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.

DISCLAIMER

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.

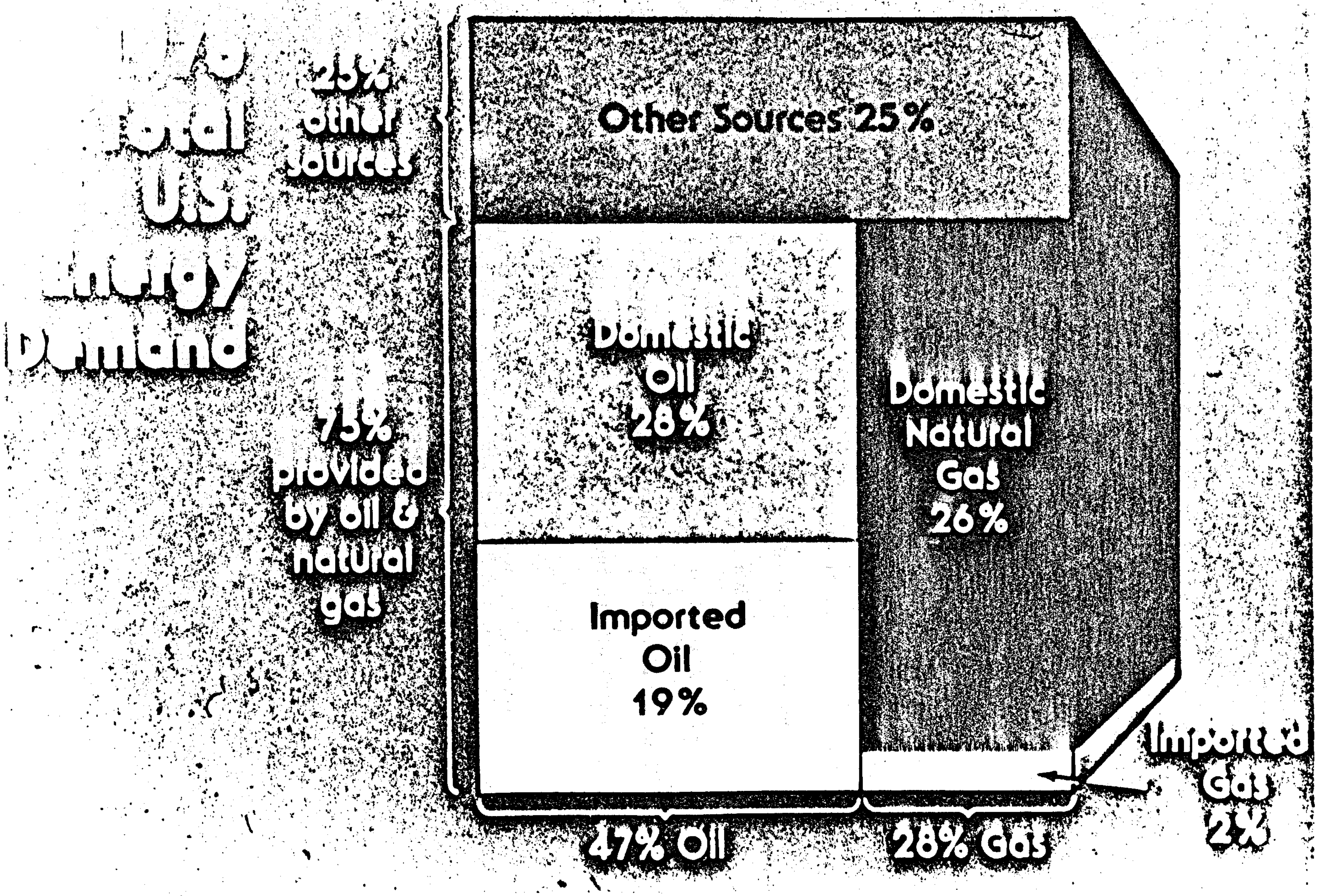
I might say that a more detailed discussion of the kind of topics I will be covering and related topics will be included in the ERDA Annual Plan, which is due to come out in about two weeks and will be available from the Technical Information Service in Oak Ridge at that time.

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.

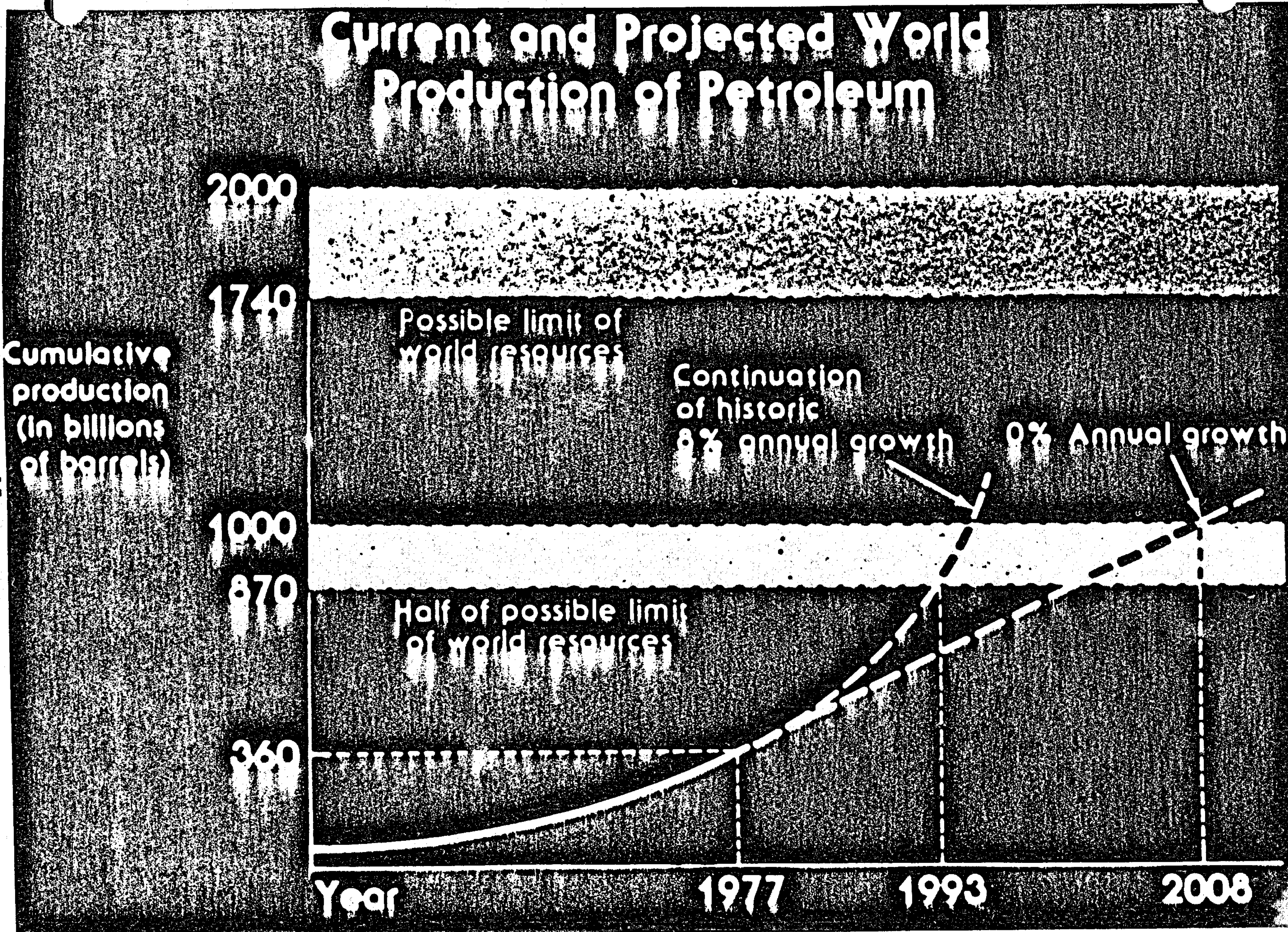
The next slide, please.

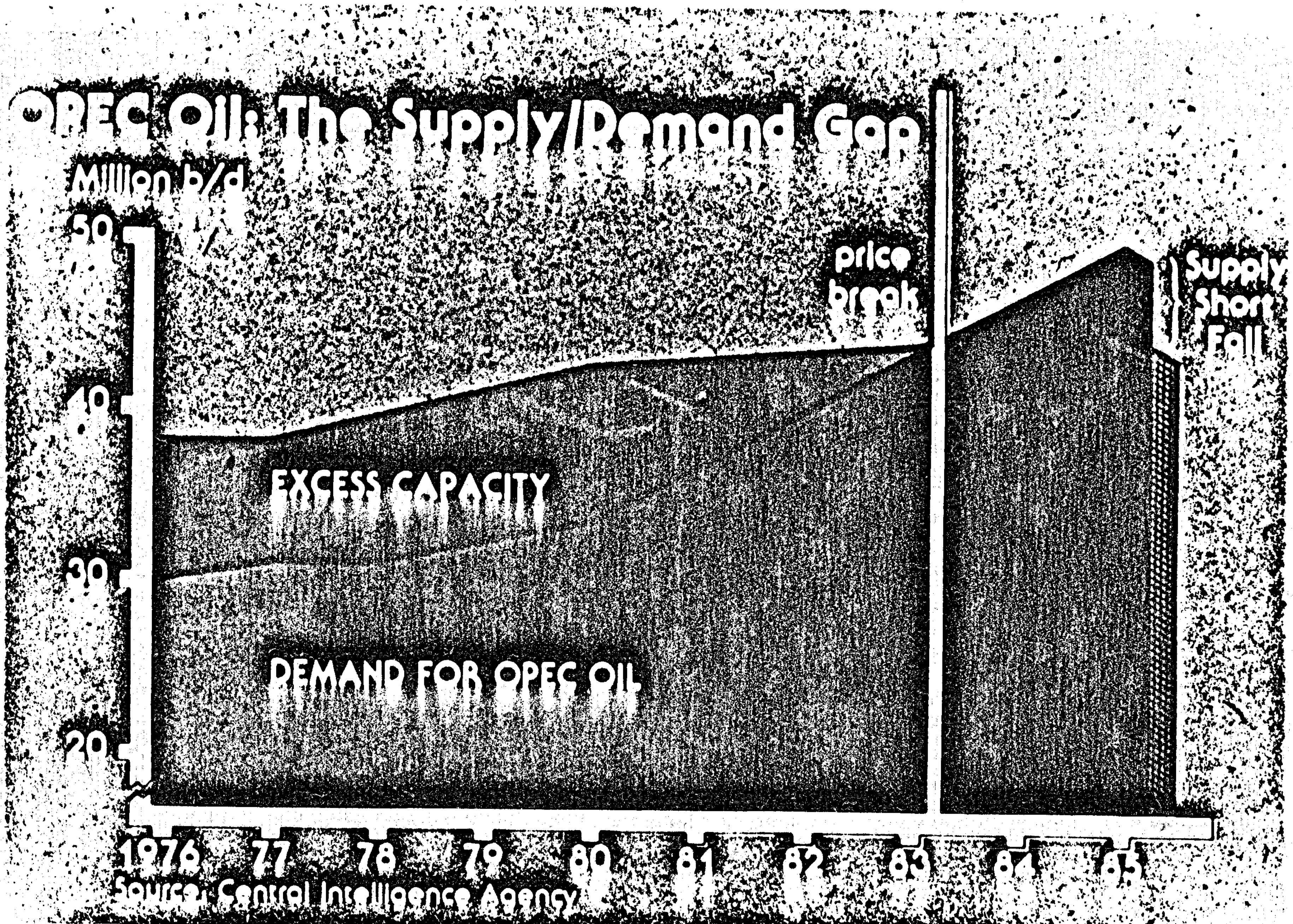
(Slide 3)

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.

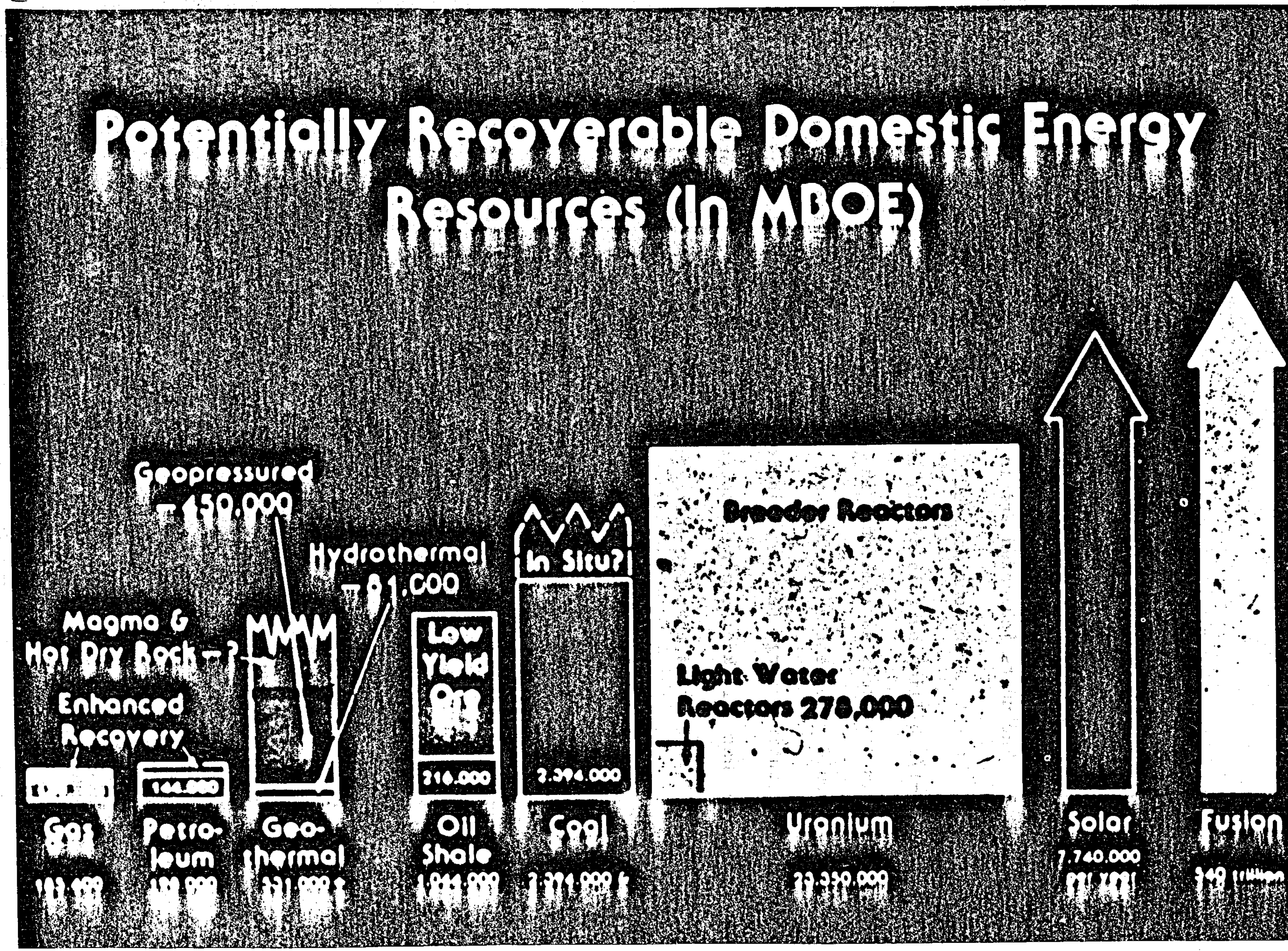
Could I have the next slide.

