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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

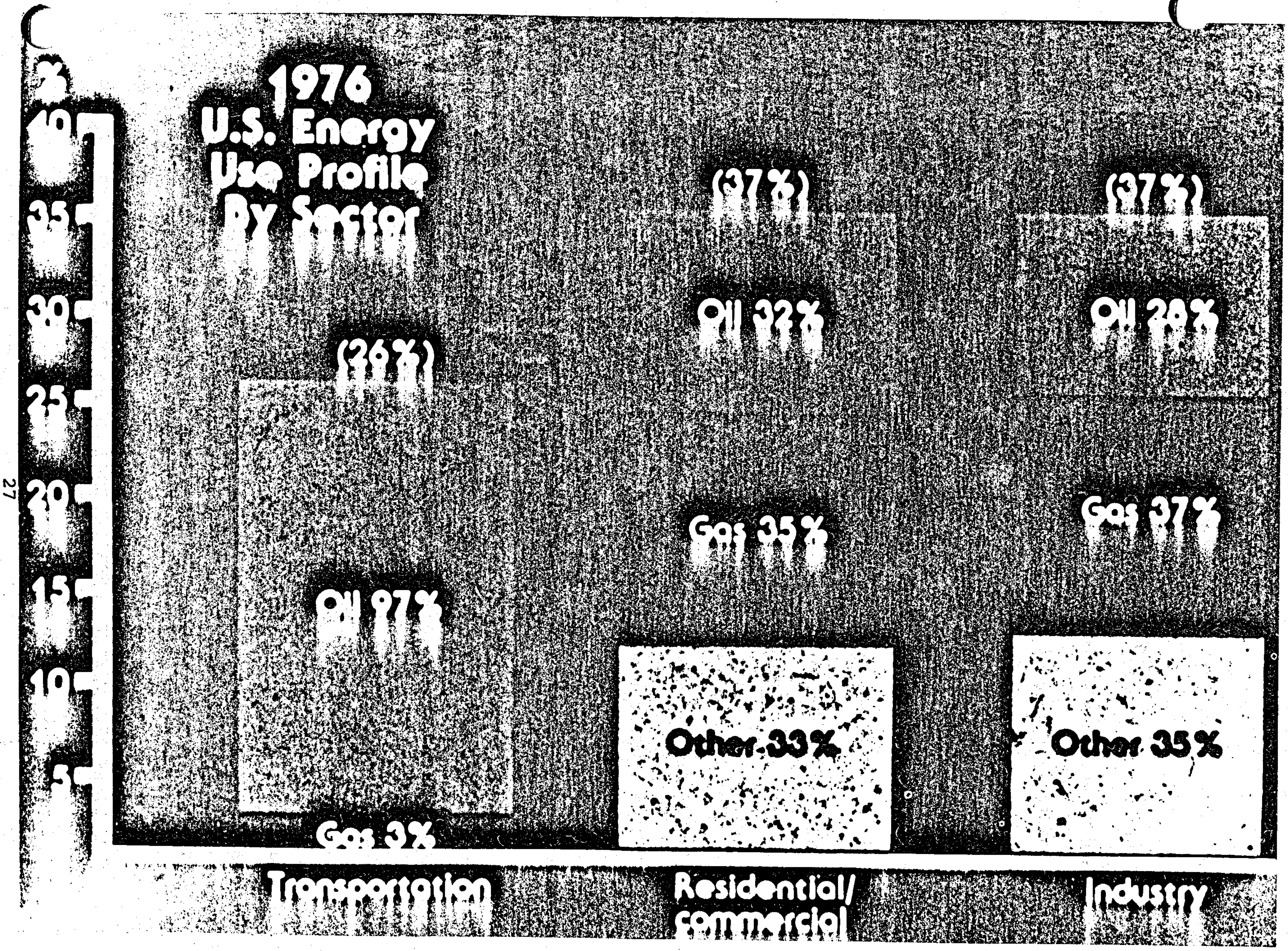
May I have the next slide, please.

