OUTLOOK FOR COAL SYNTHETICS:
TIME FOR REAPPRAISAL AND RESOLVE

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Highlights

The infant synfuels industry has entered a period of re-appraisal. But in light of what the industry is discovering, re-appraisal is normal, necessary and in the best interests of society.

For Exxon the need for synfuels remains clear. The company has so far invested about $1 billion in synfuels resources, research and commercialization worldwide.

The conventional wisdom today seems to prefer Colorado shale to coal as a source for synthetic liquid fuels. But research and development stand a good chance of making coal competitive.

Methanol from coal is an intriguing possibility, both as an octane-improving gasoline extender, and, eventually, as a neat automotive fuel.

Pittsburgh seam coal tests out as a good coal for liquefaction via the Exxon Donor Solvent technology, now in the large pilot-plant stage.

In establishing a synfuels industry, the cost-control battle in the laboratory will be as critical as the cost-control battle on the project.

Catalysis is to the petroleum and chemicals industries what solid state science is to the communications industry. We might see innovation at a rate approaching that in micro-electronics, with major applications to synfuel technologies, if the current rate of progress continues.

Introduction

Few of us need reminding of how appropriate ~~Pittsburgh is as the site for these annual coal conversion~~ conferences. Pittsburgh was one of the world's first energy capitals, and is still a meeting place of the past, present, and future in energy. Just to the north is the birthplace of the oil industry, and some 14,000 wells still produce high-grade Pennsylvania crude oil. Generally to the south are some 600 million tons of untapped Pennsylvania coal reserves. The oil wells -- mostly stripper wells -- may suggest the energy present. But coal is the once and future energy king that interests this conference -- even though in the energy transition ahead it will share its sway with a rich variety of other resources, such as oil sands and oil shale. Incidentally, Exxon is projecting that U.S. coal usage will double by the year 2000.

It is also appropriate that this is an international conference. Many in the U.S. tend to forget that the effort to use coal more cleanly, efficiently and flexibly is international in scope and has scored many of its important initial successes abroad. Many of us think that Pennsylvania coal will be supplying Europe in the not distant future.

Speech Organization

My focus this evening will be on synthetic fuels from coal and my chief message is that the outlook is for continued successes -- but not without some re-appraisals and renewed resolve. My approach will be, first, to survey the current scene, with emphasis on shifts in U.S. government policy under the new Administration. Then I'll describe some of the key features of the unfolding synfuels industry as we see them at Exxon and how our understanding of them is reflected in our own efforts. In keeping with the interests of this conference, I'll put some partisan emphasis on coal -- vis a vis competition like shale.

Very closely related to my main theme is that new science and technology, as well as engineering excellence, will remain essential ingredients in the success of any synfuels technology. So I will round out my remarks by discussing just a few examples in support of this idea.

The Current Situation

To begin with, I'll re-affirm that the outlook for synfuels from coal today is not bleak. But after a period of relative euphoria, we have entered a time of re-appraisal. Here in the U. S. the new Administration has re-directed all synfuels policy in line with the conviction that private industry should bear the brunt of commercialization, disciplined by market forces and for the most part unsheltered by subsidies. For months synfuels managers have been hunkering down, waiting for David Stockman to drop the other shoe. As you may know, the Exxon Coal Liquefaction Project took a cut of $17 million in government support. In addition, crude prices are actually declining -- delighting consumers, but unsettling managements faced with rapidly mounting cost estimates for synfuels projects. For such reasons many projects are being shelved or re-worked. Another example from my direct experience: Exxon and its partners are reassessing the multibillion dollar Rundle oil shale project in Australia, due to large increases in cost estimates.

For many of us, a period of re-appraisal would not be so painful perhaps, if we didn't have a strong sense of deja vu. We remember all those other re-appraisals -- those that terminated the many starts in synfuels history going back to the 1920's. Nevertheless, I am convinced that this time it will be different, despite the economic, technical, and social challenges of creating a new synfuels industry. In light of new knowledge, re-appraisal is normal, necessary, and in the best interests of society -- if it is combined with vision, resolve, and staying power.