(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
~ 150,000
Hydrothermal
~ 81,000
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
Petro-
leum
Geo-
thermal
Oil
Shale
1,944,000
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.

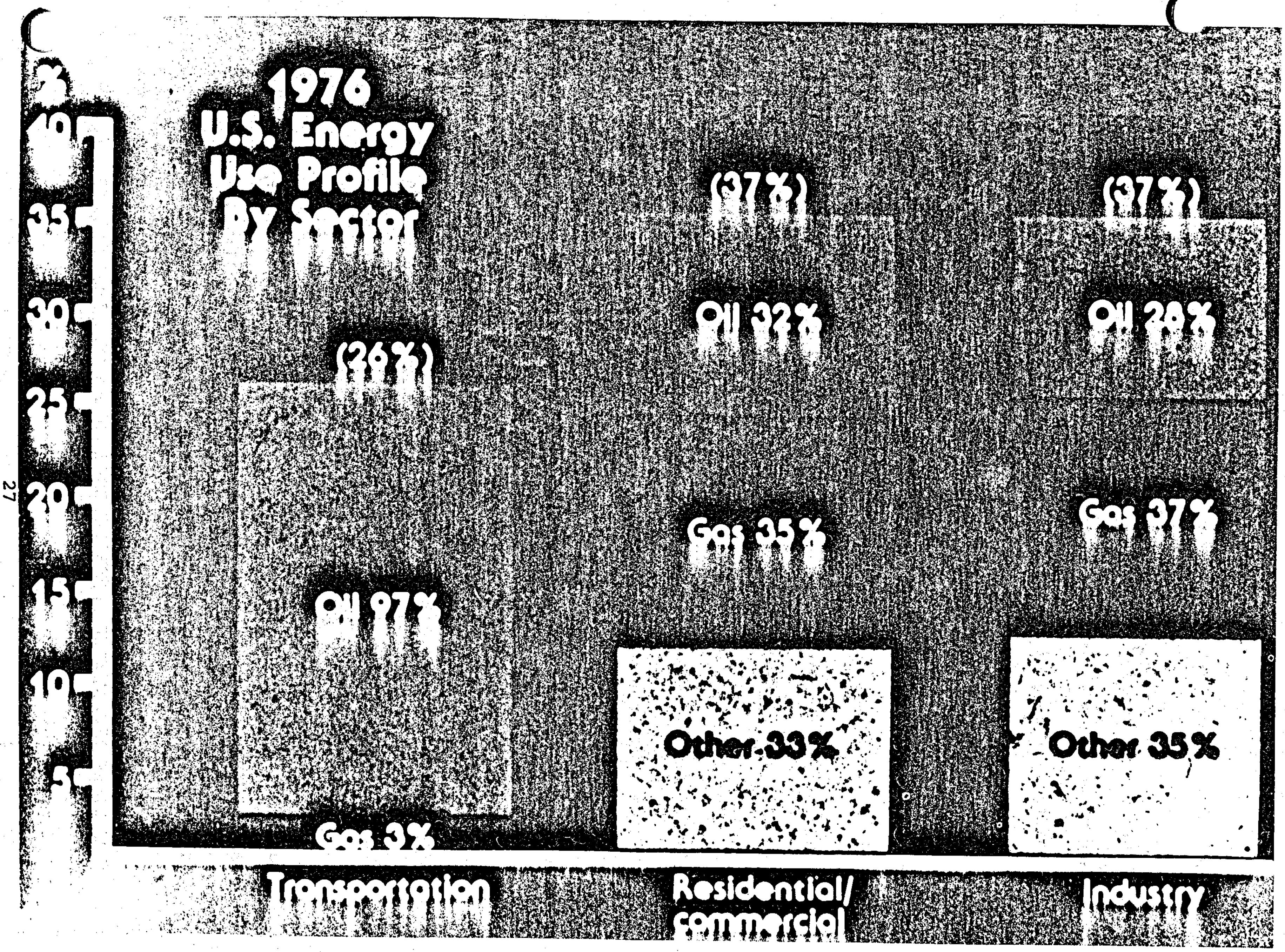
May I have the next slide, please.

(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.

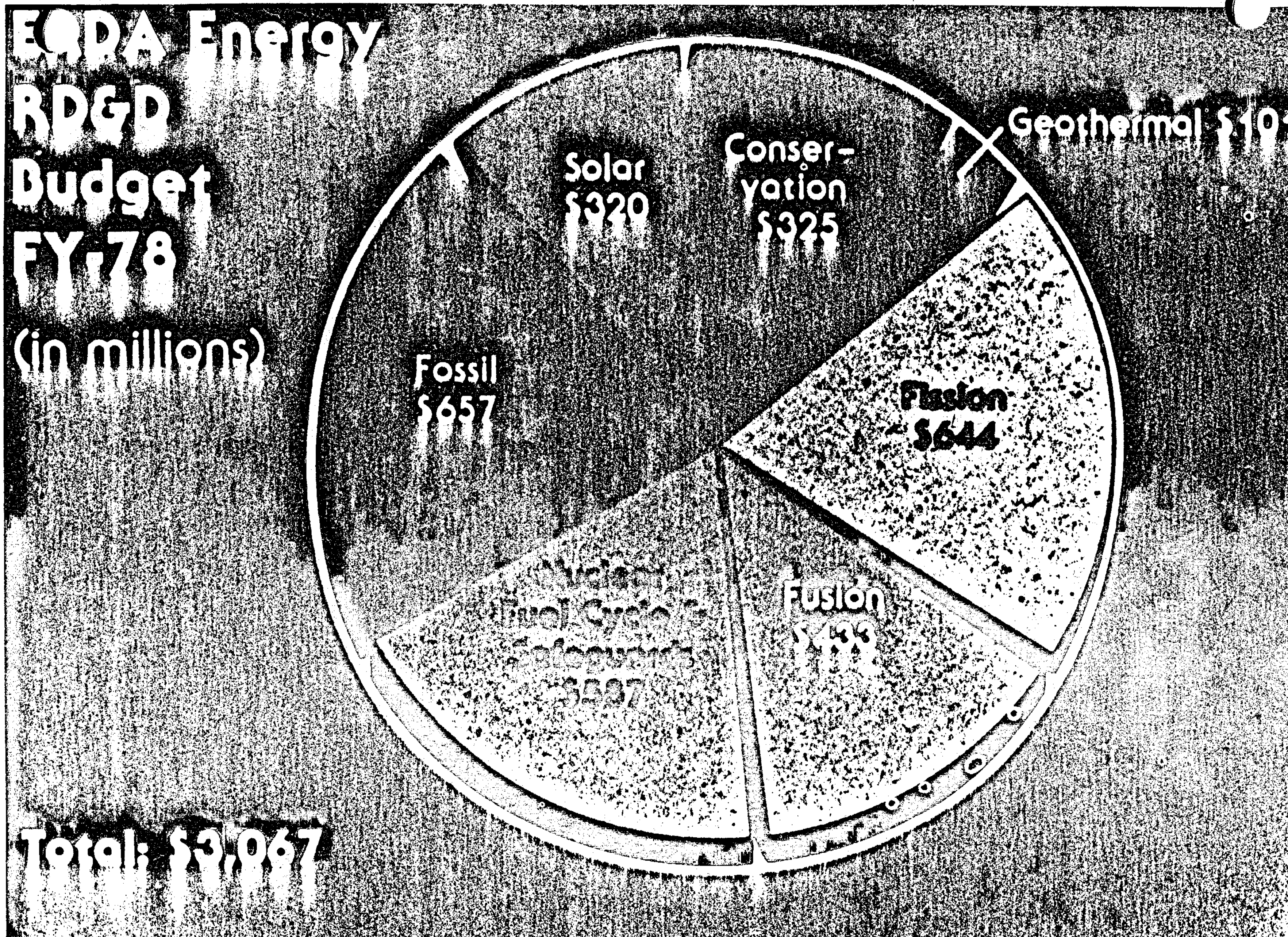
Finally, there are changes in industrial process, especially for those processes used by the most energy-intensive industries. ERDA, again, has programs in all of these areas in cooperation with industry.

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
$433
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)

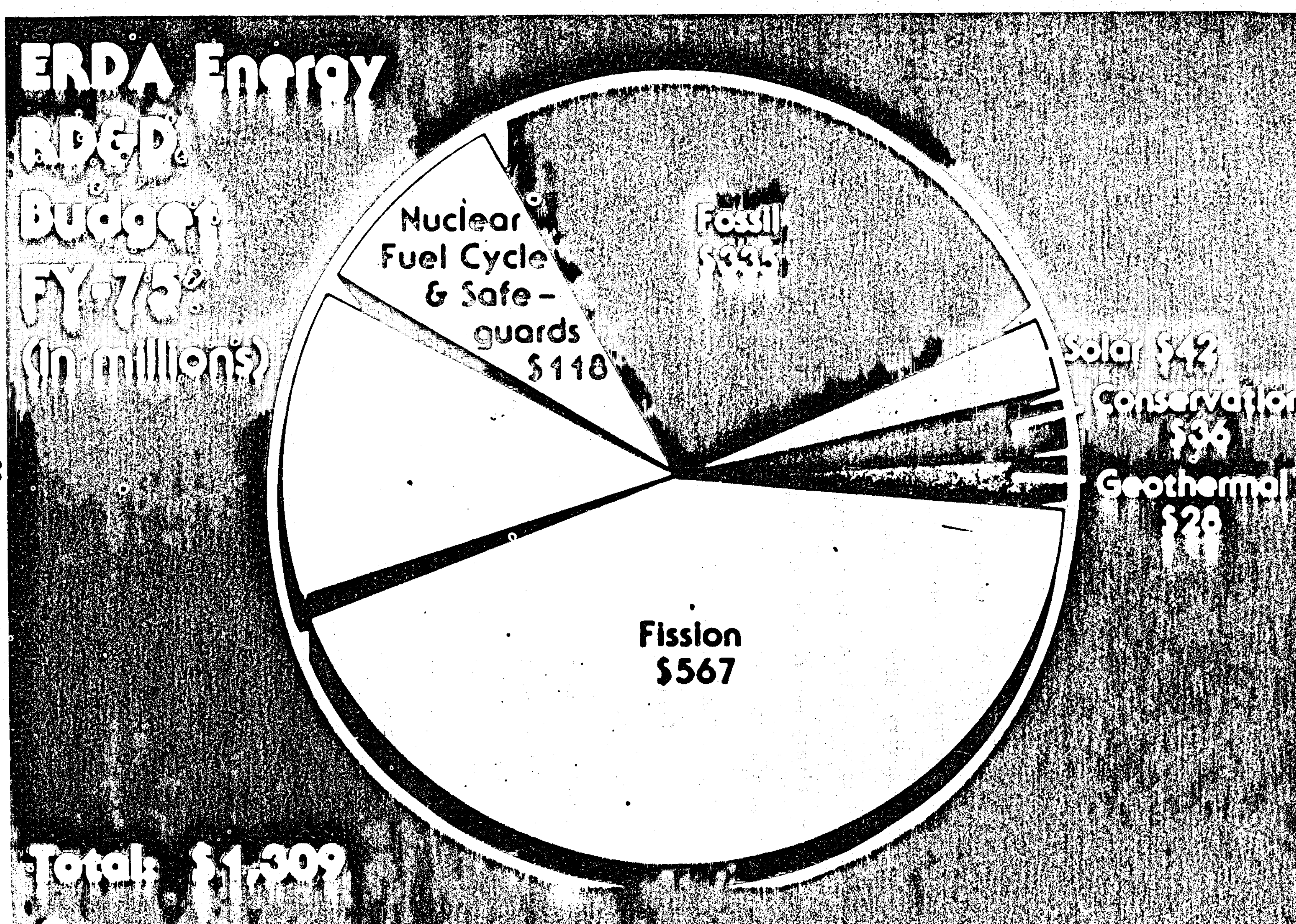
This gives you some feeling for the kind of growth that has happened in the various areas. It gives a feeling for where priorities have been, at least as far as incremental growth is concerned.

