, our crash goals that Congress is beating on our heads daily about?

Do we have that balanced with our more mid-term and long-term goals?

And do we have this balanced in terms, for example, of the scope of our program from basic to applied technology and development demonstration?

These sorts of balances: Do we have those available to us right now, within our resources?

And, for the future, one can ask those same questions, and additional ones, for example: What should be ERDA's role in manpower education and training? You heard a couple of university speakers address that problem. And this, it seems to me, is a very important thing that ERDA has to consider.

As Kobayashi mentioned, all the major high-technology agencies of the Federal Government more or less simultaneously dropped their support for graduate-student education and training in science and engineering in American universities; that is, the NDEA, the NSF fellowships, the AEC traineeships, and the NASA fellowships; all more or less simultaneously terminated. This created a very great step function in the abilities of the universities to educate and train future manpower. And does ERDA have a role in that? Should it accept some sort of responsibility for education in the same way that earlier high-technology departments of the government have accepted that role?

Next slide, please.

(Slide 7)

Here I talk about budgets. All through this meeting you've heard and seen a lot of budgets of various kinds, but this is the budget, as I see it, that is the present budget, 1977 agencywide, that is concerned with fossil-energy research.

The first entry there, Fossil Energy Division, about $20.4 million. You'll notice that is less than other numbers that you've seen, but this corresponds to the fact that in Dr. Kropschot and my judgment, part of the Fossil Energy Division research budget is in fact engineering for currently building pilot plants and demonstration plants, and that this is a realistic view of the research component.

The number 8.4 is our view of the Conservation Division's contribution to fossil energy research, and the two lower numbers for the Division of Physical Research, 5.6 and 5.8, are similar numbers for those two that you heard about in lectures this morning.

This totals, then, about $40 million -- for this current year.

Now, each of the speakers, as you'll recall, gave us at the end of their talk a set of research opportunities for the future -- the research speakers. And we have looked at those numbers and have

WHAT SHOULD ERDA's FOSSIL ENERGY RESEARCH BUDGETS BE?

($M / YEAR)

o 1977		o FUTURE (?)
FOSSIL ENERGY	20.4	50
CONSERVATION	8.4	40
DIVISION OF PHYSICAL RESEARCH :		
CHEMICAL SCIENCES	5.8	13
MATERIALS	8.4	20
	$40.2M	$123M

- o IS THE PRESENT FOSSIL ENERGY RESEARCH BUDGET OKAY ?
- o WHAT SHOULD THE ERDA FOSSIL ENERGY RESEARCH BUDGET BE ? WHY ? WHAT ARE THE PRIORITIES ?

tried to extrapolate on the basis of taking ratios to comparable sort of research budgets. We've come up with the numbers over on the right. For example, Mills's program would grow from $20 million to $50 million, the conservation efforts would grow from 8 to 40 -- that's a very large jump -- approximate doubling in chemical sciences, and in material sciences about 2-1/2 times, totaling about $120 million.

Now, those are just our estimates, but they give you a feeling, within the context of the whole agency having just over $3 billion in the energy areas. The present budget corresponds to about 0.1 percent and the envisioned budgets would correspond, then, to an overall amount of about 1/3 percent in fossil energy research.

(Slide 8)

So now the next slide, then, shows you the questions that we asked you, about -- crosscutting technologies. We have talked a lot about crosscutting technologies, and how we have a basic dichotomy. The basic dichotomy is that we need to have a focus to carry out, for example, a materials research program or combustion program that is agencywide, within ERDA. We need that.

And, yet, if we do that centralization we face the fact that we may lose the technology and science transfer from such a program to the other particular programs that need the results. So we don't have a simple solution. I think everybody that runs such

HOW SHOULD ERDA MANAGE CROSS-CUTTING TECHNOLOGIES ?

- o BASIC PROBLEM: FACED BY ALL HIGH-TECHNOLOGY ORGANIZATIONS: MATRIX MANAGEMENT.
  - -- NEED FOR FOCUS ;
    - - LEADER (S),
    - - BUDGETS.
  - -- AGENCY-WIDE PROGRAMS PRECLUDE:
    - - FALLING THROUGH CRACKS:
    - - USELESS DUPLICATION.
- o DICOTOMY
  - -- NEED FOR FOCUS
  - -- NEED TO TRANSFER SCIENCE / TECHNOLOGY.

programs has to face this dichotomy, and if you have brilliant advice for us, we'd like to have it.

(Slide 9)

So here, then, are the seven questions that we're asking you. You each have those attached to a piece of paper that's called "Purposes and Responses," and these are the questions for those of you that stay this afternoon. We want you to please give us your advice.