As for my own company, the eventual need for synthetic fuels from coal and other resources remains clear -- even if the exact timetable is not. Exxon has so far invested about $1 billion in synfuels resources, research, and commercialization worldwide. In our research and development budget, expenditures for coal, synthetics, and advanced energy forms are slated to grow four times as fast as those for conventional oil and gas.

Our rationale is simple. For more than a decade the world has been using oil and gas faster than they are being found. By the year 2000 Exxon projects that the world will be consuming two-thirds more energy than today. In the U. S., Exxon projects that even with strong conservation efforts and substitutions, there will still be an eight-million-barrel-per-day gap between domestic crude oil production and potential crude demand in the year 2000. Some combination of imports and synthetics must fill that gap. And Europe, Japan and other oil importing countries will still be demanding raw materials for manufacturing liquid fuels, because in transportation there is no really viable substitute for liquid fuels. And gaseous synfuels may also be strong competitors in many applications and markets, particularly where there is a well-developed pipeline distribution system, as in Japan, Europe, and the U. S.

Features of the Future Synfuels Industry

It is not easy to predict which technologies and resources will win out as the synfuels industry develops. But we can discern a few key features that will mark the entire industry's evolution in the decades ahead.

Not least among these features is competitiveness. No matter how we might view present U. S. government policies, most of us would agree that society will not in the long run want synfuels at just any cost. War and politics may disrupt the flow of oil imports from time to time, and then the pressures for massive subsidies may mount. Certainly, we will see selective loan guarantees and the like, such as those that the U. S. Synthetic Fuels Corporation is empowered to extend. But over the long haul, the industry, as well as individual synfuels technologies, will succeed or fail on the ability to compete economically with imported oil and with each other.

Another key feature of the new industry must be a high degree of cooperation with governments. Syn fuels development will require government action and leadership of many kinds: in setting and applying environmental standards, allocating water supplies, building infrastructure, and cushioning the social impacts of boomtown development. Not much will be accomplished without constructive industry and government relationships, with the emphasis on consensus building rather than confrontation.

I have already mentioned vision and resolve. These will surely be traits of successful companies. Societies, too, must exhibit vision and resolve if social issues associated with synfuels are to be resolved successfully. Here the U. S., as the world's largest oil importer, with one of the world's biggest stores of hydrocarbon resources, has a critical responsibility to proceed expeditiously. But the necessity to create a climate favorable to risk-taking applies to other countries as well.

Finally, extraordinary diversity will characterize the development of the synfuels industry. Widely differing raw materials, and differing local markets, will demand differing conversion technologies at differing times. Many technologies promise to be feasible, and, depending on circumstances, the advantages among them may vary.

For example, the Athabasca oil sands in Canada are a uniquely rich resource, which made them the logical candidate for the first modern synfuels projects -- apart from SASOL. Likewise, the unique qualities of Colorado shale ensure that it will be among the first shales developed in the world. Conversely, the unique characteristics of the European market, rather than the resource, suggest that coal-to-methane technologies will be among the first economically competitive synfuels projects there. Then, too, local surpluses of natural gas, such as in New Zealand and Australia, may create an incentive to convert the gas to methanol or gasoline, or both. Moreover, different technologies will supplement each other. Thus, direct coal liquefaction technologies appear most suited to gasoline production, shale oil retorting to diesel and middle distillate production.

I don't mean to suggest that the synthetic fuel technologies won't also be competing for investors' capital. Indeed, it may rankle some in this audience that the conventional wisdom in the U. S. seems to prefer Colorado shale to coal as a source for liquids. My own company agrees with this assessment for several reasons. The mining tradeoffs compare favorably. Overall shale processing is less energy-intensive than today's coal liquefaction technologies. The kerogen bound in shale enjoys a higher hydrogen to carbon ratio, minimizing the upgrading required after retorting. Shale liquids more closely resemble conventional fuels. And shale yields a somewhat more desirable product slate--mainly diesel and jet fuel, which are forecast to be in increasing demand.