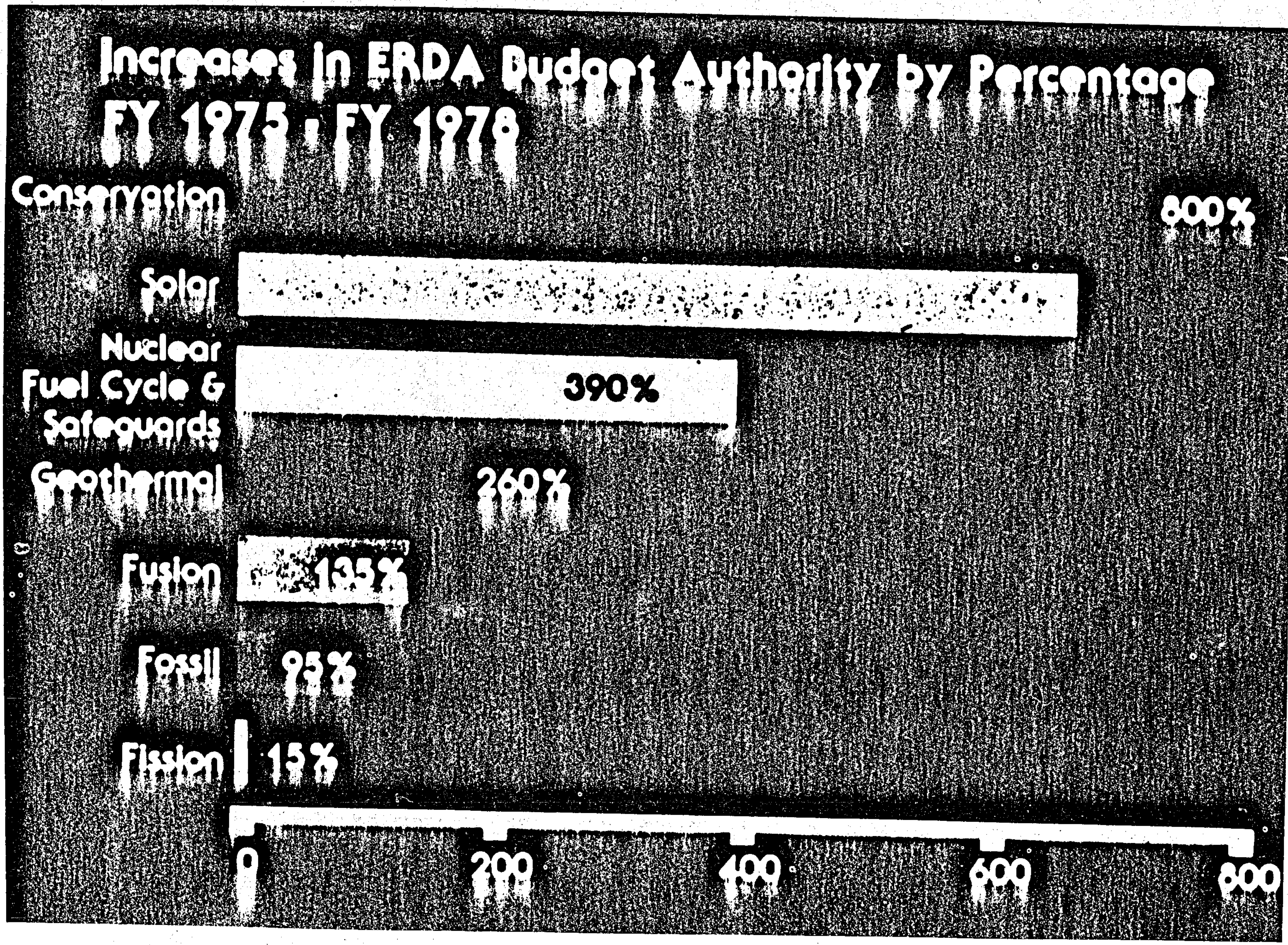
The conservation area has grown some 800 percent, consistent with the fact that it was just getting off the ground when ERDA was formed. It can have a very significant near-term impact, and it is usually cheaper to save a barrel of oil than to produce one.

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

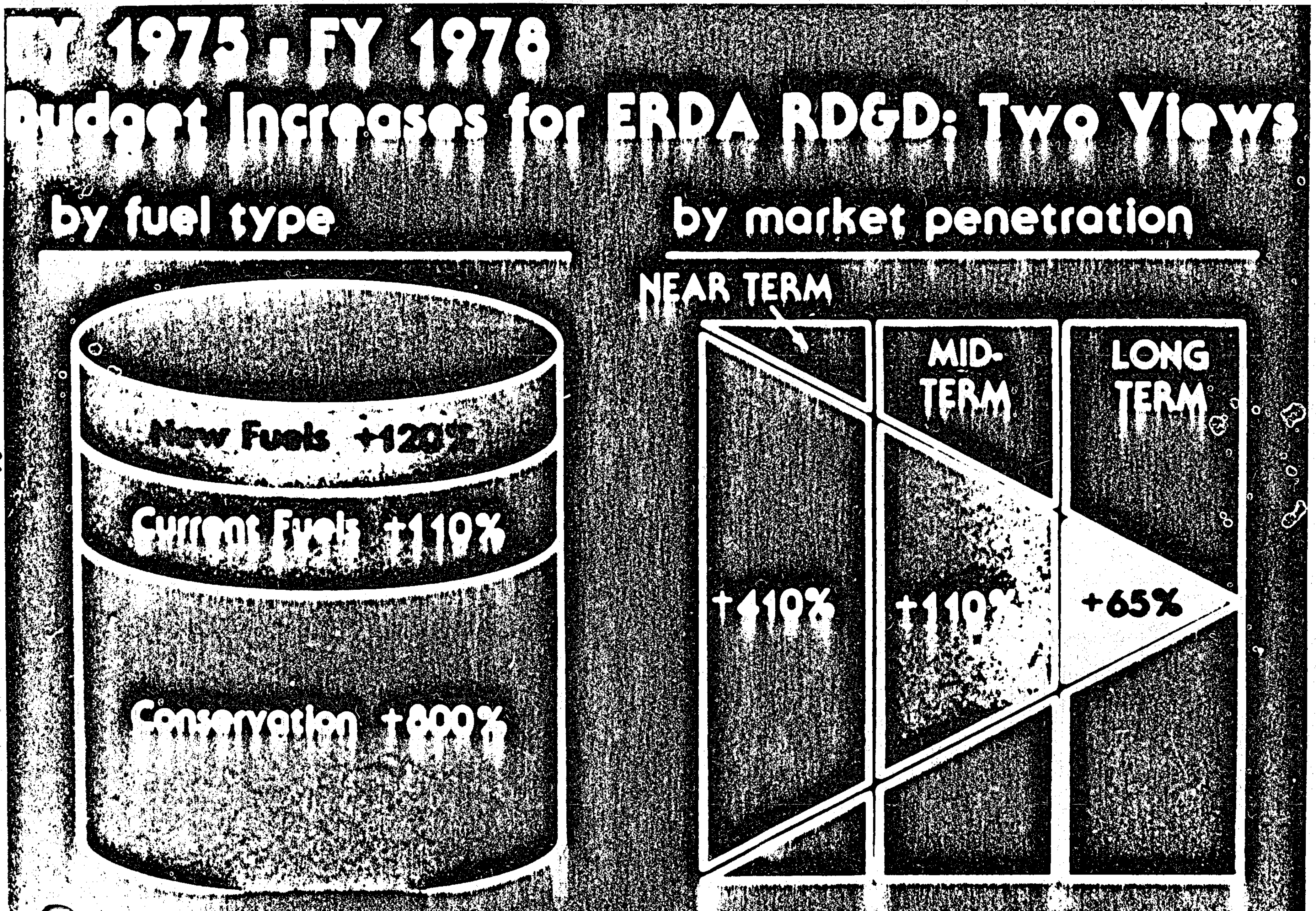
May I have the next one, please.

(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
New Fuels +120%
Current Fuels +110%
Conservation +800%
by market penetration
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

77-3387M 4/8

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?

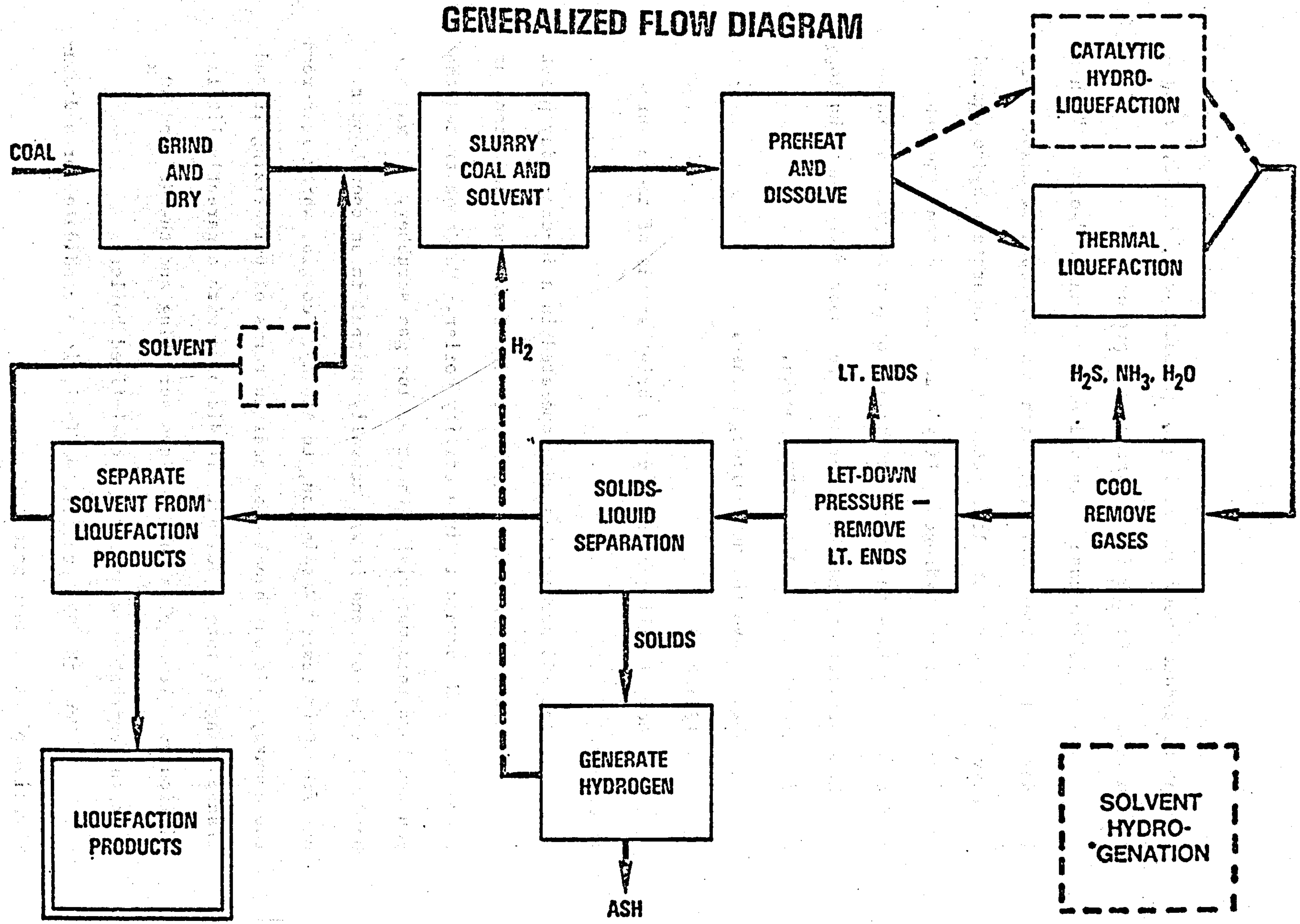
VOICE: No, sir, I don't believe so.

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



77-3387M 8/8

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

77-3387M 2/8

(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

77-3387M 1/8

Now, I have shown a typical flow sheet--

(Slide 6)

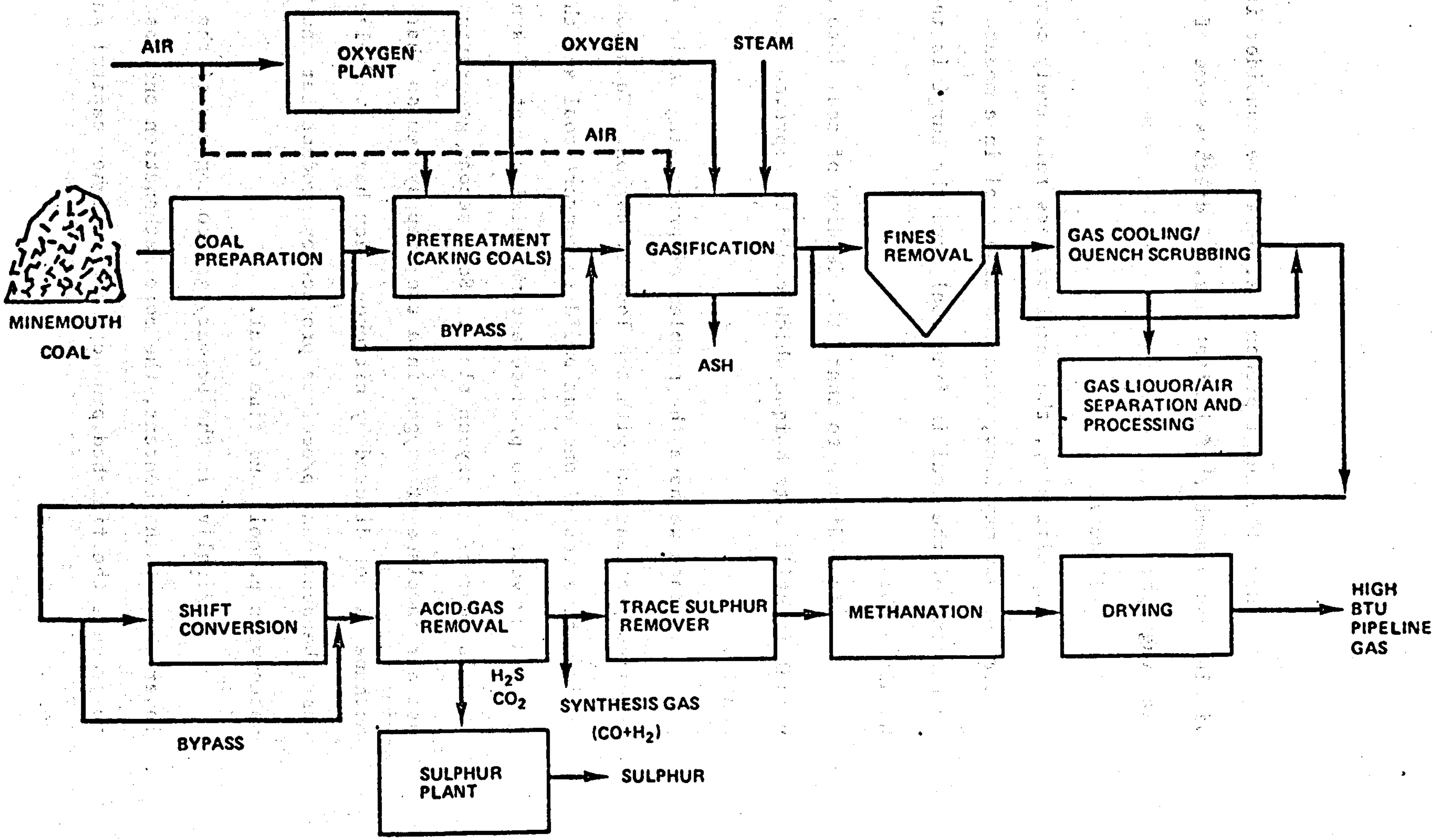
-- for a first-generation or second-generation coal gasification process.

