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15. NEW FUELS FROM COAL

FACTSHEET

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INTRODUCTION

While progress seems to go steadily forward, there are always small cycles of rediscovery and return. The rediscovery of the importance and versatility of coal is such an instance. Coal was the first of the fossil fuels to become industrially important and it is still, on both national and international scales, our most abundant resource. It was realized very early on that useful, clean fuels of many types could be made from it. Kerosene - still called "coal oil" in the rural U.S. - was produced from coal in the mid-19th century, and "town gas" or "water gas" produced from coal provided the fuel for 19th and early 20th century urban lighting and cooking. The discovery of large quantities of easily obtainable oil and natural gas led to the replacement of these coal-based fuels in the 20th century. Germany, forced by the blockade and European geology to find a substitute for oil during World War II, demonstrated on a large scale the technical feasibility of obtaining liquid and gaseous fuel from coal. The return of cheap oil and gas to the marketplace after World War II led again to a general demise in the importance of "King Coal".

A generously funded and determined research and development effort is now underway to produce cost-competitive gaseous and liquid fuels from coal. This resurgence in interest, this time, seems permanent; it is likely to remain as long as coal supplies remain. The new impetus is provided by the realization that the end of the petroleum era is near. National and international oil resources, depleted by the rapidly increasing consumption of the past 50 years, will barely last beyond the turn of the century. In addition, increasing scarcity and the near monopoly enjoyed by the OPEC nations has caused the price of oil products to more than triple over the past five years. Coal and coal-derived fuels can once again compete for the energy dollar.

RESOURCES

Coal is our most abundant resource. In the following table is shown the "ultimately recoverable" resource (the total resource, discovered and potential, which is thought to be economically exploitable with present technology) both in Calories (the scientific term would be kilocalorie),* and in tons, barrels, etc. The coal resource is ten times larger than the others.

The latest data on energy - those for 1975 - show U.S. coal production to have been 646 million tons. At that rate of use, the U.S. coal resources would last about 600 years. The rate of use will increase,

* See the Glossary Fact Sheet, #18, for further discussion and definition.

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of course, especially if new fuels are successfully produced from coal. Even if use increases exponentially by only 2 percent per year, coal will last only 100 to 150 years.

Ultimately Recoverable Resources

Coal	390 billion tons	2,380 x 10^{15} Cal
Oil	112-189 billion barrels	168-284 10^{15} Cal
Natural Gas	761-1094 trillion cubic feet	198-284 10^{15} Cal

TECHNOLOGY

Coal is almost entirely carbon, containing only small amounts of hydrogen, oxygen, sulfur, and nitrogen. The synthetic fuels must be hydrocarbons - molecules made up of hydrogen and carbon. The basic conversion task, therefore, is to add hydrogen to the carbon atoms.

The numbers give some idea of how much hydrogen is needed. In coal there are sixteen carbon atoms to each hydrogen atom, in heavy fuel oil the carbon to hydrogen ratio is 6 to 1, while in gasoline it is about 1 carbon atom to every 2 or 3 hydrogens, and in natural gas (methane - CH_4) it is 1 to 4. To make any of these fuels from coal, a rather large amount of hydrogen must be supplied.

The four primary ingredients are carbon, hydrogen, oxygen, and heat. Coal supplies the carbon and some of the hydrogen. Additional hydrogen is usually provided either by breaking down natural gas or by reacting coal with steam (H_2O). Oxygen is either supplied in a pure form or as air and the heat is supplied by burning coal or a by-product gas.

The basic chemical reaction for coal gasification is the following:

Coal + water + heat $\rightarrow$ carbon monoxide + hydrogen
($C + H_2O + \text{heat} \longrightarrow CO + H_2$)

The gas, a mixture of carbon monoxide and hydrogen is combustible but has a low heat value, about one third that of methane. It can be burned on site but long distance pipeline shipping is uneconomical.

To make a natural gas substitute, the "power gas", as this low Btu gas is called, goes through a second "methanation" step in which the carbon monoxide and hydrogen are combined, in the presence of a catalyst* to make methane, the chief component of natural gas.