(Slide 5)

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

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

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


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

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

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

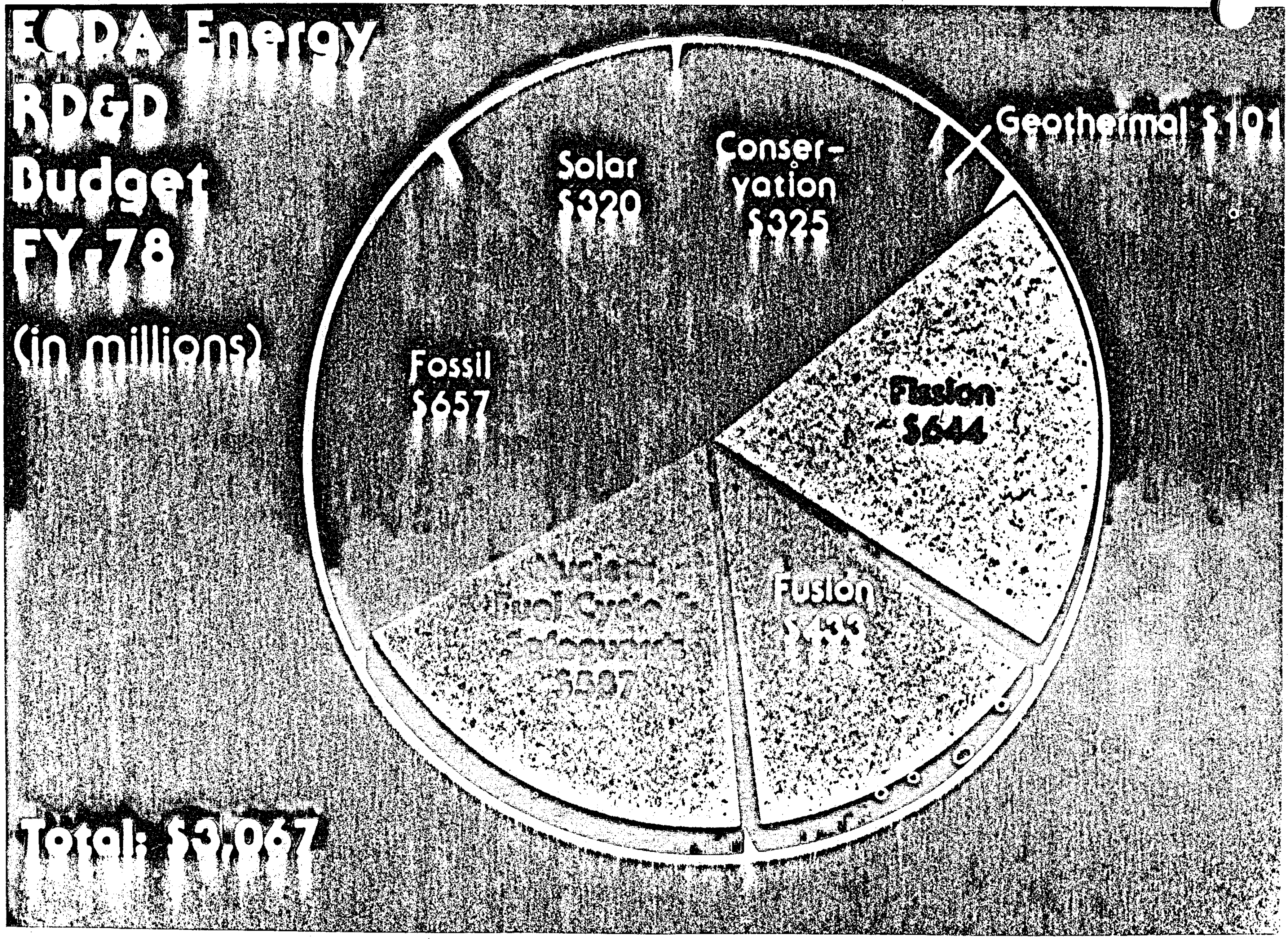
Finally, there are changes in industrial process, especially for those processes used by the most energy-intensive industries. ERDA, again, has programs in all of these areas in cooperation with industry.

Can I have the next slide, please.

(Slide 6)

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

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


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

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

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

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

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

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

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

May I have the next.

(Slide 7)

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

Can I have the next vugraph.