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

77-3387M 3/8

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)

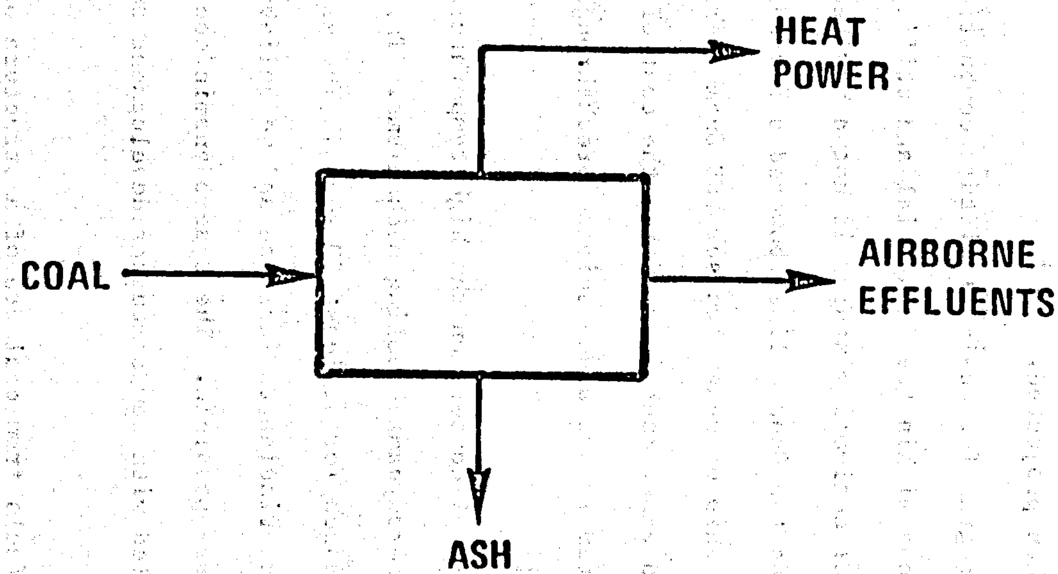
Here is a rough sketch that depicts utilization of coal in an energy conversion process for production of clean and economical heat or power. We have coal to be used as a resource. We are concerned with utilization of heat and power and the minimization of airborne effluents while making the ash and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

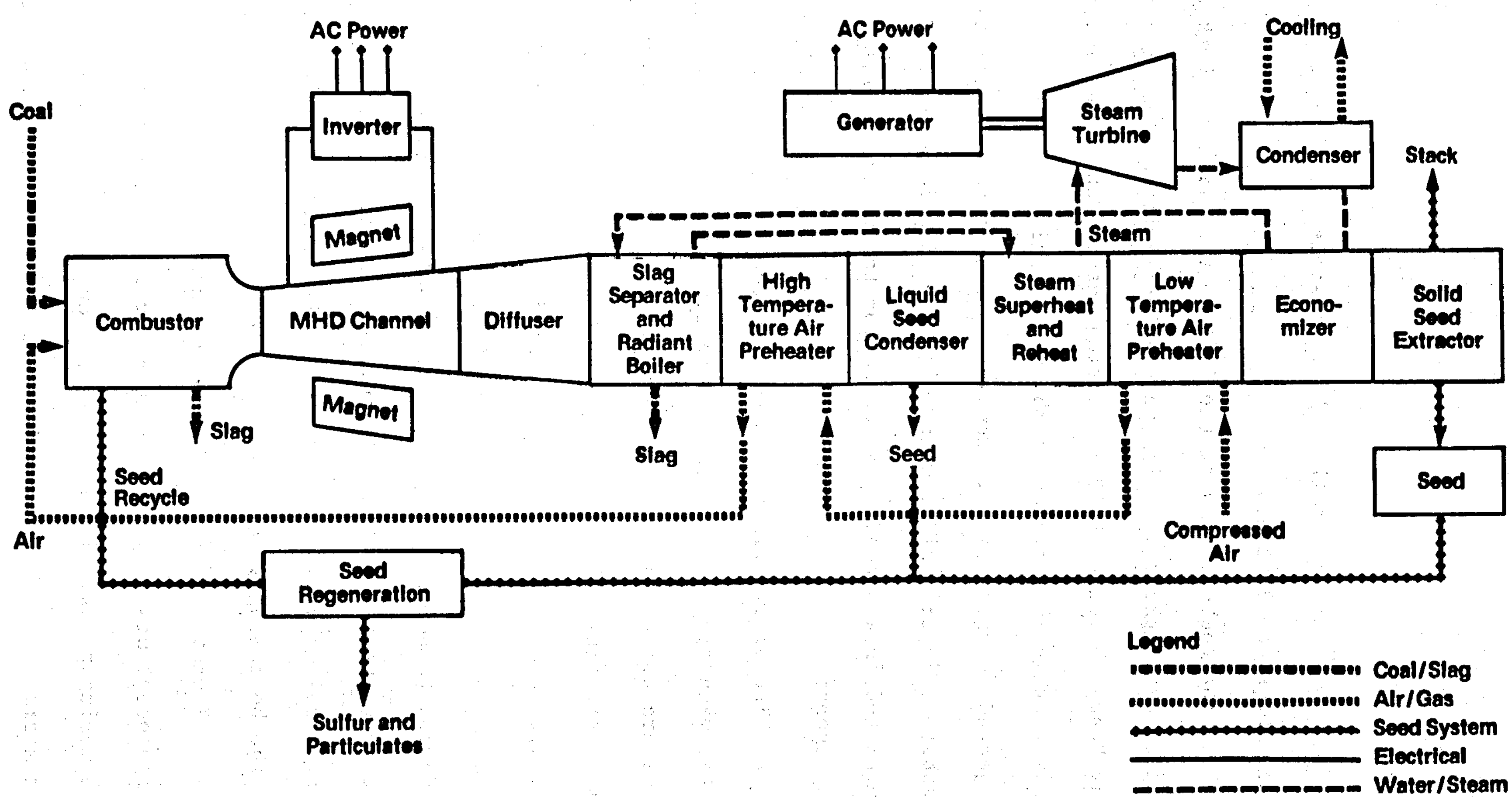
The next figure (Fig. 2) represents a schematic of a typical MHD-steam system.

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

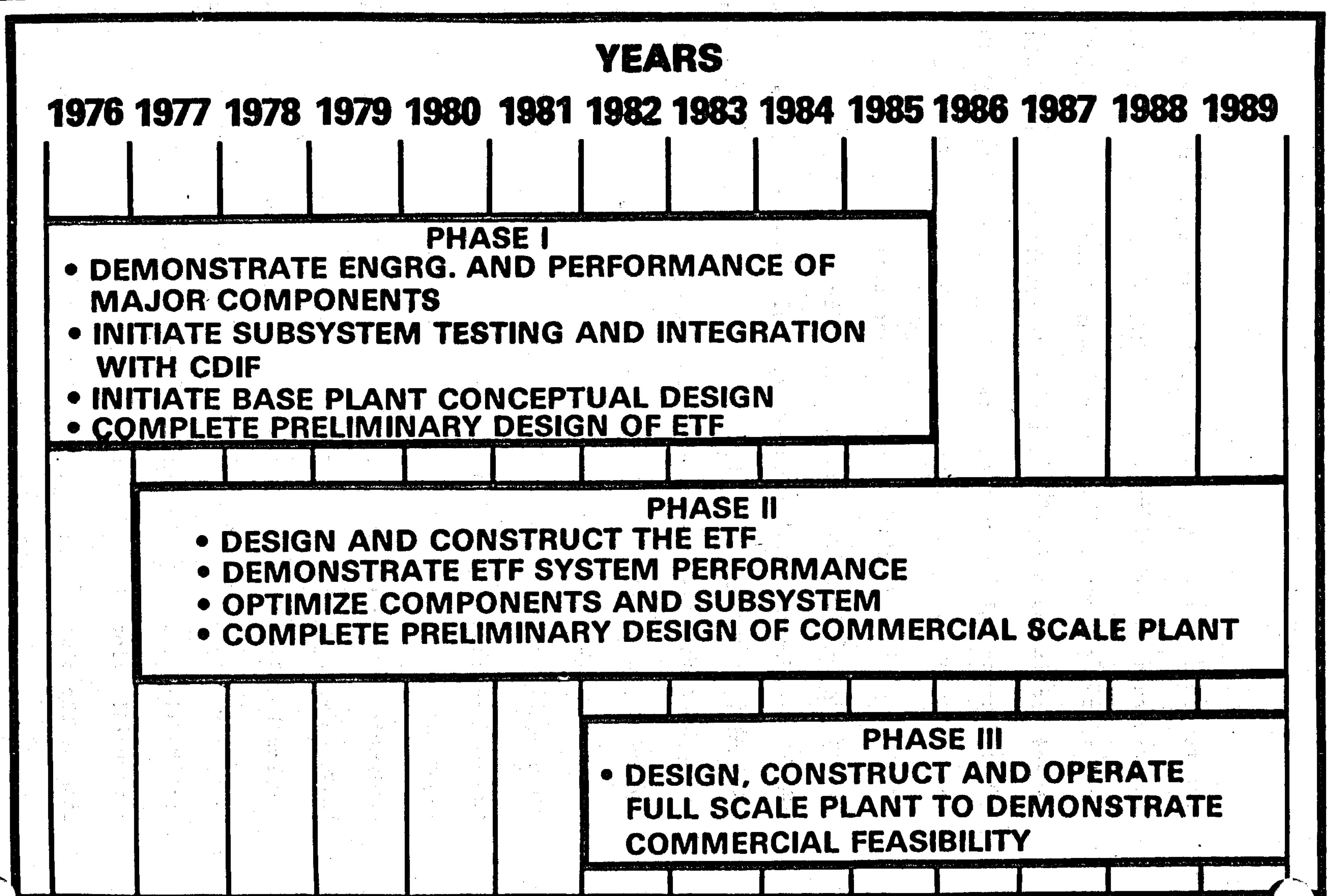
MHD Schematic — Coal-Fired/Directly-Fired Air Preheater



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,

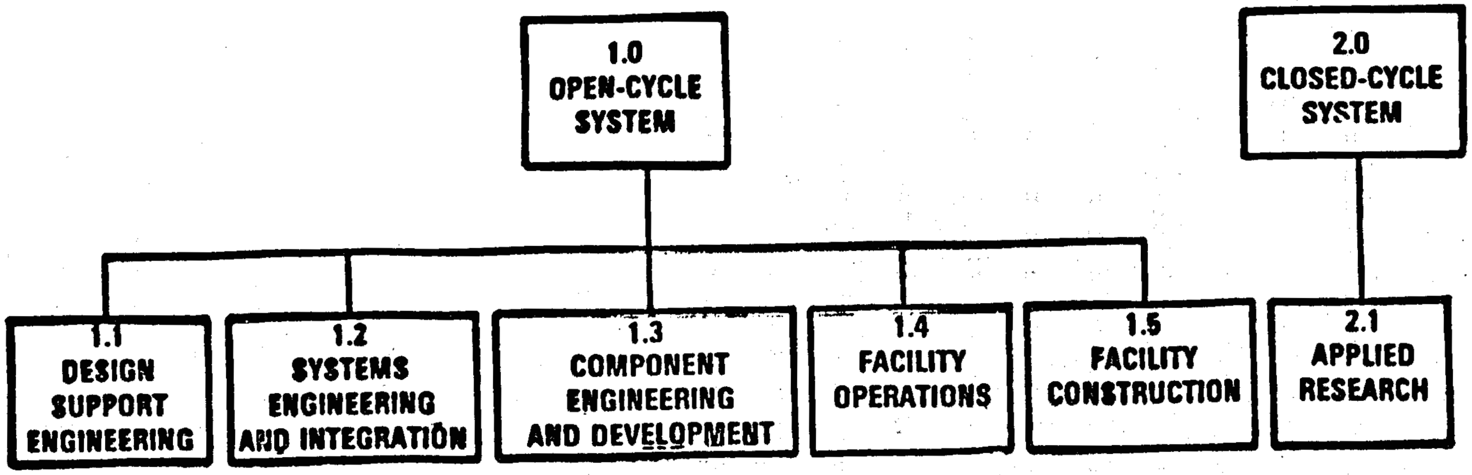

1.0 OPEN-CYCLE SYSTEM
2.0 CLOSED-CYCLE SYSTEM
1.1 DESIGN SUPPORT ENGINEERING
1.2 SYSTEMS ENGINEERING AND INTEGRATION
1.3 COMPONENT ENGINEERING AND DEVELOPMENT
1.4 FACILITY OPERATIONS
1.5 FACILITY CONSTRUCTION
2.1 APPLIED RESEARCH

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

(1) COMPONENT DEVELOPMENT AND INTEGRATION FACILITY – DEMONSTRATE ENGINEERING FEASIBILITY (50MW_t)
(2) ENGINEERING TEST FACILITY – DEMONSTRATE COMMERCIAL FEASIBILITY (≈ 250 MW_t)
(3) COMMERCIAL DEMONSTRATION PLANT – DEMONSTRATE COMMERCIAL OPERATIONS (∧ 1000 MW_t)