That's the end of my speech. Let me now thank all of the speakers that presented, I think, very interesting and informative material to all of us here at this meeting. I know that many of you, in fact most of you, went beyond the call of duty to prepare this material, and I want to thank each of you in the audience for attending. We appreciate it very much, and we look forward to your counsel in the future.

Thank you.

The meeting is adjourned.

(Applause)

DR. KROPSCHOT: Are there any questions for Dr. Phillips before we adjourn here.

MS. FOX: I have a comment I'd like to make.

On the first questions that you have up there, I think perhaps it's not appropriate to ask whether or not these technologies are environmentally acceptable. I think a more reasonable question

RESPONSES REQUESTED

- o ARE PRESENT ENERGY TECHNOLOGIES COST AND ENVIRONMENTALLY EFFECTIVE?
- o DOES ERDA HAVE RESEARCH NEEDS/OPPORTUNITIES?
- o DOES ERDA HAVE RESOURCES NOW/IN FUTURE?
- o ARE THE NATION'S NEEDS PROVIDED FOR IN:
  - GROWTH OF BASIC KNOWLEDGE
  - MANPOWER TRAINING
  - MANAGEMENT OF PROGRAMS ?
- o IS THERE A SPECIAL ERDA ROLE IN FOSTERING CROSS-CUTTING TECHNOLOGIES? HOW SHOULD IT BE MANAGED?
- o IS THE QUANTITY OF ERDA'S FOSSIL ENERGY RESEARCH BALANCED FOR:
  - BUDGETS
  - SCOPE: (BASIC/APPLIED/TECHNOLOGICAL DEVELOPMENT/DEMONSTRATION PLANTS)
  - TIME TERM: (NEAR/MID/FAR)
  - GOAL: (EVOLUTIONARY/REVOLUTIONARY)
  - SCIENCE/TECHNOLOGY TRANSFER
  - RESOURCE: (INDUSTRY, UNIVERSITY, NATIONAL LABS/ERC's)
- o IS ERDA's QUALITY OF RESEARCH ADEQUATE TO ITS MISSION ?

would be whether or not the environmental problems can be solved with existing technology in a cost-effective manner.

I don't see why environmental problems are singled out any differently than, say, problems in materials research areas. I think the questions that we should be asking is whether or not they can be solved, and how can they be solved in a cost-effective manner. And then the environmental issue becomes, as we all know it is anyway, nothing more than the question of cost-effectiveness. It's not fair to ask whether or not they are environmentally acceptable.

DR. PHILLIPS: You're saying that the environmental problem is just another beautiful example of a crosscutting technology, and I certainly agree.

MS. FOX: Right.

DR. KROPSCHOT: We would like to have Dr. Haas introduce his staff. That, then, could be the focal point for our feedback sessions before we adjourn, and perhaps, Greg, maybe the thing to do is to let the groups meet together just for a short period of time or what time they want to, and set their own schedules, and Dr. Phillips and I will be available to the groups. We will, as Gerry mentioned, have our co-chairmen, and then Phillips and I will be available as resources.

DR. HAAS: Thank you, Dick. We have divided those who indicated an interest in participating in the groups up into four groups, with chairmen. We have two suites, and we will hold two of the groups up there and two of the groups down here. Unfortunately, we could not get any more suits than that for today.

The first group will meet up in Room 1030 with myself. The second group will meet in Room 1032 with Dr. Jim Ling. Jim, do you want to stand up?

The third group and the fourth group will meet down in here, at opposite ends of the room. We will have the chairs rearranged during the noon break, with a table, and chairs placed around them. One group will be under Roy Peterson. Do you want to stand up, Roy? And the other group under Chuck Bliss. You may want to get together at this point in time, in order to have a preliminary get-together, and then probably break for lunch, since it's a quarter of 12, and then return possibly to spend about two hours in these smaller groups, giving us the feedback that we would like to have to incorporate into a summary document, which we will produce within the next month.

So, the most important aspect of this meeting from our standpoint is the next two to three hours, really, to get your feedback and your responses.

One other point I would like to make. We recognize that this is a very short notice in which to give possibly detailed thought to some of these issues. Therefore, I would like to encourage you, after you leave, if you have further thoughts on these subjects, to please put them in writing and mail them in to us. Any written statements that we obtain will be included in the proceedings of this meeting, and we would very much like to have your comments in writing, possibly after you have had more time to think about this and to go back and even discuss it with your colleagues at your various institutions and organizations. So I would encourage you to please write us any thoughts that you have.

Thank you.

(Whereupon, at 11:45 a.m., the meeting was adjourned).

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