(Slide 8)

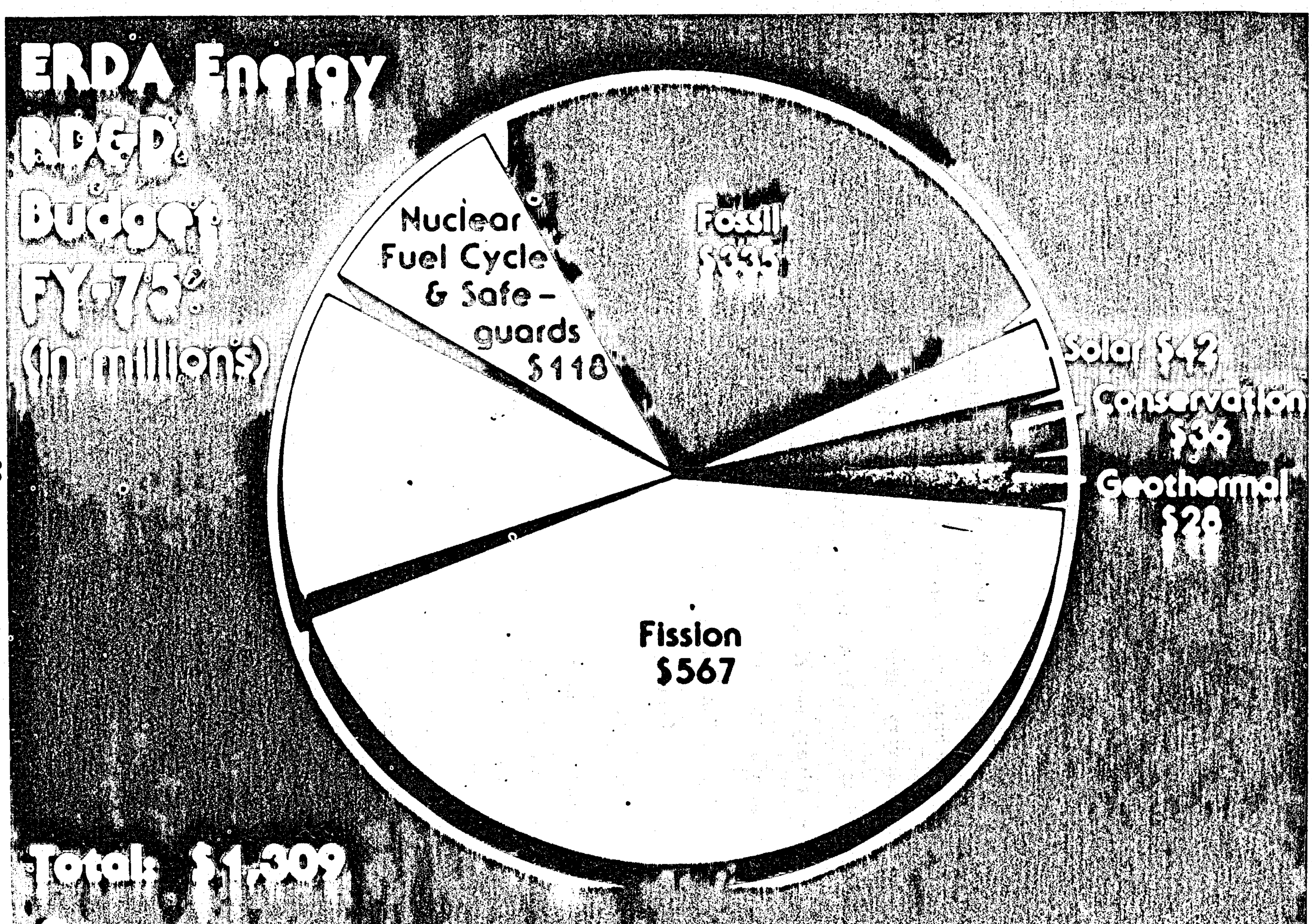
This gives you some feeling for the kind of growth that has happened in the various areas. It gives a feeling for where priorities have been, at least as far as incremental growth is concerned.