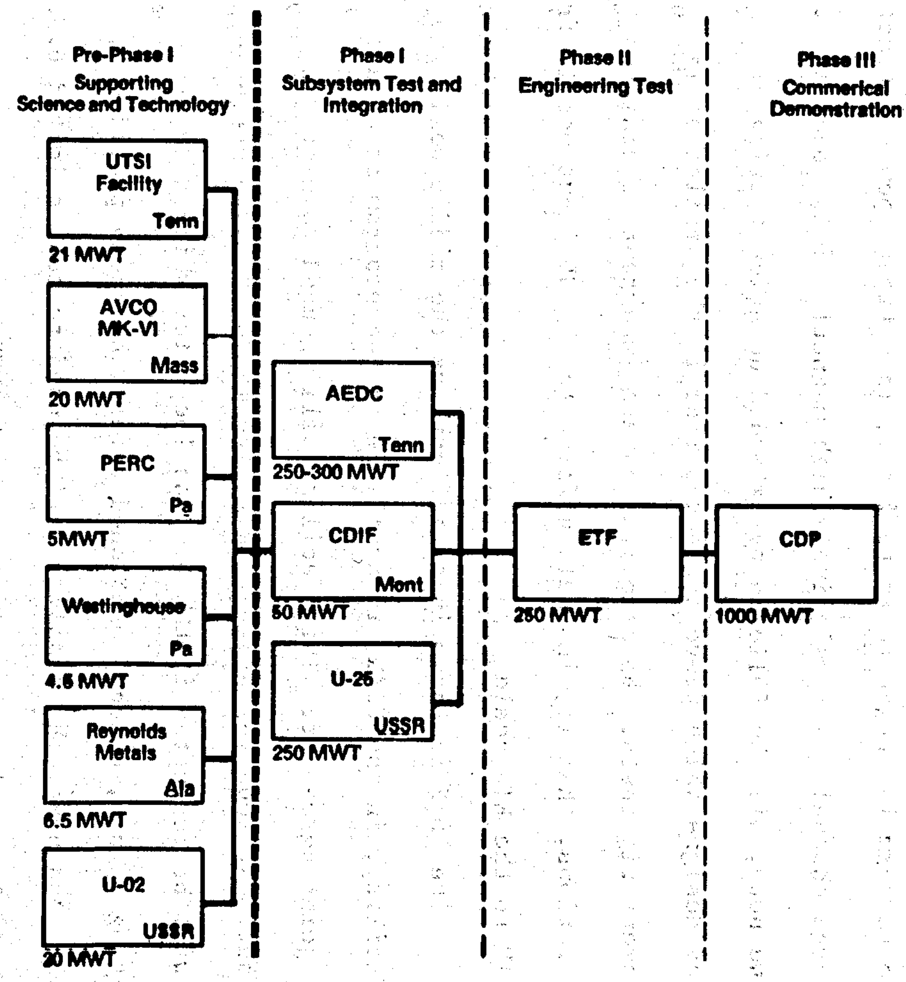
evaluating electrode and insulator materials under simulated channel design conditions, and so forth.

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

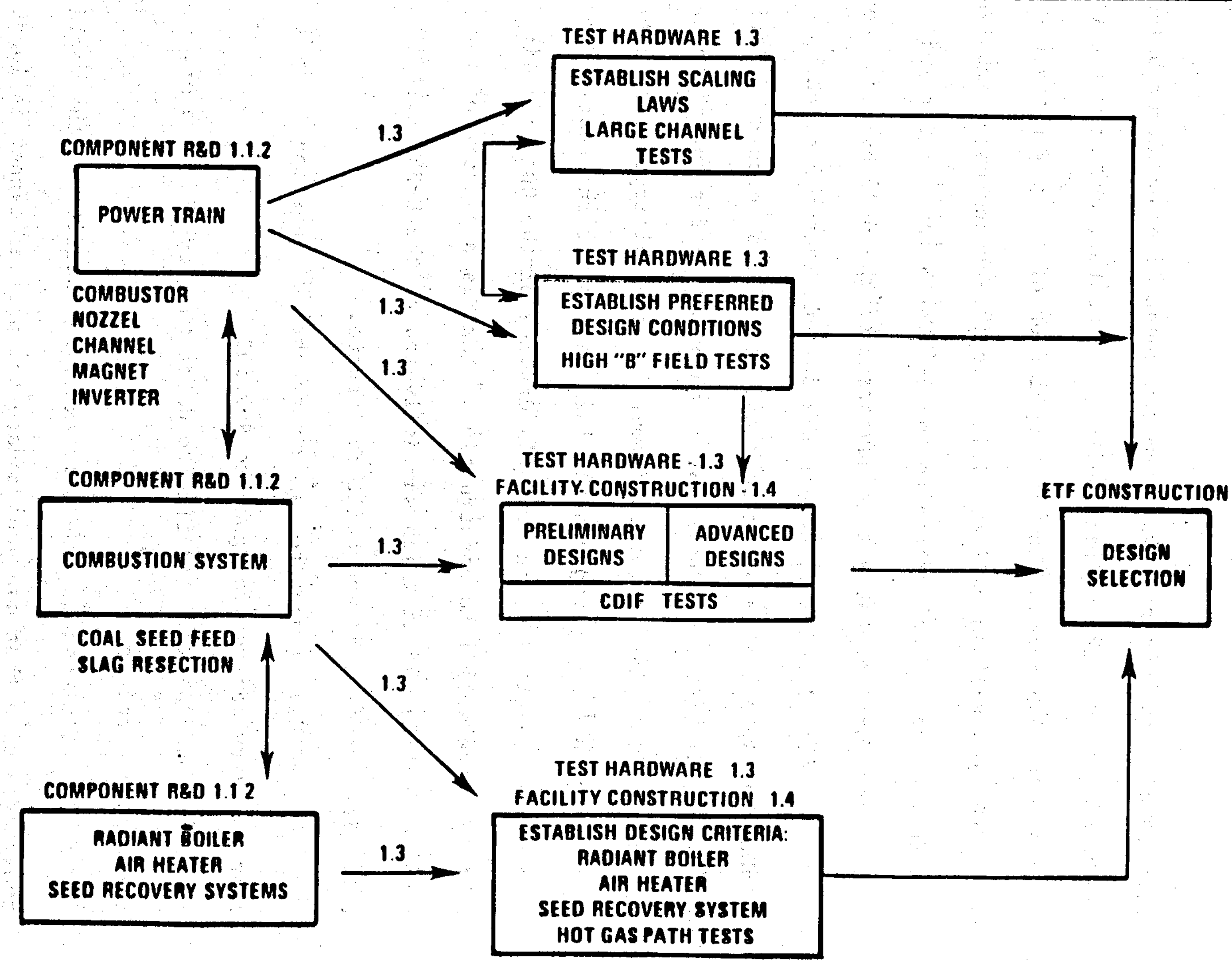


at a larger scale and under more stringent engineering conditions. The first box here is the Arnold Engineering and Development Center in Tallahoma, Tennessee. They have a 250MWt facility in which we plan to perform important tests to first, investigate power extraction in a large channel under relatively 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.

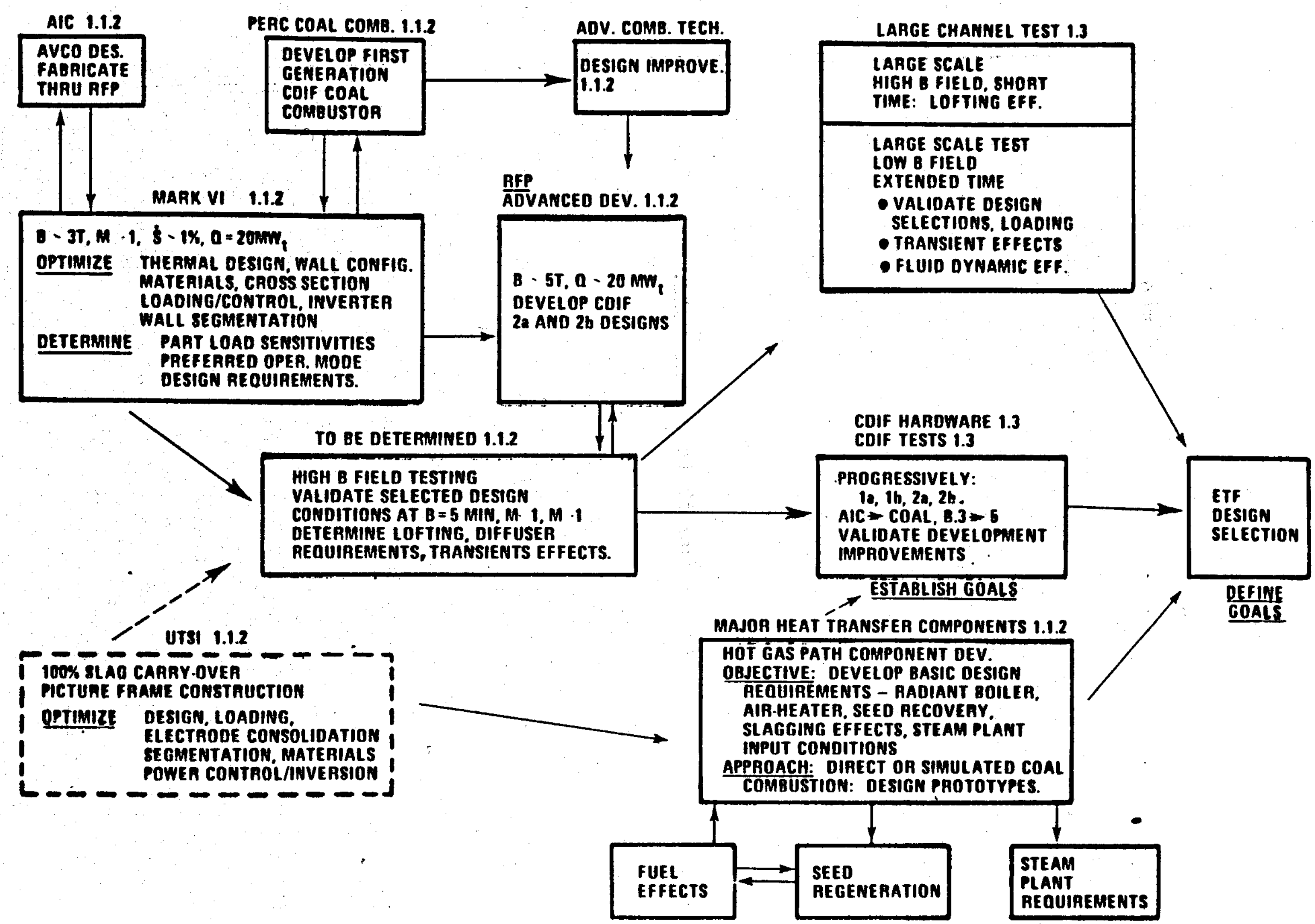
This, I believe, covers the salient features of our program. As you see, we are attempting to keep our efforts focused on a firm objective, namely, development of a sound design for the ETF combined MHD-steam pilot plant to prove commercial feasibility. The next slide (Fig. 8) simply repeats the last 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)

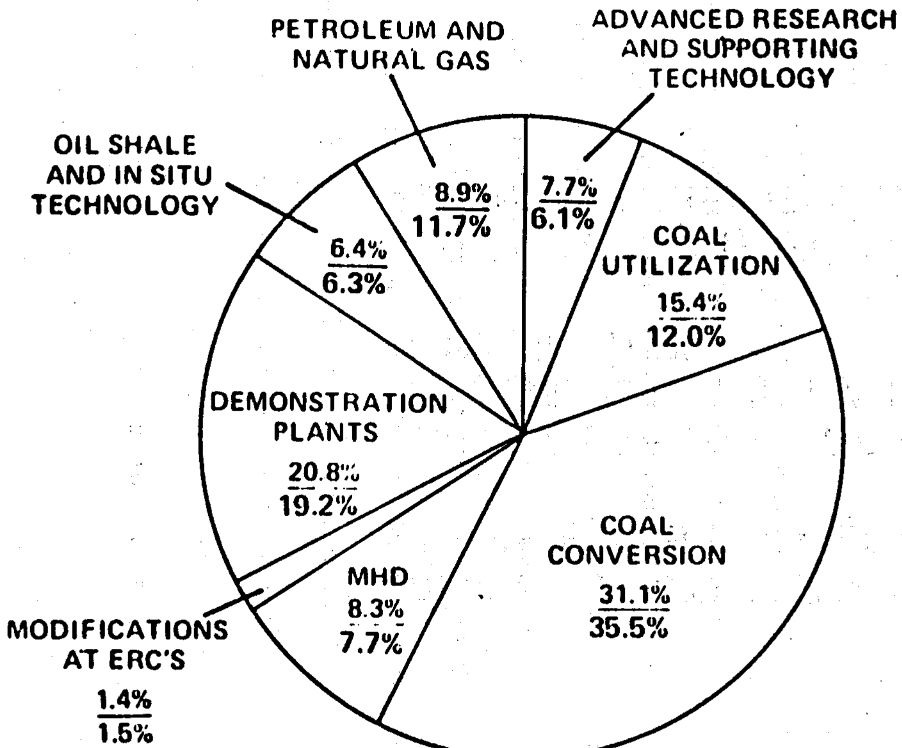
The next slide deals with the distribution of funds. And you see under "Advanced Research and Supporting Technology," in 1977 some 7.7 percent and 6.1 percent in the '78 budget. The Division of Materials and Exploratory Research is a major part of that, but not all. There is a planning function within 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:

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

(Slide 4)