There is an intermediate step in which the carbon monoxide (CO) reacts with steam to produce carbon dioxide (CO_2) and hydrogen. The CO_2 is then removed and along with it another gas, hydrogen sulfide (H_2S), formed by combining hydrogen with the sulfur impurities in coal. Thus sulfur, the most damaging pollutant in coal, is not present in the gaseous fuel produced from it. Furthermore, the H_2S can be easily converted to elemental sulfur and disposed of or sold.

The steps just outlined are basic to all the various gasification processes. The processes differ in how the heat is obtained and in other details such as whether pure hydrogen and/or oxygen is required, and in operating temperatures and pressures. Brief descriptions of each of the various commercial processes under development are provided in the first reference listed in the bibliography at the end of this Fact Sheet.

Synthetic oils and new solid fuels: There are two other types of fuel being developed from coal -- liquid fuels, and a solid fuel with higher energy content and less sulfur and ash impurities.

The problem of producing a liquid fuel from coal is basically the same one which occurred in gasification. The 16 to 1 ratio of carbon to hydrogen needs to be lowered - at least to the 6 to 1 ratio of fuel oil. There are three basic processes: hydrogenation, the addition of pure hydrogen; pyrolysis, the heating of coal in the absence of oxygen; and catalytic conversions between carbon monoxide and hydrogen.

Hydrogenation produces a heavy fuel oil usable in power plants. Pyrolysis produces three fuels: high Btu or pipeline gas, a synthetic crude oil (syncrude), and char, a carbon residue which itself can be burned (if it does not contain too much sulfur). Hydrogen is added in the hydrogenation process while in the pyrolysis process the coal molecules - which contain some hydrocarbons - are reformed into the hydrocarbon molecules (C_nH_{2n}) and the excess carbon is removed. In the catalytic conversion process the gasifying reaction described earlier takes place producing CO and H_2 and these are combined under pressure and in the presence of a catalyst to make liquid fuels.

The process of producing a solid fuel from coal is called "solvent refining"; the product is "solvent refined coal" (SRC). In the process, crushed coal is mixed with a hydrocarbon solvent - a light oil for instance - at high temperature and pressure. The coal dissolves and the ash and much of the sulfur can then be filtered out. The fuel, which is like solid tar, can be pulverized or heated and melted and thus piped if desired. Its heating value is higher than coal, 32 M Btu per ton vs. about 18 Btu per ton, and of course, it is a much cleaner fuel.

* See Glossary, Fact Sheet #18 for definition.

Comparative efficiencies: The range of conversion efficiencies to be expected is shown in the table below.

Summary of Overall Coal Processing Efficiencies

Process	Efficiency (percent)
Solvent refined solids	65 to 70
Liquefaction	62 to 69
Low-Btu gasification	65 to 95
High-Btu gasification	54 to 68

While low Btu gas and solvent refined coal have the highest conversion efficiencies it must be remembered that these fuels will be used, for the most part, in the inefficient (about 30 percent) conversion of heat to electrical energy. Overall, the reliance on coal-based synthetic fuels will lower the efficiency with which we use our primary energy resources. Given the dwindling supplies of oil and natural gas, however, this inefficient use of coal seems necessary.

ECONOMICS

In the previous section we described how we may use our huge coal resource to supplement our dwindling domestic supplies of oil and natural gas. That coal can be used in this way is beyond question. Whether it will be is not so much a question of technology as of economics.

Middle Eastern oil, now selling for about $12 per barrel ($2 per million Btu's), can be produced for about 50¢ a barrel (which is only about 8¢ per million Btu's). We may be able to produce synthetic oil or gas from coal at a cost which will compete with imported oil at present prices. But if OPEC then reduces prices we could be left with expensive white elephants. It is not likely that private companies will make the huge investments these plants will need without some guaranteed minimum price for their product. This country will have to balance its political/security needs against the disadvantages of taking energy prices out of market competition.