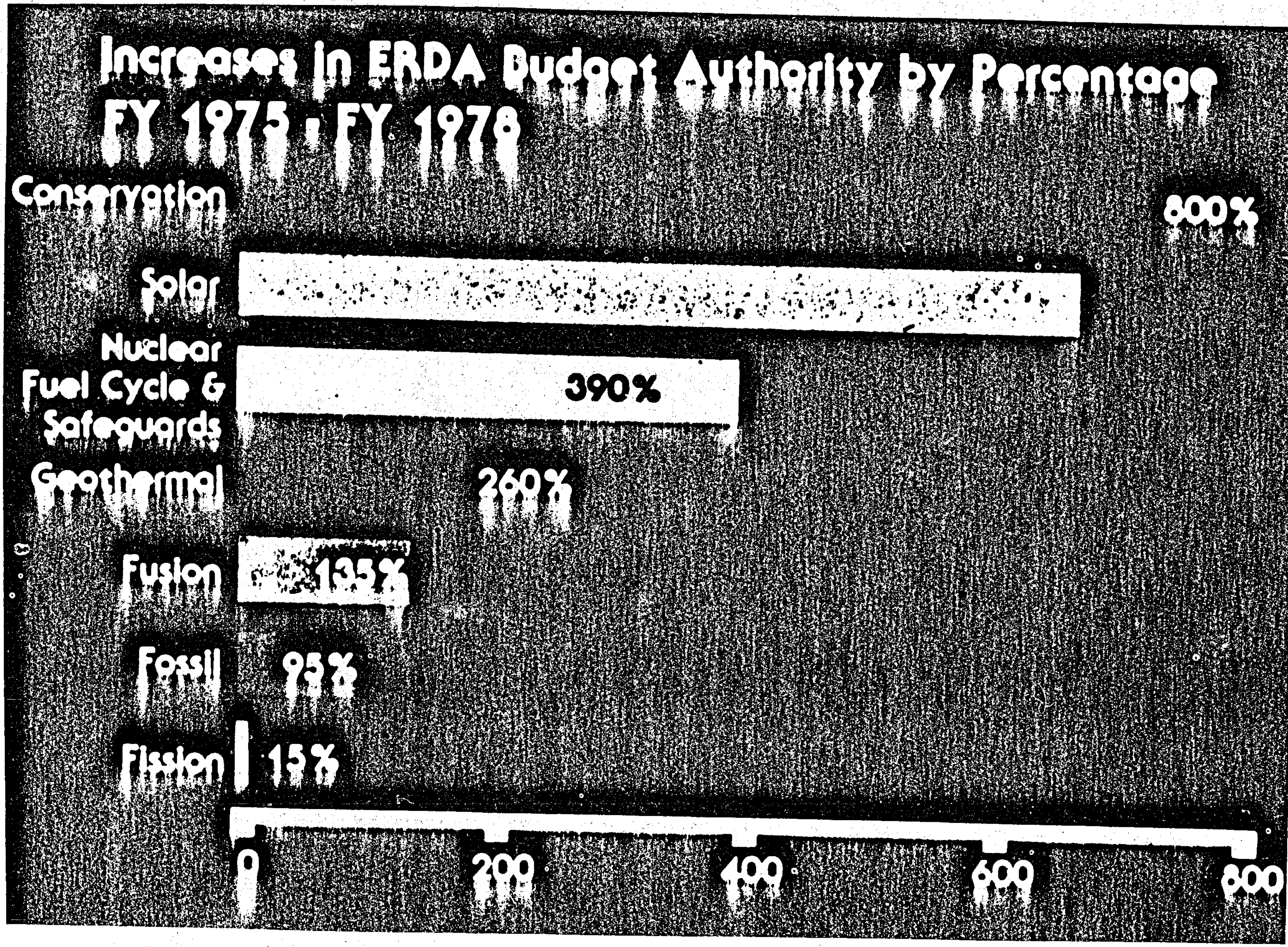
The conservation area has grown some 800 percent, consistent with the fact that it was just getting off the ground when ERDA was formed. It can have a very significant near-term impact, and it is usually cheaper to save a barrel of oil than to produce one.