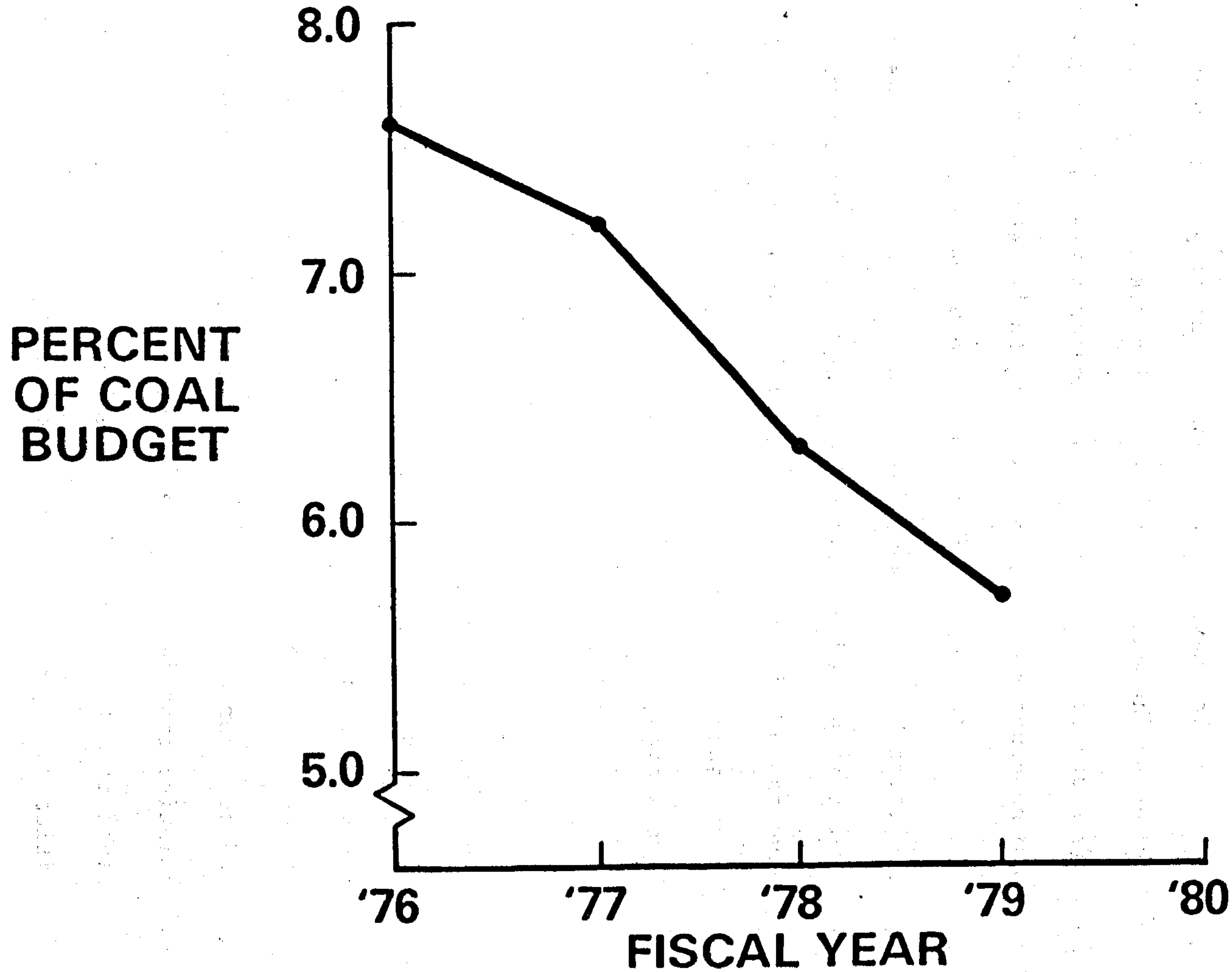
The next vugraph--and I want to go over some of these to get to the end few, which I think are more significant--related to the share of funds for this particular division in percentage, and I'm no doubt somewhat self-serving to illustrate it this way.

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.

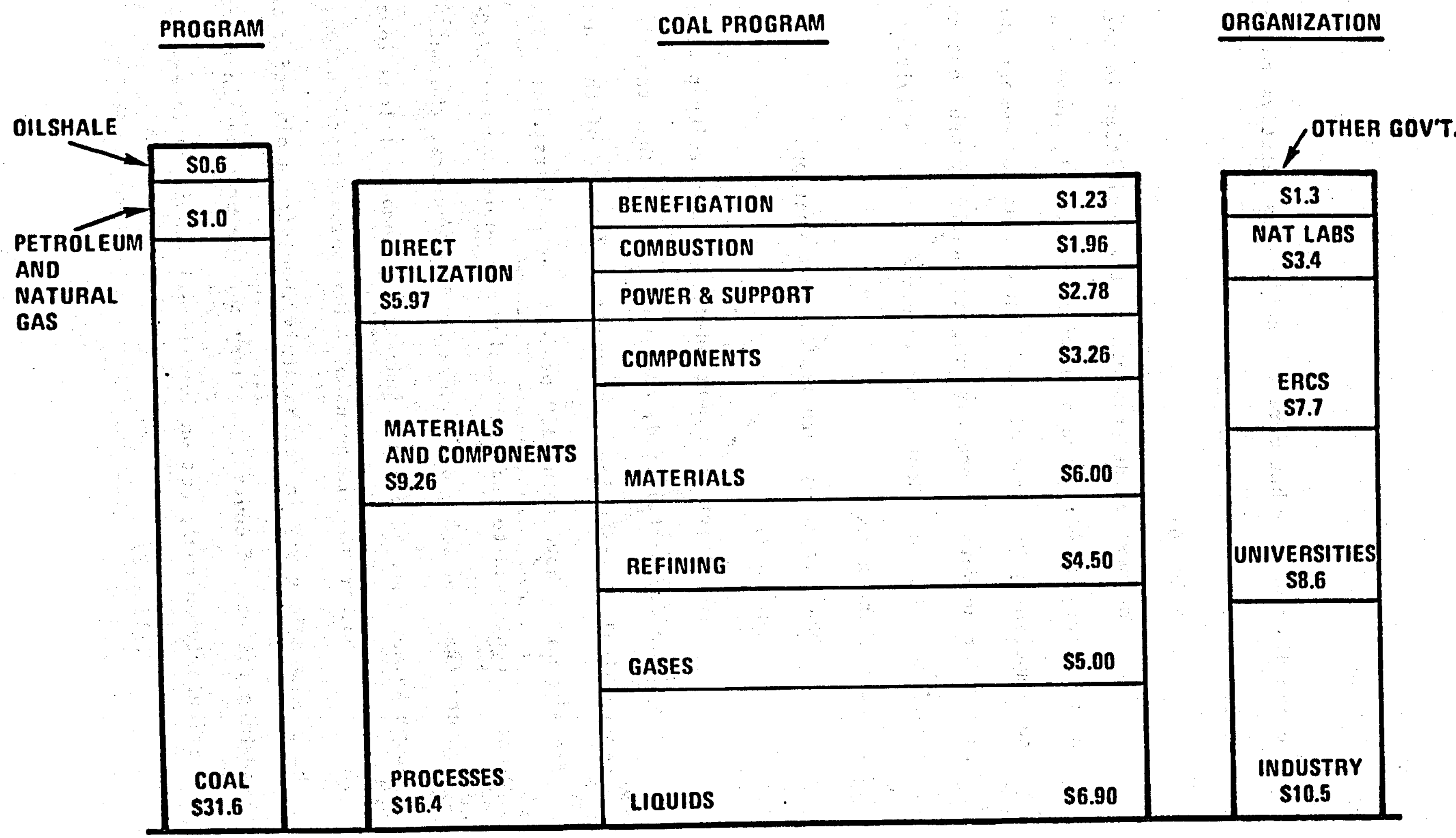
(Slide 5)

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.

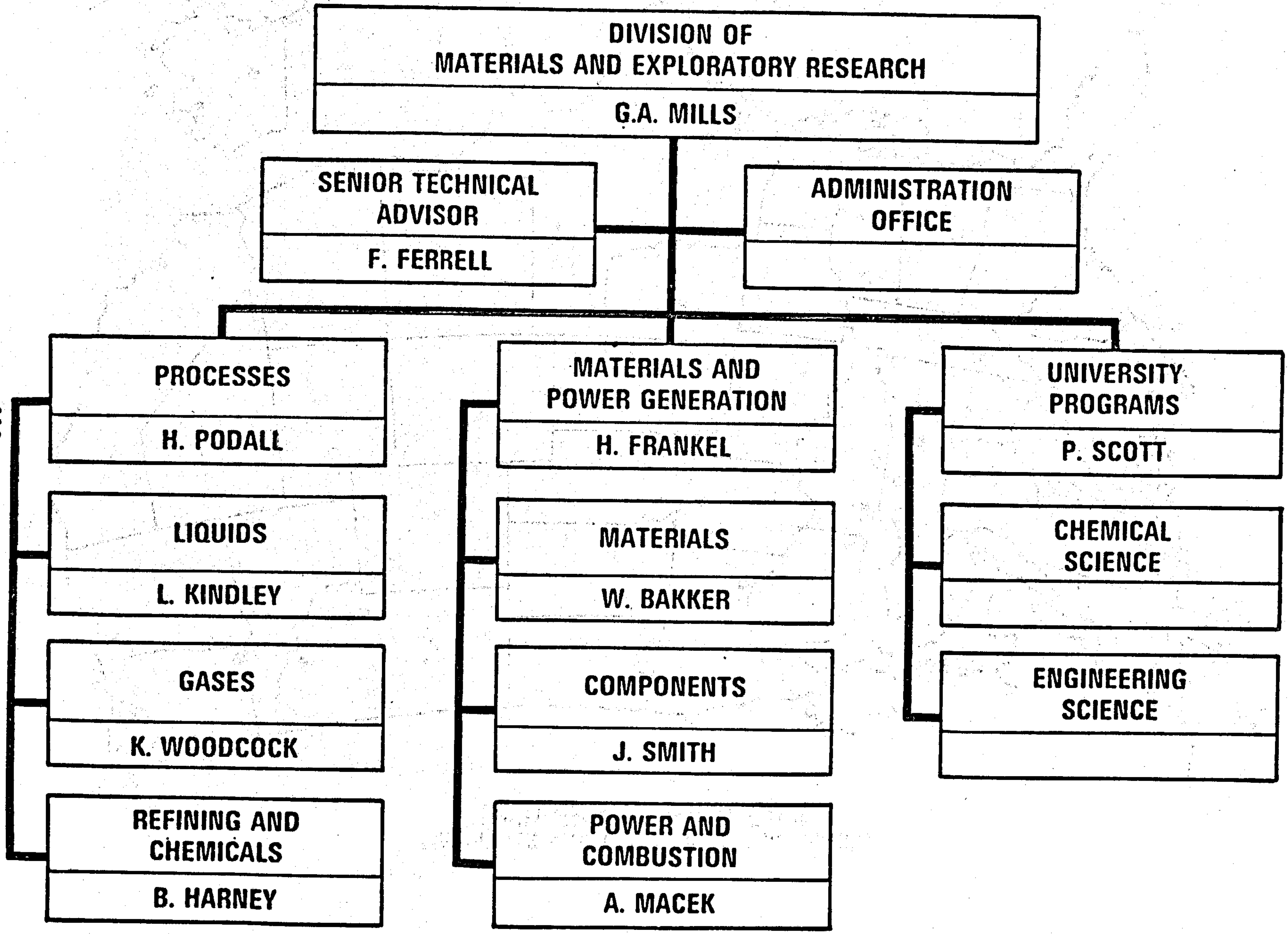
(Slide 7)

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.

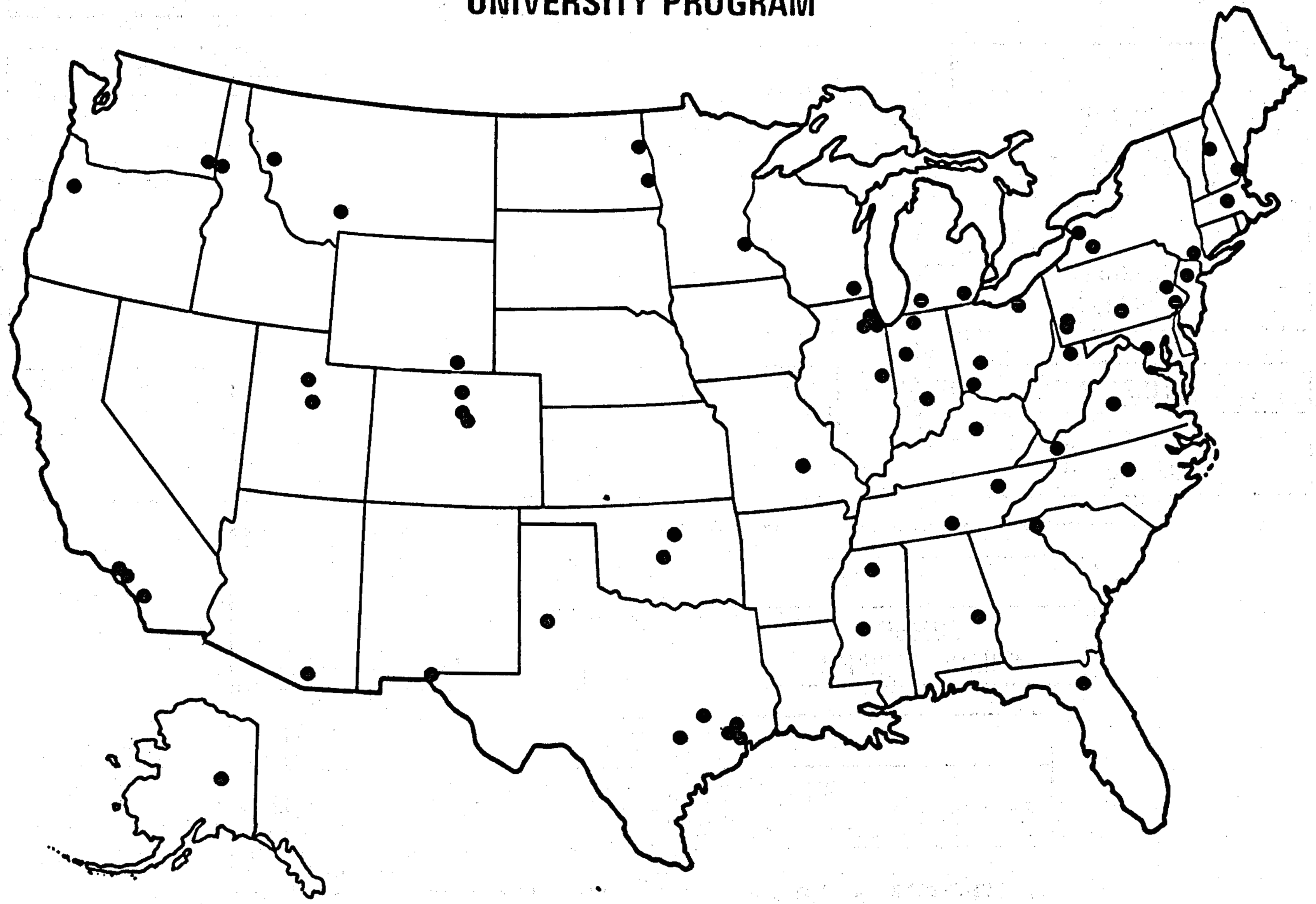
So, from a viewpoint of geographical distribution, we have come a long way in deliberately involving a diversity of groups, seeking talent, of course, to carry out the programs in research, particularly on coal, but on fossil--all fossil energies.