On the other hand, research and development stand an excellent chance of making coal more competitive through exploiting coal's own set of advantages. Remember that one of the biggest expenses in synfuels manufacture involves simply moving around the solid materials. Yet the energy density of coal is far greater than shale's. A ton of coal yields, say, two barrels of liquids; a ton of shale rock just two-thirds of a barrel. Thus, the materials input for shale is at least three times greater for shale than coal. And the waste material output for shale is at least 10 times what it is for coal. Or look at the processing technologies. Shale retorting breaks loose the hydrocarbons through pyrolysis, a heat-intensive approach. Coal conversion involves some fairly sophisticated chemistry, including catalysis in some cases. Does this mean that coal technologies are more open-ended, more susceptible to improvement? Perhaps. Our own long term cost projections indicate that coal liquids will likely be competitive with shale liquids.

Finally, a wild card. Today, methanol appears to be the lowest-priced liquid fuel available from coal, using technologies commercially proven on certain coals. Indeed, methanol looks very intriguing, both as an octane-improving gasoline extender, and eventually, as a neat automotive fuel in its own right. The octane rating of neat methanol is high enough to allow, in theory, jacked-up compression ratios and direct injection in lean-burn engines that could attain efficiencies perhaps 30 percent higher than comparable gasoline engines.

I'm sure that you can spot gaps in all these arguments favoring coal over shale. For example, methanol fuel would be a newcomer on the fuel markets, demanding not just a new engine but its own separate distribution system. Nevertheless, add to these arguments the geographical dispersion of coal deposits, and the proximity of many of them to population centers, and you may have a very powerful case for coal. I personally have no doubt that coal synthetics will play a substantial role in our energy future.

Obviously, the more you descend to particulars, the more room there is for controversy. Most of you will probably agree with my central point. No single synfuels technology is likely to win out over all others. Rather industry is collectively in the process of creating the kit of tools that will enable it to exploit these resources in an optimum fashion.

Exxon Synfuels Activities

Exxon's own activities reflect this outlook. World-wide, the company's first commercial projects have focused on Canadian oil sands and shale. But although the company has reached no decision, it is in the midst of engineering studies on a project to produce the equivalent of 60,000 barrels per day of gases and associated liquids from East Texas lignite. Also, despite the fact that Exxon does not think other coal conversion technologies are competitive now, coal plays a central role in Exxon's long-range plans. Some years ago the company began a grass roots program to build coal production. By the middle of the decade it expects to be producing 25 to 30 million tons per year in the U. S. Abroad, Exxon is developing a coal project at Cerrejon in Colombia to produce 15 million tons per year of high-quality thermal coal.

Many of us at Exxon Research and Engineering are optimistic that in not too many years Exxon will be liquefying some of this coal production in a commercial plant utilizing the Exxon Donor Solvent technology. My colleagues are reporting extensively on progress in commercializing this technology. So I will confine myself to noting that we have passed a major milestone with the successful completion of some 3,900 hours of testing of Illinois coal at the project's 250-ton-per-day pilot plant in Baytown, Texas. Incidentally, we have also tried Pittsburgh seam coal in smaller pilot plants. The results suggest that it is a good coal for liquefaction in the process.

As I said, the DOE has reduced its funding of the project by $17 million. As a result, the project sponsors have dropped a large-scale effort to adapt an Exxon petroleum coking technology to liquefaction bottoms processing and substituted a more modest program to evaluate other alternatives. In line with my earlier comments, this may delay commercialization, but it may yield a more attractive technology in the long run.

As for high BTU gas, by 1985 Exxon is planning to start up a 100-ton-per-day pilot plant in Rotterdam, the centerpiece of a more than $500 million project to develop an Exxon catalytic process for converting coal to methane.