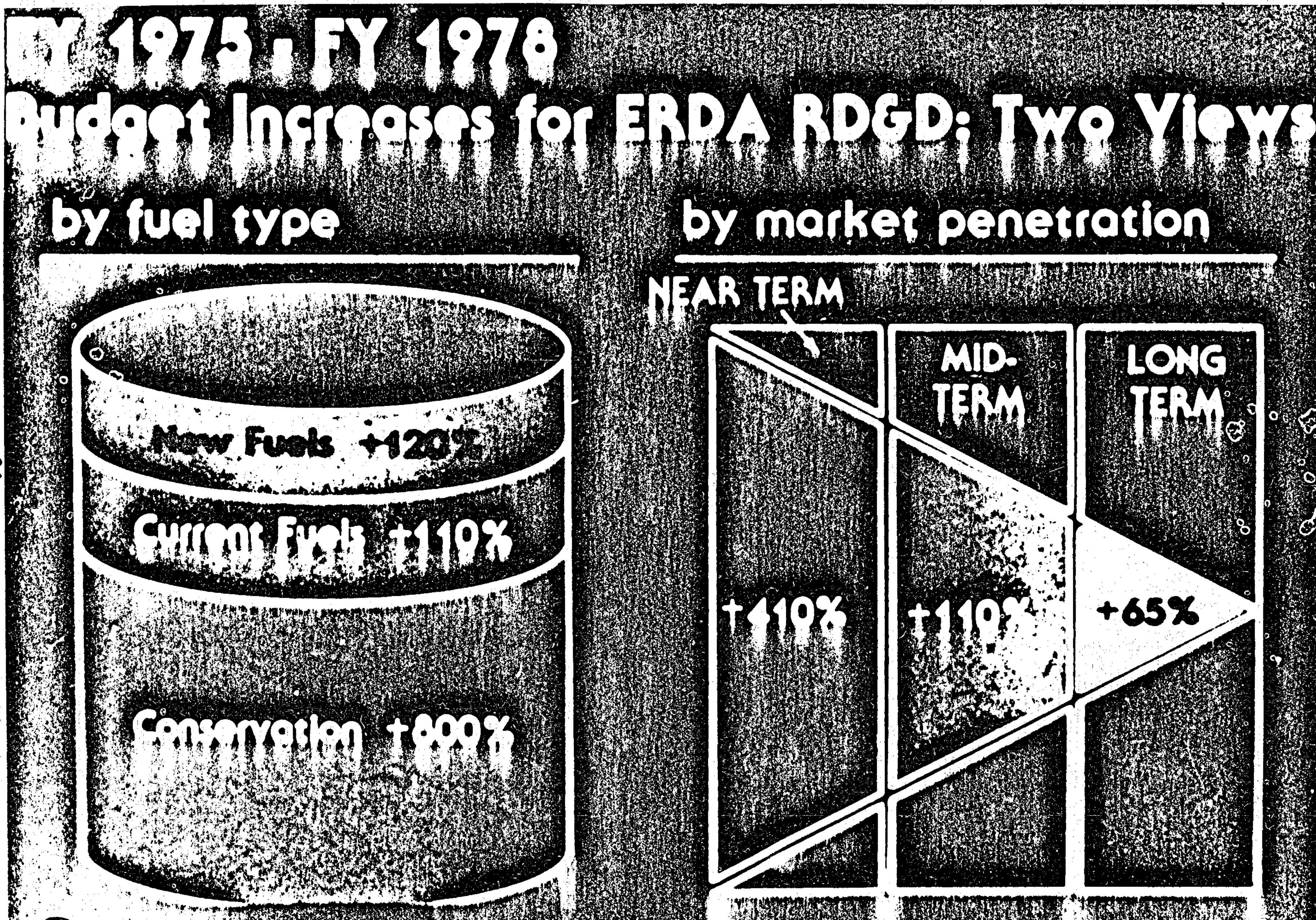
Solar, nuclear, et cetera have grown. Safeguards, supporting LWR has grown significantly. You can see the rest of the slide.

May I have the next one, please.

(Slide 9)


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


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


FY 1975 - FY 1978
Budget Increases for ERDA RD&D: Two Views
by fuel type
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 interest is the one on the right-hand side, which does it by essentially the time frame in which a technology would have an impact. Notice that near-term technologies have grown some 410 percent since ERDA was formed. Mid-term, 110 percent; long-term, 65 percent. This represents, first of all, our recognition of our problem; it has made us realize that we need a lot more emphasis on near-term solutions. It also represents the fact that before ERDA was formed, before the Arab embargo, the federal role was considered to be principally to handle the long-term stuff that would ease our transition to the inexhaustibles. Since that time, there's been a recognition of the need for the Federal Government to make sure that the other technologies, that can get us away from our dependence on gas and oil, needs some federal support to insure that they are implemented on a timely basis.

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

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

Are there any questions:

DR. RAMSEY: Norman Ramsey. Harvard University.

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

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

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

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

DR. RAMSEY: I see.