(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	55.4	107
– 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		
• 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)	7.6	7
– FAILURE ANALYSIS		
– TECHNOLOGY TRANSFER – NEWSLETTER		
• IMPROVED DIRECT UTILIZATION OF COAL	5.8	39
– BENEFICIATION (SRC, PERC, AMES, PERC)		
– COMBUSTION PROCESSES (MRI, GFERC, MERC)		
• 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 WITH-DRAWING 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.

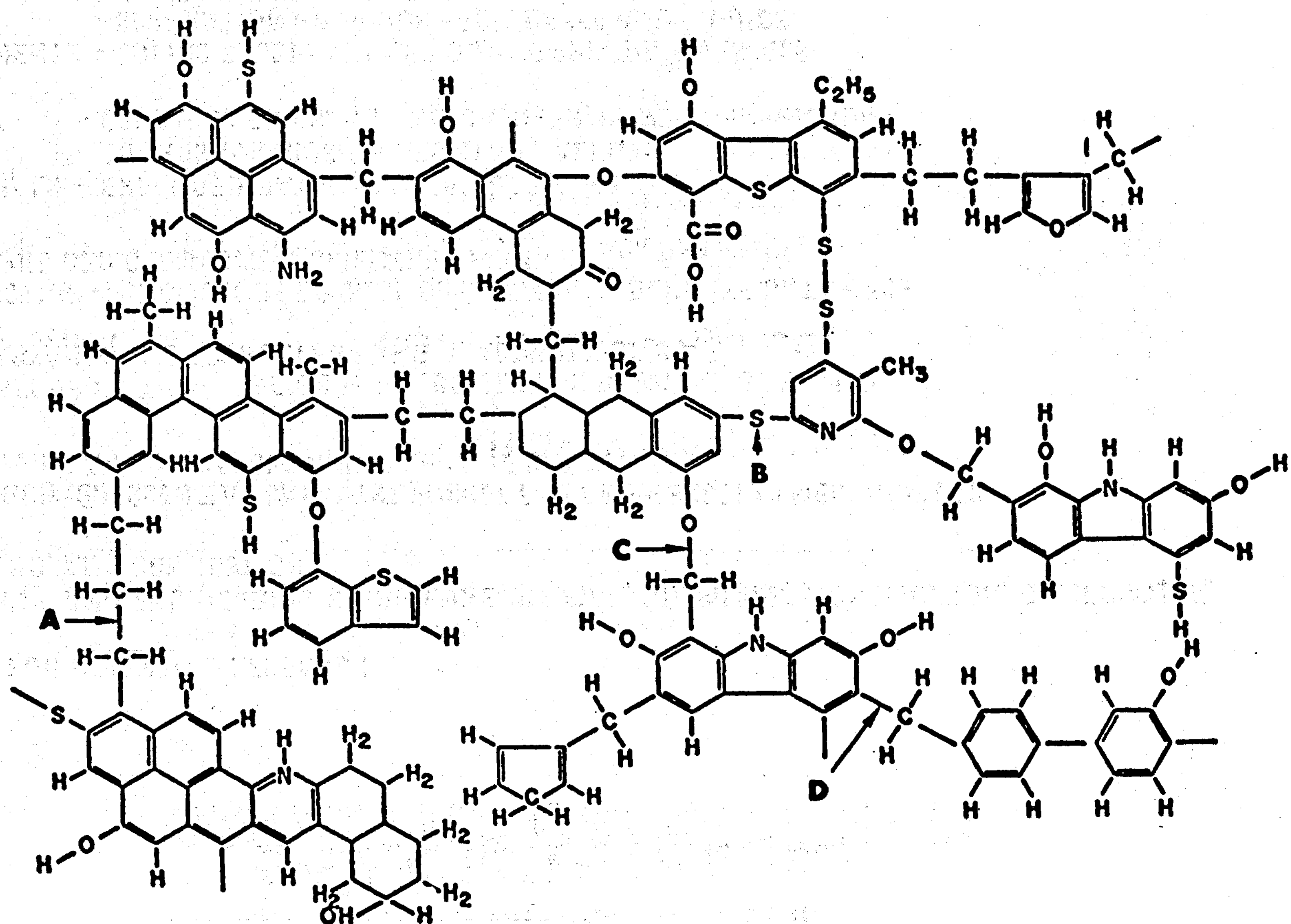
Now, the last slide which--

(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


A
B
C
D

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.

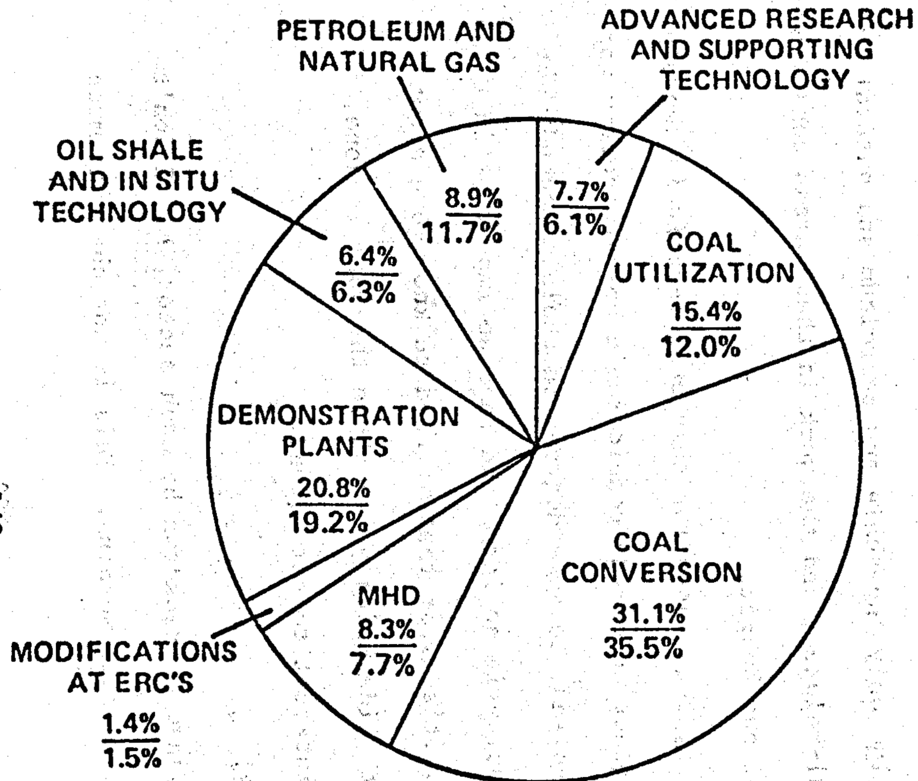
I'm going to run through the same sort of briefing that we've given our budget committees in Congress, which is as good a job as we can do of summarizing our total fossil energy program.

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, but much of the supporting system can be used and save 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

1977 ACCOMPLISHMENTS

- COMPLETED 1000 HR COMBUSTION TEST OF COAL-OIL SLURRY IN A 100 HP BOILER
- 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

1978 CHANGES

- 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

77-2656M/2-4

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 <u>Wall Street Journal</u> 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 ($0.2-0.5 \times 10^6$)	DEFINITIVE ($2-5 \times 10^6$)	DETAILED ($20-50 \times 10^6$)
• 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

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

PRELIMINARY ($\$0.2\text{-}0.5 \times 10^6$)	DEFINITIVE ($\$2\text{-}5 \times 10^6$)	DETAILED ($\$20\text{-}50 \times 10^6$)
• COST CURVES	• DO	• VENDOR BIDS
• EXPERIENCE FACTORS	• VENDOR QUOTES ON MAJOR ITEMS	• ACTUAL LABOR COSTS AND PRODUCTIVITY
• RULES OF THUMB	• EXPERIENCE FACTORS BASED ON MORE DETAILED DRAWINGS	• DETAILED ENGINEERING EVALUATION
• GENERAL COST INDEXES	• SPECIFIC COST INDEXES	• FINANCING UNDER ACTUAL CONDITIONS
• ASSUMED FINANCIAL CONDITIONS	• PROJECTED FINANCIAL 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.

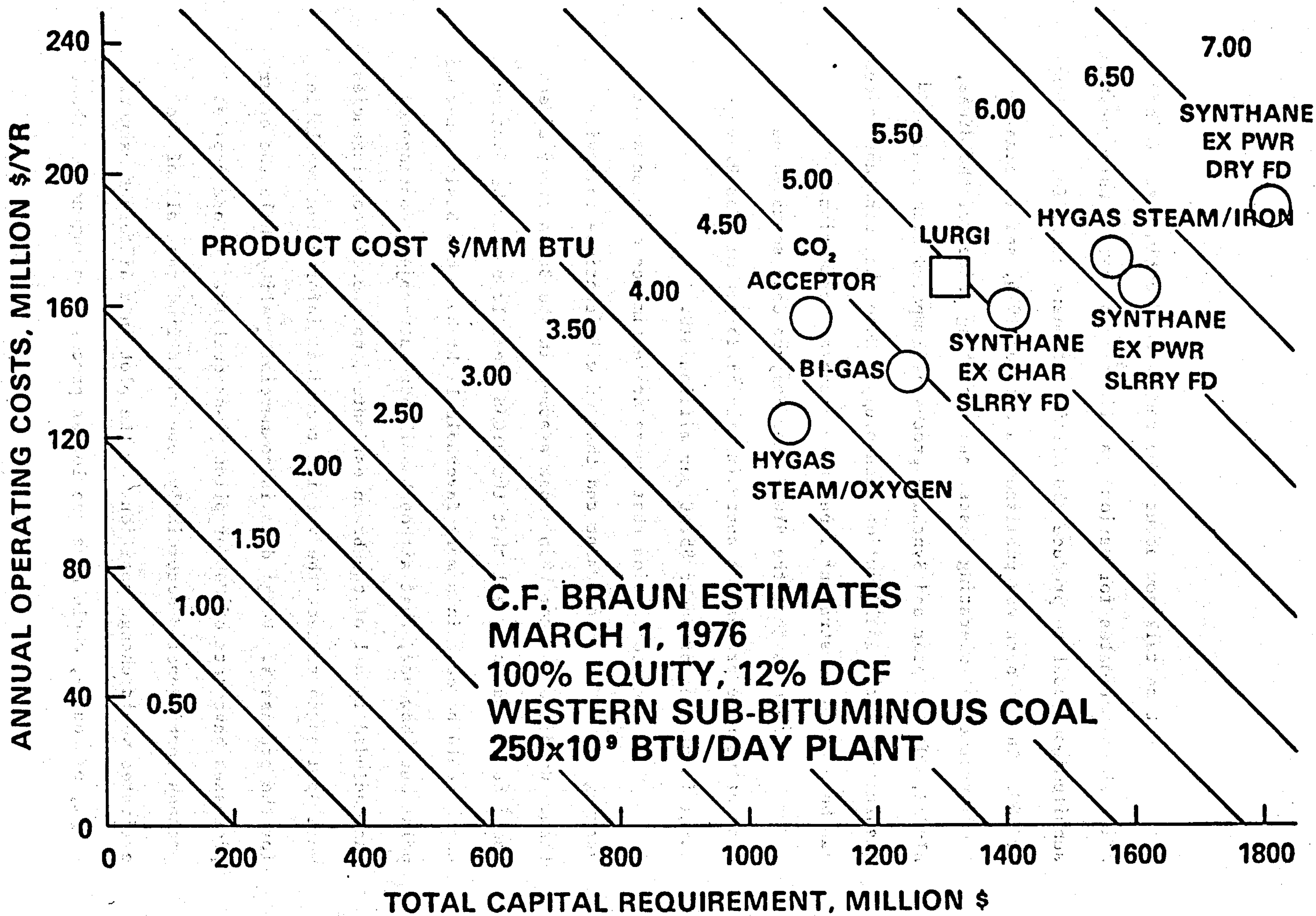
The project contingency one might assign to a study estimate would be typically greater than 20 percent. At the preliminary estimate level, a 15 to 20 percent. At the preliminary estimate level, a 15 to 20 percent project contingency might be appropriate. For the definitive estimate level, a 10 to 15 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
HYGAS STEAM/OXYGEN
SYNTHANE EX CHAR SLRRY FD
SYNTHANE EX PWR SLRRY FD
C.F. BRAUN ESTIMATES
MARCH 1, 1976
100% EQUITY, 12% DCF
WESTERN SUB-BITUMINOUS COAL
250x10⁹ 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.