Present cost projections leave little room for optimism. In terms of dollars per million Btu's, the synthetic gases are expected to cost about $3.00 and synthetic oils $4.00 to $5.00. These prices are to be compared to $0.50 for regulated and $1.80 for unregulated natural gas and $2.00 to $2.50 for oil.

Although several commercial proposals exist, construction has not yet begun. It is easy to see why. In November 1972, for instance, the El Paso Natural Gas Company estimated the cost of its project as $353 million and the completion date as 1976. In December 1975 the same estimates were $1 billion and 3 to 3 1/2 years. The experience of the other companies has been similar.

The average total assets of the 10 largest gas companies (1974 data) is $2 billion. It is no wonder that they are hesitating to take on projects now running at $1 billion apiece with all the uncertainty we have described. The WESCO group has been quite specific and says it cannot take on a project of this magnitude without "government incentives".

ENVIRONMENTAL PROBLEMS

The most serious problem faced by the synthetic fuel plants, the gasifiers in particular, is their need for water. Not only is water one of the raw materials, providing the hydrogen, but it also carries out its usual cooling role. Water needs will be 1-1/2 to 3 lbs. (or about 2 qts.) for each lb. of coal processed. This is about twice the needs of an electric power plant of the same energy output.

Unfortunately most of the coal which is targeted for gasification is either in the arid Southwest, in the Four Corners area, or in the equally arid North Central region of the Dakotas, Montana, and Wyoming. There will be some hard decisions to be made between agricultural, industrial, and synthetic fuel needs for water in these areas.

A large amount of solid waste will be generated along with the gas. Presumably this will be dumped back in the mine. The air emissions will require both particulate and SO_x removal units since the potential air emissions are large. As we reported earlier, the process itself allows the sulfur to be removed as H_2S.

Land Use: Most of the coal for the gasification plants presently under construction will be strip mined. This is an economic necessity since surface-mined coal is about 20 percent less expensive than deep-mined coal. To provide the tons of coal per day needed by a typical plant from a coal seam 10 feet thick (typical of Southwestern coal deposits) will require the stripping of almost 400 acres per year. The problems associated with strip mining will be aggravated by the fact that irrigation will probably be required for land reclamation in the arid Southwest and North Central coal areas.

Carcinogens: A new and different worry for the synthetic fuel industries has recently surfaced. It has been known for some time that at the high temperatures used in these coal conversion processes, molecules know as "polycyclic aromatic hydrocarbons", PAH, are formed. There is ample evidence that many of these PAH's are carcinogenic, that is , cancer causing.

The pieces of evidence come not only from observations of workers in coal liquefaction plants, but also from studies of men working in existing coal gasification plants. Coal-produced synthetics seem, from the evidence, to be more dangerous than petroleum products. The same hazard exists for oil distilled from oil shale, a process which also produces PAH's. In one study it was reported that a worker exposed to shale oil was 50 times more likely to get skin cancer than one exposed to oil from a Pennsylvania well. This problem has so far not been publicly addressed by the proponents of a coal-based synthetic fuel industry.

SUMMARY

The technologies for coal gasification, liquefaction, and for producing clean, high Btu solid forms of fuel have been demonstrated in laboratory and small pilot plant processes. These synthetic fuels are not presently economically competitive with other primary energy forms - oil or natural gas in particular.

The Federal Government, if it wishes to assure the development of large scale demonstration plants will, therefore, be forced to depart from its usual role of supporting only research and pilot plant development and underwrite the construction and operation of some large scale demonstration plants.

ERDA funding in Fiscal Year 1977 of the various coal synthetics is expected to be: liquefaction, \$73.9 million; high Btu gasification, \$45.2 million; low Btu gasification, \$33.1 million; demonstration plants, \$107.0 million, for a total of \$259.2 million. This is about half the level of support for nuclear fission.

The long range goal of the program is to produce 14 of the 180 or so quadrillion (10^{15}) Btu's of energy we are expected to use in the year 2000. It would appear that the abundance of coal and the continuing decline in domestic production of natural liquid and gaseous fuels makes such a goal an obvious one. Whether it is reached, however, will depend on resolution of some difficult environmental problems and on the international economic and political conditions that prevail during the next few years.

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