DR. ROBINSON: Yes?

DR. GREEN: Leon Green, General Atomic Company.

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

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

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

DR. GREEN: Thank you very much.

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

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

Is Dr. Neuworth here?

DR. NEUWORTH: Yes

DR. KANE: Oh, good.

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

DR. NEUWORTH: Thank you.

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

DR. NEUWORTH: Okay.

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

Could I have the first slide.

(Slide 1)

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

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

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

Essential Steps in Coal Liquefaction

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

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

New slide please.

(Slide 2)

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

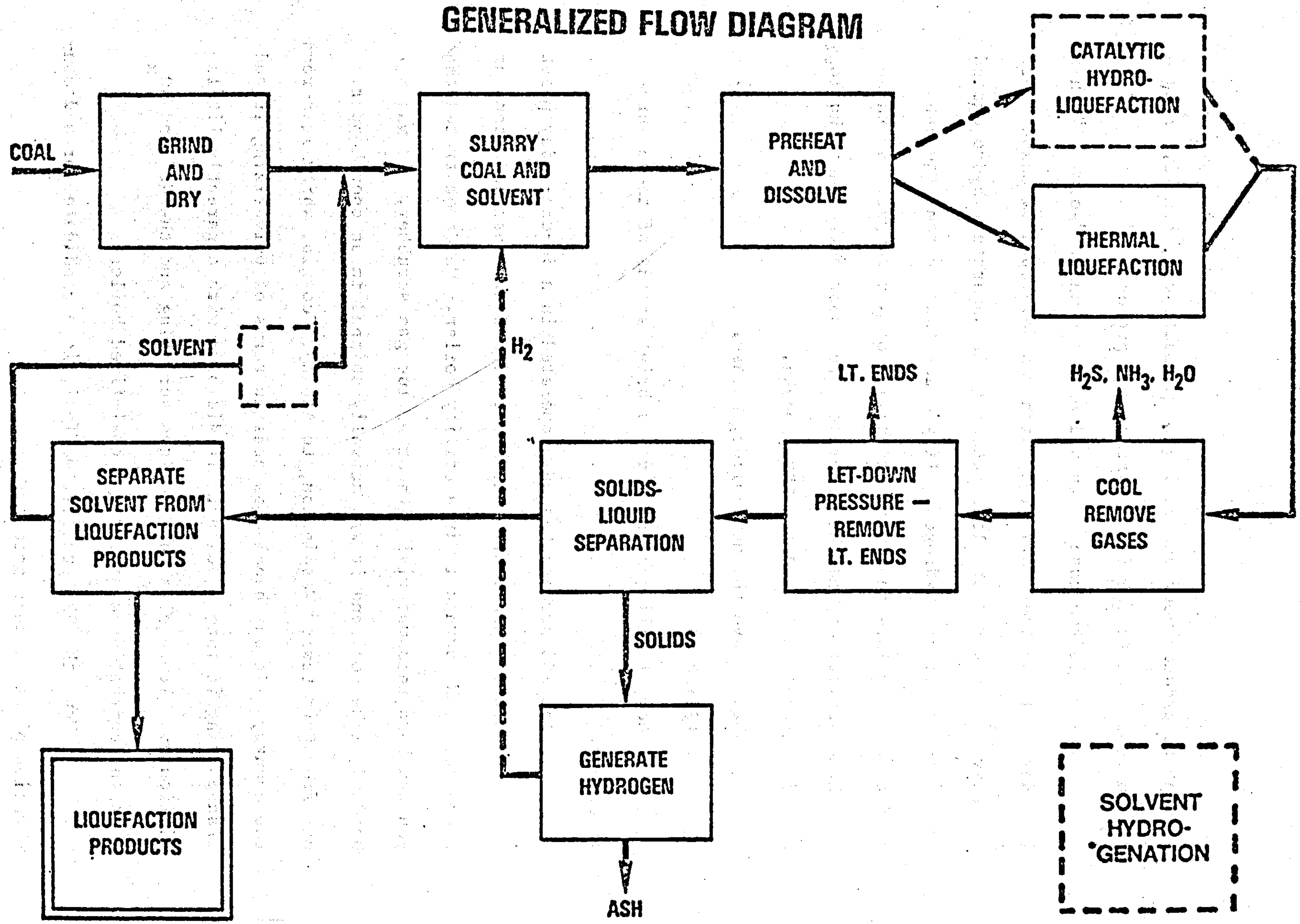
VOICE: No, sir, I don't believe so.