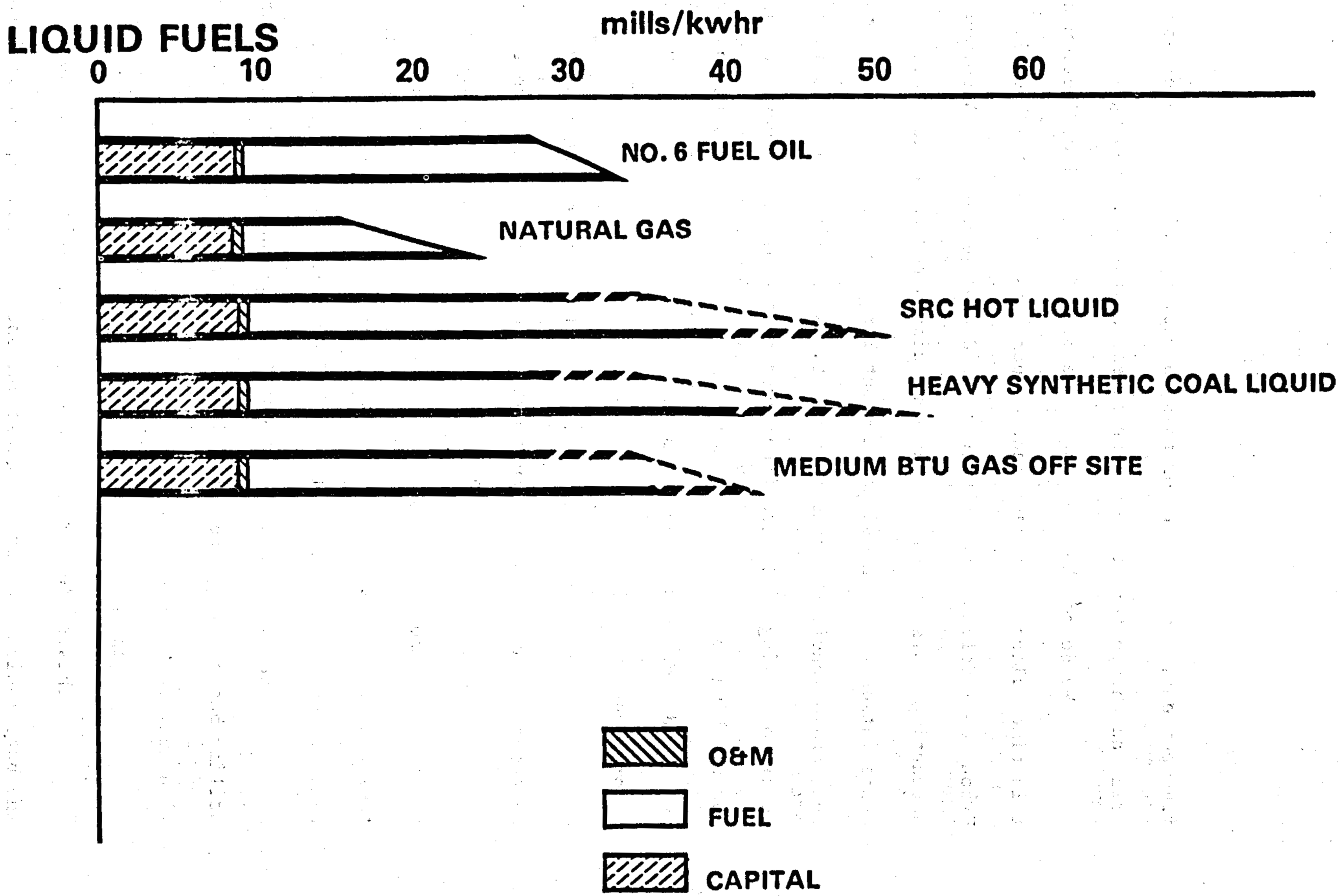
However, on a preliminary basis, liquefaction processes are indicated to produce synthetic crude at $30 per barrel or higher; a fuel oil product may be $5 per barrel less. This assures a 15 percent rate of return on a discounted cash flow, 100 percent equity basis.

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



181-1

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.

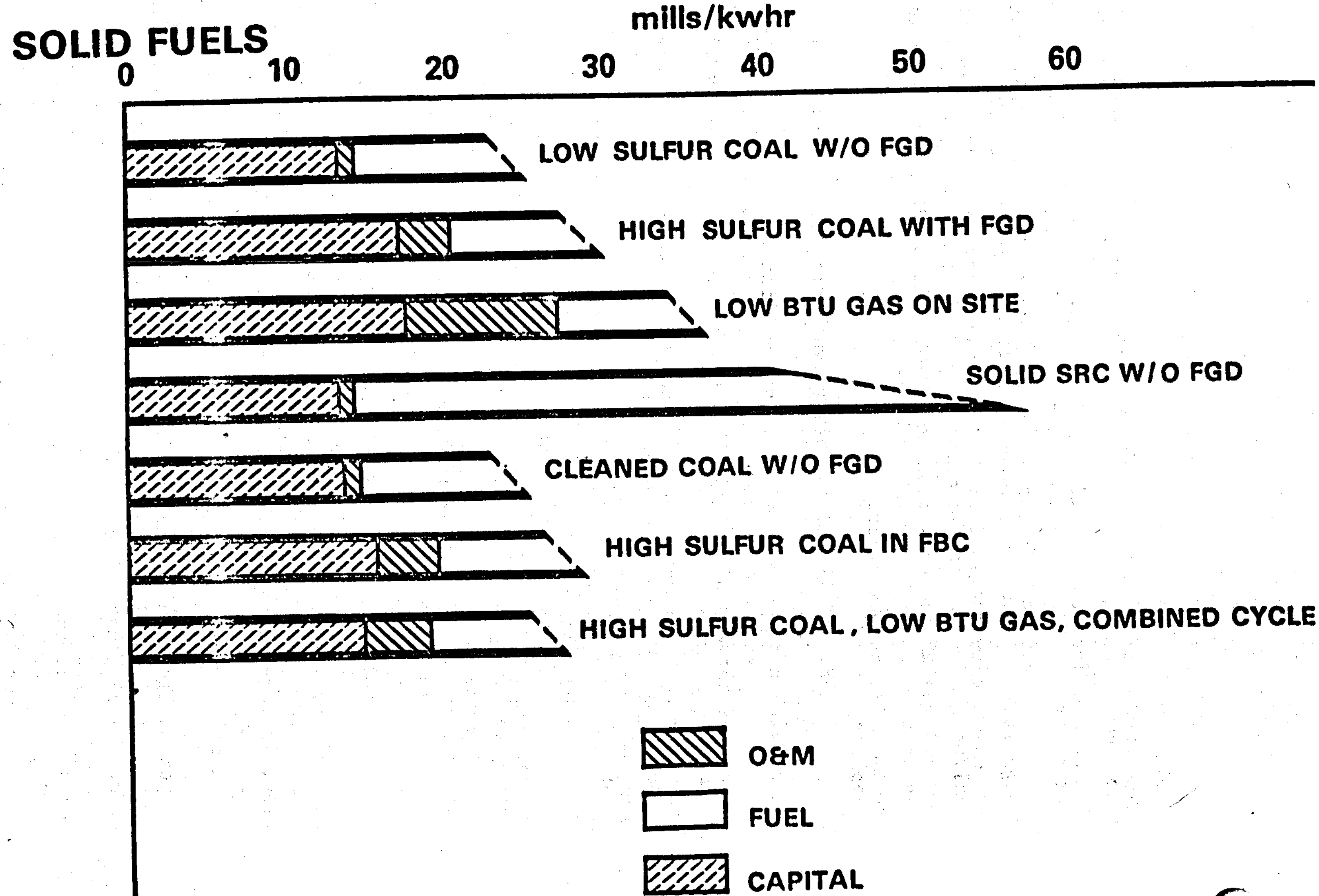
SRC hot liquid and heavy synthetic coal liquid, both estimated within a range of $3 to $5 per million Btu, produce electricity at a cost between 35 and 50 mills per kilowatt hour. The medium Btu off-site case assumes a cost for the gas between $3 and $4 per million Btu and produces electricity between 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.

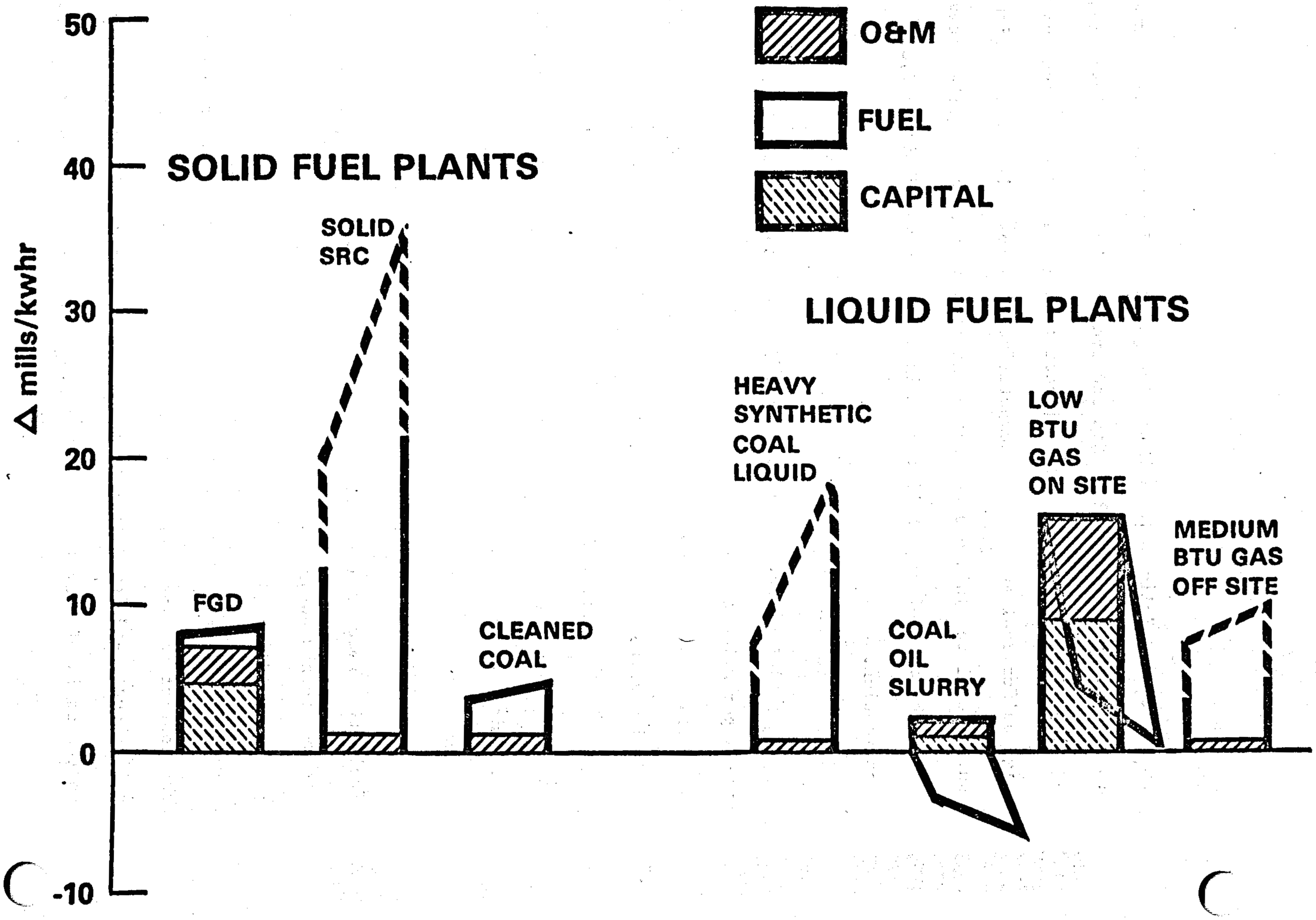
For liquid fuel plants, the retrofit of \$3 to \$5 per million Btu heavy synthetic coal liquid adds about 20 mills. And in the coal-oil slurry retrofit, substituting coal for part of the No. 6 fuel oil, a small saving results.

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.

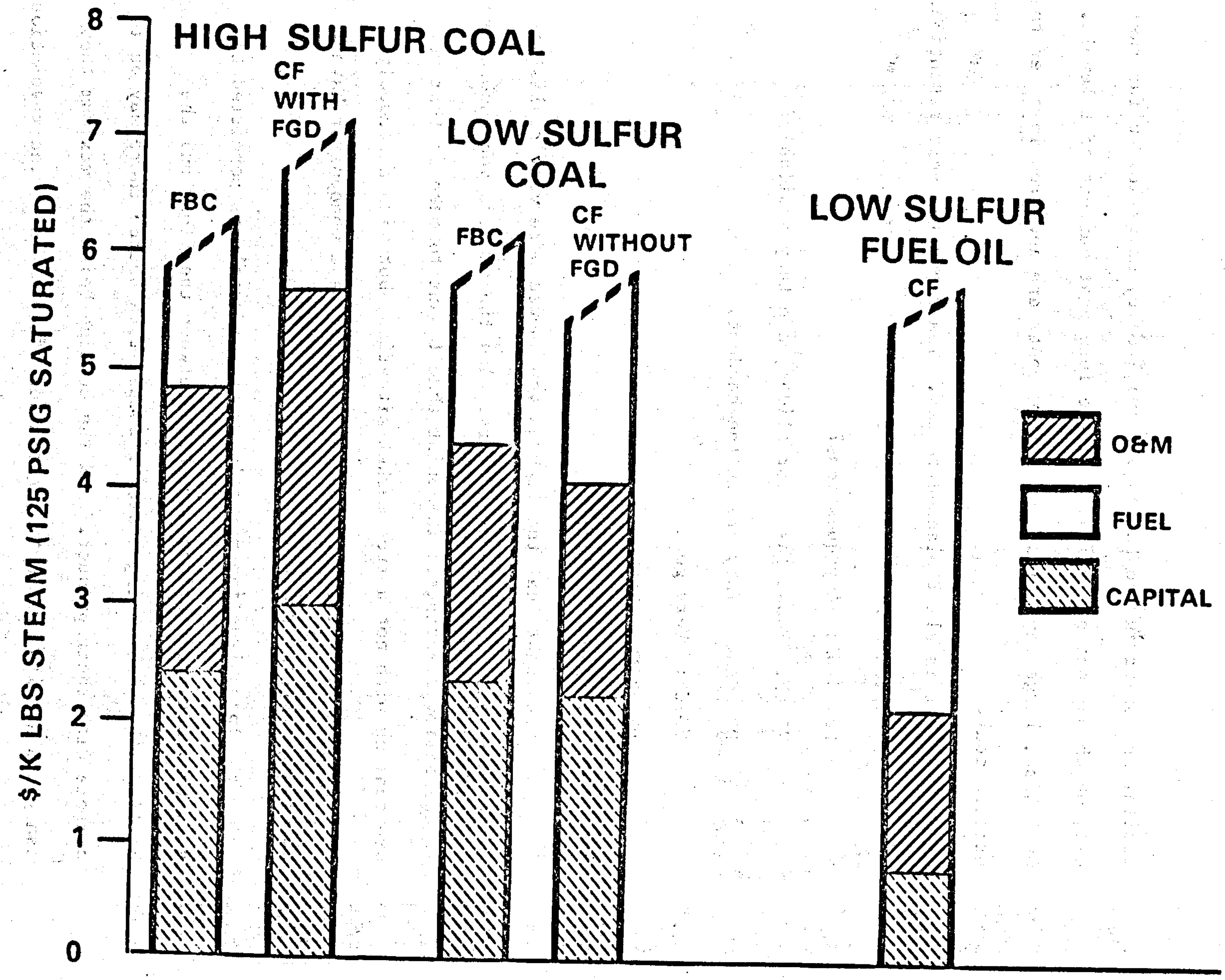
(Slide 9)

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.)

\- - - - - - -