In sum, Exxon is attempting to move into the synthetic fuels era along a broad front. In research and development, the strategy is tailored accordingly -- emphasizing a diversity of approaches in a diversity of technical areas.

Intensifying Role of Science, Technology and Engineering

In considering the synfuels outlook I have stressed the intensifying role of science, technology and engineering. Now let me probe the particulars a little more deeply -- beginning with engineering, specifically project engineering.

The multi-billion dollar "mega-project" is a fixed feature of the energy landscape today, but nowhere more than in synfuels. With a "typical" 50,000 barrel-a-day synfuels plant expected to cost some $4 billion, the energy industry is facing higher risks and a more urgent need to control project costs than at any time in its history.

Just a word on one of the more obvious risks, governments. Since the pyramids and the Great Wall of China, right through the days of the Panama Canal and the trips to the moon, mega-projects have been traditionally the province of governments. And with good reason: governments make the rules, companies live by them. Governments don't need to be self-supporting, companies do. Finally -- and this is my central point -- governments levy taxes, companies pay them. With inflation rates of even a "modest" 10 percent, a mega-project that is only profitable in real terms, will be netting several times the original investment in inflated money during its later years. This creates the illusion of high profitability and is a very tempting tax target for politicians who can conveniently ignore inflationary effects and the time-value of money.

But the challenge goes far beyond the risks posed by huge front-end costs. First of all, there is the difficulty of forecasting these costs with sufficient accuracy to permit managers to make prudent investment decisions. We have seen some chronic underestimating, a problem rendered all the more acute by the nature of synfuel technologies. In synfuels we're installing processing technologies which are first of their kind at the scale contemplated. Optimization of the entire plant complex is more critical than when capital costs per daily barrel were not so high. It is clear that to forecast and control costs in the synfuels era will require uncommon ingenuity by engineers and project planners to define projects that are both technically and economically feasible.

Two other tasks turn out to be critical in managing mega-projects: assembling and coordinating engineering manpower, and managing the construction force. Synfuels mega-projects will typically require three to ten million hours of engineering -- exceeding the resources any single engineering office can, or would want to assign to a single project. With an alert project management team, we think the challenge of coordinating the efforts of several contractors is a manageable one.

Construction labor poses more difficulty. High attrition rates and low productivity make a very unpalatable combination and both are to be expected in the remote areas where many synfuels projects will be constructed. As an example, the Syncrude Project called for a peak construction force of some 8,000. Yet during the 4 1/2 years of construction, high turnover forced management to hire 60,000 people, averaging 1,100 per month -- with a peak hiring rate of 3,000 per month.

Commercial success will depend heavily upon how well the industry improves techniques of project definition and management. Still, in establishing the synfuels industry the cost-control battle in the laboratory and at the pilot plants will be as critical as the cost-control battle on the project. Remember that many of today's technical approaches hark back to science as much as fifty years old. This suggests that modern science and adept researchers will find ways to leap-frog current technologies. In fact, the real future of the synfuels industry may well lie in second and third generation technologies that sharply reduce energy and capital requirements.

Let me illustrate this point by referring to work by one of our scientists, Dr. Lonnie Vernon. Both scientific and engineering research have intertwined during all phases of the Exxon Coal Liquefaction Project. Beginning in the late sixties, Vernon used model molecules to confirm the conventional wisdom of the time that, in liquefaction, pyrolytic cracking of low strength bonds in coal forms free radicals that abstract hydrogen from the donor solvent. Then, in later studies he went on to show something new: that the molecular process hydrogen actually enters into the free radical reactions, forming hydrogen atoms that are themselves free radicals. These atomic hydrogen free radicals furnish another mechanism for liquefaction, by attacking bonds in the coal molecules that are too strong to break thermally at process temperatures. Vernon's findings have proved useful -- for example, in pilot plant work studying the effect of hydrogen pressure on yields, gas make, solvent degradation and so on. The findings have also given us interesting leads for exploratory research aimed at fundamentally improving liquefaction technology.