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

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

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

COAL LIQUEFACTION GENERALIZED FLOW DIAGRAM



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

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

May I have the next slide, please.

(Slide 3)

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

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

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

Slide #3 is not available.

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

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

(Slide 4)

Oh, you're going too fast.

VOICE: I'm sorry.

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

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

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

LIQUEFACTION PROBLEM AREAS

Engineering Problems

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

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(Slide 5)

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

That is a quick look at liquefaction.

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

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

PROCESS PROBLEMS

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

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Now, I have shown a typical flow sheet--

(Slide 6)

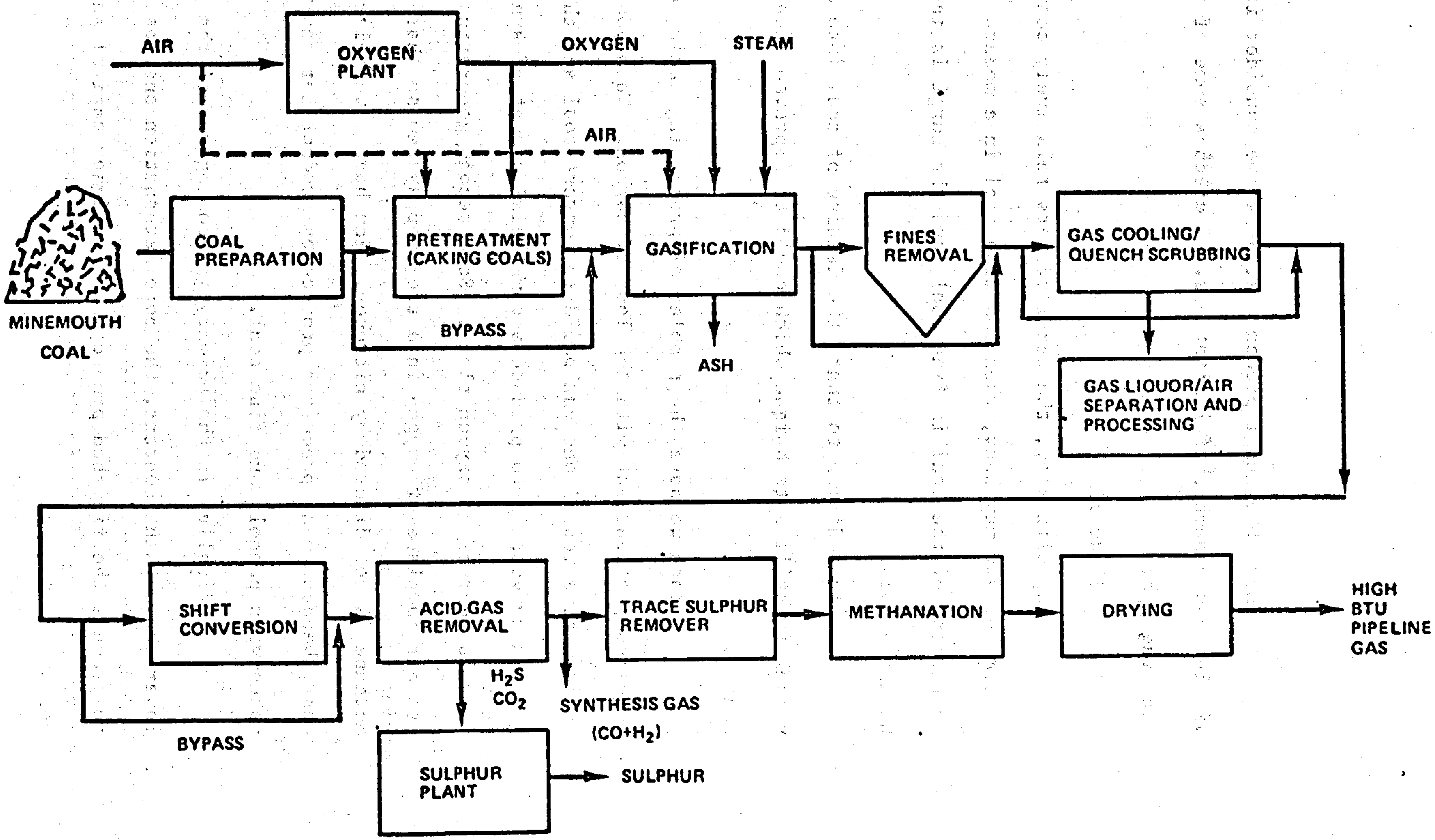
-- for a first-generation or second-generation coal gasification process.

