Future Sources of Organic Raw Materials

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The contribution of the chemical industry to society can be assessed in various ways. On a worldwide basis, the industry provides an estimated 5 million jobs and contributes the equivalent in U.S. dollars of $300 billion to gross world product. If one includes the jobs and output of the industries that purchase chemical products, and cannot operate otherwise, the importance of the chemical industry increases. In fact it is not possible to run a modern, international economic system unless this particular industry, among others, is able to make its contribution.

Summary. Industrial organizations, academic institutions, and national governments should agree on the cooperative roles each will play in planning the decades-ahead raw materials needs of the chemical industry, which is vital to a modern, international economic system. The raw material future of the industry depends as much on political and social concerns as it does on technical and economic considerations. The generation in charge now cannot in good conscience go on consuming the world's supply of hydrocarbons and not acknowledge a duty to generations that will follow.

The value of the chemical industry can also be assessed by the amount that chemical technology adds to raw materials. Oil at today's price of $12 to $15 a barrel is worth five times that much by the time it is synthesized into polymers such as the large-volume plastics. It is valued at ten times as much when made into fibers, and 100 times as much if converted into agricultural chemicals or photosensitive materials such as x-ray film.

In a number of applications, it is more efficient to use chemical synthetics than to return to older products. For instance, the manufacture of some products would actually consume more energy if a switch was made from plastics back to metal. An example is the molded, glass-reinforced nylon lock housing for automobile steering columns, which requires a minimum of 35 percent less energy to produce than die-cast zinc, and also requires less finishing and weighs less. The same is true for man-made fibers. Manufacture of an all-cotton shirt requires 88 percent more energy than that required for a shirt containing a blend of 65 percent polyester and 35 percent cotton (*1*).

The chemical industry in its present form is built on energy and feedstocks from oil and natural gas, and there is in the short-term no practical way to make today's broad range of chemical products without these materials.

But in spite of this dependence on petroleum, the chemical industry's consumption of feedstocks accounts for only about 3 percent of the world total demand for oil and gas. One might therefore assume that the industry will get all the raw materials it needs, at least until the wells run dry. However, this would be a safe assumption only if the markets for petroleum were completely open. But oil and gas do not trade in such a market. The flow is moderated and in some cases completely controlled by governments, and economics is only one of the rationales for decisions.

The questions that concern us thus fall into a broad domain of national and international policy, where the governments of the world have much more influence than do scientists, academicians, or industrialists. Decisions on resources are based as much on political and social concerns as on the technical and economic facts.

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Problems to Be Faced

In considering the future of the chemical industry, we should consider our raw materials needs as part of an overall package that includes energy; we should consider the degree of importance the public attaches to the chemical industry's products; and then we should ask what steps should be taken by us and others.

It is useful to examine the problem of energy supply in three different time frames.

1) Over the next decade we can expect the supply of oil and gas to be in reasonable balance with demand on a worldwide basis. There will probably be local problems to test our patience and statesmanship, but our major effort should be in preparing for the years that will follow.

2) The second time frame begins in the late 1980's or the 1990's, which will mark the beginning of the energy transition period. To meet world needs we will look to conservation; the use of additional liquid hydrocarbons from coal, shale oil, tars, and heavy oils; and nuclear energy generation. It would not be economical for the chemical industry to rebase all its manufacturing processes during this period. Oil and gas should still be available for synthesis.

3) Energy requirements beyond the year 2000 indicate a need to turn to fusion and to extensive use of solar energy and biomass, to reduce demands on fossil resources. It is assumed that by then the chemical industry will be drawing more on coal as the initial source of its hydrocarbons, and less on what remains of the oil and natural gas.

Every major nation will admit to having problems with programs that relate to one or another of these time frames. In the United States we admit to having problems with all of them, and our experiences illustrate the predicaments that many other nations will face in coming to grips with resource problems.

One such predicament is research. If we need dramatic new technologies to meet the next century's energy needs, the fundamental scientific work should be under way now. Yet in recent years this area of research has been treated less generously than almost any other. There is widespread concern that a disproportionate amount of support for R & D goes to short-term applications, and that the investment in academic science is too low. Scientists report that it is often harder to get a few thousand dollars for a long-range, academic project than it is to get many times as much mon-

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ey for a developmental project with a more predictable outcome. That may be understandable, but it is not very farsighted.