More wide-ranging study of coal and oil shale chemistry offers further, tantalizing possibilities. In recent years science has learned much about the molecules in coal and the various bonds holding them together. We are beginning to do the same for shale. But even now we possess no really good ways of predicting how different shales and coals will respond to specific conversion technologies, without expensive empirical investigations in pilot plants. Given more sophisticated chemistry, we may be able to shorten this process and find ways to break molecular bonds in coal and shale more selectively -- at much lower temperatures and pressures than in current processes. Industry can reap large rewards through discovering practical methods for taking coal and shale apart with a chemical scalpel rather than the sledgehammer used today.

The field of catalysis holds as much or more promise. Catalysis is to the petroleum and chemicals industry what solid state science is to the communications industry. And we might see innovation at a rate approaching that in micro-electronics, if research continues to support the momentum that is now carrying catalysis from black art to science and, one day, to engineering discipline. Through high-resolution electron microscopy adapted specially for the task, we're beginning to observe directly what is happening on the catalytic surface. This work by Dr. Terry Baker using the Controlled Atmosphere Electron Microscope was described recently in Physics Today. If we can define precisely the relationship between the structure of catalytic surfaces and the reactions that they induce, and at what rates, we may one day be in a position to design catalysts to order, with virtually any specificity desired.

There are many promising applications for improved catalysts. One that springs immediately to mind is in Exxon's catalytic coal gasification process now approaching the large pilot plant stage. The process yields methane in a single gasifier, providing a heat-balanced operation that translates into important savings in capital and operating costs. But kinetic theory suggests that, with a better catalyst, lower temperatures and far greater savings may be possible. Fischer-Tropsch chemistry is another example. A synfuels producer would obtain immediate, significant benefits from a repertoire of catalysts that would selectively synthesize specific ranges of hydrocarbons from the carbon monoxide mixtures produced in commercial coal gasification processes like the Lurgi.

The Clean Air Act is now undergoing its legally mandated review by Congress. But I won't comment on regulatory matters any further this evening, beyond pointing to the useful role that better science and technology can play here as well. It is a poorly kept secret that many environmental standards have been set in an arbitrary relationship, if not at odds with the scientific findings, if any -- for example, the air quality regulations that affect pristine areas like Colorado shale country. The nation will have to reconcile its environmental goals with its economic and energy goals, and science can help define the tradeoffs.

Conclusion

In conclusion, while the current Administration's position may seem discouraging to some people, the long-term question is not whether synthetic fuels will enter the energy mix, but when. Successful efforts in the new industry will be marked by far-sighted risk-taking, competitiveness, and enlightened cooperation among industry, government and citizens. Government leadership will be especially important in creating the right economic and social climate. And excellence in science, technology and engineering remains the ace in the hole for winning the way through the energy transition ahead.

Today's energy crisis is really nothing new. Industry has met and mastered several already and has every prospect of doing the same again. Many of those who worry the question have in mind the wrong paradigm, something like the Mad Tea Party in Alice in Wonderland. When the tea and cakes were exhausted at one seat, the natural thing for the Mad Hatter and the March Hare was to move on and occupy the next seat. When Alice inquired what would happen when they came around to their original positions again . . . . the March Hare changed the subject.

Obviously, the Mad Hatter philosophy ignores the creative powers of the scientific and engineering intellect. True, the oil and gas will run out one day. But men and women like you, backed by far-sighted and resolute managements, will keep the table full by replacing those resources with the fruits of new knowledge and information.

Synthetic fuels from coal is not a dead area, but heading toward a new era. Many firms are moving strongly forward with research, development and commercial demonstration. Without subsidies, progress may be slower, but results may be sounder. Coal synthetics represent a promising frontier, and there is an urgent desire among scientists and engineers to push it back. As a result, they may transform not just the energy industry but the auto industry as well. It won't be easy . . . .but then pioneering never is.