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

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

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

ANATOMY OF GASIFICATION PROCESSES
HIGH BTU VERSION



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

(Slide 7)

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

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

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

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

Coal Gasification Problems

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

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

May I have the next slide.

(Slide 8)

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

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

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

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

(Slide 9)

DESCRIPTION AND STATUS OF HIGH BTU GASIFICATION PILOT PLANTS

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

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

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

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

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

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

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

Thank you.

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

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

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

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

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

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

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

MR. SHANNON: My name is Robert Shannon.

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

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

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

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

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

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

DR. NEUWORTH: Methane?

DR. BARON: --methane.

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

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

DR. BARON: Thank you very much.

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

(Short recess.)

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

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

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

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

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

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

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

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

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

Thank you.

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

DR. FREEDMAN: Welcome.

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

(Slide 1)

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

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

I tell people that . . .

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

COAL UTILIZATION
BACKGROUND

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

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

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

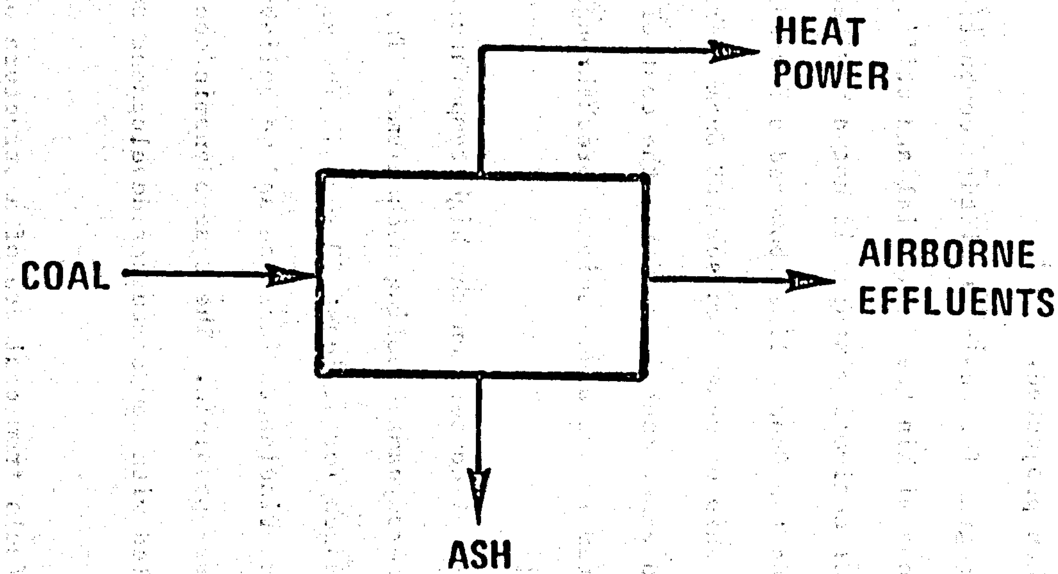
(Slide 2)

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

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

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

COAL UTILIZATION
ERDA R&D



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

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

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

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

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

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

(Slide 3)

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

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

COAL UTILIZATION

RECENT HISTORY & CURRENT STATUS

- FLUIDIZED BED COMBUSTION
  - INCINERATORS
    OPEN BED, TOP FED
    COMBUSTION RELIABLE
  - SO_2 SUPPRESSION
    LAB DATA
  - HEAT TRANSFER & FLUID MECHANICS
    EMPIRICAL
  - BOILER DEVELOPMENT
    IMMATURE EQUIPMENT
- COAL-OIL MIXTURE
  - RESURRECTION OF OLD TECHNOLOGY
  - PRACTICALITY & COST
- GAS TURBINES
  - MATERIALS & ADVANCED COOLING DESIGN
  - LARGE TECHNICAL BASE
- HOT GAS CLEANUP
  - NEW TECHNICAL AREA

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

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

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

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

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

(Slide 4)

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

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