Projects with a shorter lead time—say a decade instead of a generation—face their own set of constraints, mostly economic. An expansion of the resource base will require massive investments both to build new facilities, such as coal gasification plants, and to pay for conservation technologies. In the United States the chemical industry has a goal of a 14 percent reduction by 1980 of its energy use per unit of output. Once that goal is reached increasing amounts of capital will be necessary for additional conservation.

Need for Understanding

There is a clear need for a better public understanding of the resource outlook and options and of the sacrifices that ought to be made to meet future needs. The true costs will have to be met sooner or later, and this is not now sufficiently understood. If government policies are confused, they reflect the fact that the public itself is confused and is sending contradictory signals to its political leaders.

As a step toward rectifying this situation, the chemical industry and its related technologies would do well to develop an educational program to explain the long-term resource problem, to point out how dependent modern civilization is on the chemical industry, and to make clear that priorities and a sense of responsibility are required to avoid very serious problems in the future.

An attempt should also be made to clarify the roles of the government and other groups, so that each is handling the resource assignments it is best qualified to handle. In nations with a well-developed private industrial sector, industry can be more efficient than government in developing and delivering new technology, and academic institutions can make important contributions. Once the resource goals are defined, the most effective action that governments can take is to turn over as much as possible of the task to industry and the universities.

Role of Government

What people in industry and academic life cannot do, and only governments can do, is to create the policies and climate conducive to the achievement of national goals, and harmonize the actions of various government units so that the goals can be achieved.

It is in this area above all that we must look for more responsible governmental leadership. The problems are admittedly complex and difficult, and each national government will approach them in its own way; but the questions to be resolved are more or less the same for all.

Whatever the form of government a nation may have, its ability to cope with resource problems is linked to the health and vigor in its economy. Therefore, the first question is whether government policies lead toward a strong future economic base, or are trading that away for short-term expedients.

In the case of more specific resource needs, if the objective calls for a large investment by the private sector in a developing technology—say coal gasification or liquefaction—then the question is whether government policies make such investments attractive or unattractive.

We must also reexamine old policies in terms of current needs. Whatever the merits or justification for various laws and regulations when they came into being, we should ask how appropriate and timely they are now. For example, perhaps the antitrust codes need to be examined to see if they discourage the kinds of cooperative efforts that ought to be mounted.

Patent codes also come into question. Is the life-span of a patent long enough to encourage innovation? Does experience show that inventions of value can withstand infringement or other challenges, or are they being undercut by administrative and judicial rulings? If they are being undercut, the incentive for R & D may evaporate. Are the codes consistent from one country to another? The European Economic Community countries are now working toward a common code, a development that should be followed with great interest in the United States.

Trade-Offs

Questions of trade-off can be found in almost any area involving governments and resources. Environmental protection is a good example. Is a nation reaching for goals in this area—perhaps very desirable goals—but doing it in such a way as to block equally worthy programs related to resource development?

One of the main problems in debates about trade-offs is the absence of a body of credible, agreed-upon facts. There are separate reports and bits of data coming into government from different sources, but these do not add up to a coherent whole. Moreover, some of the positions taken are obviously partisan and not very persuasive.

What is needed, I suggest, is a broader role for the academic institutions. They could work across the disciplinary boundaries, look at the interlocking economic and political factors as well as the technical data coming from scientists and engineers, and try to set forth in a rational way the options that exist and the consequences of each. All sorts of institutions would have a hand in generating such trade-off profiles, but the universities are the obvious center pin because they can bring objectivity as well as high talent to the task.

Need for Cooperative Efforts

There are many ways for industry, government, and the universities to cooperate more actively on resource conservation and development projects. Let us look at similar ventures in the past. Putting a man on the moon was a national objective, regardless of cost, set by President Kennedy. Government set the goal and provided the resources. Academe contributed not only theoretical knowledge but also some operational development. A professor of psychology from the University of Michigan, for example, developed a method and put together a team for selecting astronauts. Meanwhile, industry produced the hardware and managed the project. And it worked.

An example from the World War II period is the development of synthetic rubber. Research and development had been under way for a number of years on various kinds of substitutes for natural rubber. As the war spread, it became apparent that an alternative—in quantity—was vital. Government gave it priority, financed the research of scientists, provided funds, and facilitated the process. Industry built the plants and managed the production.

Both of these cases illustrate cooperation among industry, government, and the universities in major national, and even international purposes. Cooperative efforts of this kind ought to be encouraged today.

When the risks and costs are too great for an individual company, there are a number of options open—joint ventures, tax relief, subsidies to R & D or capital projects, or a price floor under substitute raw materials where a business cannot trust the forecasting process because it can so easily be short-circuited by political events. Canada has devised a system whereby deductions are allowed for oil and gas exploration and development up to full cost plus two-thirds. I would urge that similar treatment be considered for R & D programs for new energy sources. Partnerships and cooperative ventures will work best, however, if they fall under clear, consistent, dependable governmental policies. We all need to know what the ground rules will be.

Conclusions

It is clear that the chemical industry should stop lamenting the decline of research and put more resources into it; not merely into projects promising to pay out in a decade or so, important as those are, but also into projects which will pay out after most of us are gone from the scene.

Some of this research can be done in industry and contract laboratories; much of it fits more logically into the universities. Wherever it is done, the important thing is that the work be given a wide range, and not be pointed only at obvious targets.

More research should be done that might have a bearing on chemical feedstock needs in the next century. Some examples would be basic research on the structure and chemistry of coal and research to help take the pressure off petroleum and coal as energy stocks—through fusion power and large-scale conversion of solar energy to electricity.

The only prediction it is safe to make about such projects is that the percentage of hits will be low and some people will be quick to criticize because the research is not relevant to current needs. All the same, this is a necessary type of investment, and the stakes are too high for the industry to be stingy. Basic research is not that expensive, and the nations of the world can afford to put a lot of eggs in a lot of baskets, and watch them all.

The generation in charge now can not in good conscience go on consuming the world's supply of hydrocarbons, and not acknowledge a duty to the generations that will follow. Thus we must work together across the boundaries of nations and institutions, through research, through development, and through education, to be responsible stewards of the raw materials at hand, and to create new resources for the future.

References

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NEWS AND COMMENT

Technology Creep and the Arms Race: Two Future Arms Control Problems

This is the last of three articles about the impact of technology on the arms race.

Military policy debates in the United States have usually revolved around perceived major dislocations in the U.S.-Soviet balance—often around some supposed new threat to U.S. forces and the question of whether to deploy a big, expensive weapon system in response. In fact, this preoccupation with major decision points has inspired an entire literature perpetrating the view that the arms race escalates through a set of well-defined steps, up which the leaders of the United States and the Soviet Union deliberately tread.

Overlooked in the cliché, however, is the possibility that the arms escalator moves upward of its own accord, too. In the vast majority of U.S. military programs, which are neither very new nor very large, lower level bureaucrats, project managers and engineers, and systems commanders are constantly trying to find ways to make their weapons systems better. And this cumulative pressure for change can sometimes transform the capabilities of a system in unexpected or dramatic ways. Finally, both political leaders and the public often are unaware of this process of technology creep, or its implications in any particular case.

Another contrast between the notion of the arms staircase and that of technology creep is the question of motive. In the conventional view, political leaders make deliberate decisions to escalate the race, and thus by the same logic have the option to step down, or deescalate. But the race may be propelled as much by a few good or evil decisions as by human nature in general: it is hard to imagine the scientist who will not advertise the implications of his work, or the project engineer loath to incorporate improvements, or the military planning officer who does not want a system to work more smoothly, accurately, or faster.

As Herbert F. York, a former director of Lawrence Livermore Laboratory and a previous director of Pentagon research, has written of the U.S. contribution to the arms race, "The root of the problem has not been maliciousness but rather a sort of technological exuberance that has overwhelmed other factors."

The most urgent current example of technology creep is the gradual improvement in intercontinental ballistic missile (ICBM) accuracy over the last decade, which promises to bring the missile forces of both the United States and the Soviet Union to the point of having a destabilizing first-strike capability in the 1980's. This problem has become the touchstone for a major national debate over the future of the U.S. land-based missile force, and was the subject of the first two articles in this series (*Science*, 22 September, p. 1102, and 29 September, p. 1192).

There are two other, less well known cases of technology creep that may become the subjects of future national debates. One is the work in ballistic missile defense and antisatellite systems, which could make antiballistic missile (ABM) defense seem practical and could spark pressure to change the 1972 treaty by which the United States and the Soviet Union renounced virtually all deployment of ABM systems. The second case is arising from modernization of U.S. space satellites. Modernization is turning these peaceful systems into both peace and wartime tools and perhaps is the incentive for the Soviet antisatellite drive. Modernization of space technology may be fueling the very arms race that U.S. policy has tried to avoid.

The military programs from which these capabilities spring are not necessarily expensive. They are programs that the public decided long ago were desirable. None has had much publicity lately, partly because of a widespread belief that nothing has changed. So these pro-

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