UTILIZATION OF PETROLEUM AND PETROLEUM PRODUCTS

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Petroleum has been utilized by man throughout most of his stay on this planet. An ancient Babylonian tablet reports, for example, that Noah calked his Ark with bitumen. This story suggests that petroleum was used before the advent of recorded history(3). Up until fairly recent times, however, crude oil and its products were quite scarce and its consumption was limited.

In the mid-1800's, the oil industry as we now know it emerged. This development was made possible when Colonel Drake improved the technology then in use for drilling salt wells and drilled instead for oil in 1859. The Drake well, which was the first well deliberately drilled for oil, was successful and resulted in production of eight to ten barrels of oil a day. As Colonel Drake's approach came into widespread use, crude oil production rose rapidly and during the next year total domestic crude oil production was 500,000 barrels. One year later over two million barrels were produced. The costs of crude oil declined sharply as production rose, and petroleum utilization increased rapidly.

The broad expansion of oil markets that came about after 1859 was made possible by many factors including: (1) high and rising prices for animal and vegetable oils, (2) a radically improved technique of exploration and production, and (3) improved techniques of utilization. This experience illustrates the fact that the utilization of petroleum is the resultant of a wide variety of forces which ultimately make themselves felt in the market place. The equilibrium achieved, however, is quite fragile and changes in the underlying forces lead to continued and sometimes rapid shifts in utilization patterns. Hence, in discussing utilization, it is not sufficient to consider existing or potential technology of oil consumption alone. It is also necessary to indicate the effects of potential changes in supply and of new competitive forces. Any projection of utilization must contain, at least implicitly, some assumptions about future supply and competing technology as these factors can have important consequences today. Thus an anticipated shortage of a particular form of energy some years in the future leads consumers to begin searching for ways to economize in the use of the resource or to convert to alternate sources today. Producers begin to look for new supplies or to improve methods of producing known deposits. Producers of competing fuels search for ways to substitute their products for the one in short supply. All of these activities tend to delay or to prevent an actual scarcity.

This point is well illustrated in the case of petroleum. The rapid rise in crude oil production after the Drake discovery led to increasing fears that the industry would be unable to continue meeting the demands being made upon it. In 1909, when the industry was a mature half century old, the U. S. Geological Survey expressed the fear that the nation's petroleum resources would soon prove inadequate to meet the needs of industry and suggested further that, in the face of approaching scarcity, petroleum should be limited to uses where there were no reasonable substitutes such as lubrication and illumination(5). The introduction of geological techniques to the oil-finding process around the turn of the century, however, eventually ushered in a new era of oil discovery which prevented the anticipated scarcity from developing.

The rapid acceptance and growth in the use of the automobile led to an even greater demand on resources and the cry of forthcoming shortage was again heard through the land. A leading professor of engineering here in Michigan typified this view when he stated in 1920 that the gasoline powered vehicle would have to be abandoned by 1940 at the latest because of a shortage of petroleum(1). The subsequent introduction of geophysical techniques and their gradual improvement ushered in an era of discoveries so great, however, that within a fairly short period overproduction, not shortage, became the major problem.

The forecasts of shortage just cited were not isolated events. Competent authorities have forecast impending scarcity almost since the inception of the oil industry. The important point is that the threat of scarcity so stimulated research that shortages were effectively forestalled. Furthermore, research was continuing simultaneously on a wide variety of substitutes, which could conceivably have filled the gap, at no dramatic increase in cost, if oil resources had not kept pace with requirements. Developments in these areas have influenced utilization at least as much as have technical improvements in the consumption of energy.

TECHNOLOGY OF PETROLEUM UTILIZATION

In reviewing present and potential utilization patterns, it is useful to begin with the current state of consuming technology and the developments which appear most likely to occur in the near term future. This technology enables us to make a reasonable estimate of the demands which will be made on resources over the period of a decade or two. Using our present knowledge of the nation's resources we can then determine whether or not the demand pattern appears reasonable and, if not, we can adjust it as necessary.

In the longer term future our ability to predict is increasingly inaccurate, and we do not have a clear picture today of the technology or the resources which will be available more than about twenty years from now. The repeated groundless fears of shortage in the past indicate that it is probably unwise to determine capital budgets, formulate research policy, or even establish national policies on the basis of developments which are anticipated more than twenty years or so in the future. Longer range forecasts serve to indicate potential trouble spots which should be watched, but they do not serve as a reliable guide for policy today.

In projecting future demand patterns it is also necessary to make some explicit or implicit assumptions about the relative prices of fuels. For the present we shall assume that relative prices will be unchanged for the foreseeable future. Subsequently we shall inquire whether this assumption is reasonable or whether there are factors which would make petroleum increasingly costly relative to competing fuels and which would hence necessitate a modification of the projection.

Transportation

In the United States approximately 50 per cent of all the oil consumed is used in the transportation sector. Oil has over 90 per cent of this market. Abroad, these percentages are probably somewhat lower, but they are not radically different from the levels prevailing in the U. S. Since oil cannot increase appreciably its market share, its growth in this market is essentially limited to the overall growth in the transportation sector.

There are a wide variety of technological developments which could have an impact on the transportation market. For personal transportation, however, there appears to be little threat to the hydrocarbon powered vehicle, at least for the

next twenty years. Most of the devices which might compete with the gasoline-powered piston engine are hydrocarbon engines themselves. Among these are the gas turbine; the light-weight, high-speed diesel engine; the stratified charge engine; the free-piston engine; the Stirling engine; and the NSU rotary combustion engine. Based on present information, none of these engines presents a major threat to the gasoline piston engine, although highway diesel use is growing. In the longer run, there may be some shift toward the stratified charge and the gas turbine engine. None of these changes, however, would seriously affect the total demand for hydrocarbons although they might necessitate a shift away from gasoline toward middle distillates in the refining process.

It is possible that the battery or fuel cell may replace the gasoline piston engine in a limited number of special vehicles primarily used for city driving. The probability of this development appears quite small, however. Either device would require a technological breakthrough to be economic and, even if such a breakthrough should occur, these devices probably would not capture a large segment of the private transportation market in the foreseeable future. Furthermore, a workable fuel cell has a reasonable probability of requiring hydrocarbons as a fuel. For these reasons, it is not considered likely that either battery or fuel cell powered automobiles will have a significant impact on petroleum demand for the next twenty years although they could affect demand in the longer run.

Railroads are another segment of the transportation market in which oil is dominant. The rapidity with which the railroads converted to diesels following World War II shows that significant changes can take place in short periods of time. The major threat to oil in this market is electrification. This threat is more potential than real for the foreseeable future, however, as substantial new electrification projects probably cannot be justified in the U. S. until such time as railroad mergers and rerouting of lines result in higher traffic density. Gas turbines may ultimately replace diesels in some railroad applications but, in any event, most of this market appears to be secure for hydrocarbons for at least twenty years and probably much longer.

In the area of marine transportation the major threat to oil comes from nuclear energy. Although it is unlikely that nuclear energy can compete economically with hydrocarbon engines in the U. S. in private marine transportation over the next twenty years, it will be of growing importance in military applications. Abroad, introduction of nuclear energy in marine transportation will probably be inhibited by capital limitations.

The aviation market appears quite safe for hydrocarbons in the years ahead. The rapidity with which the gas turbine replaced the piston engine in this market argues strongly against oil industry complacency, but the technological developments in the offing do not appear to be of a nature to challenge oil's dominance of this market.

The future of oil in the important transportation sector can be readily summarized as follows:

1. Because of oil's overwhelming position in the transportation market, its growth in this area will be largely limited by the growth of the market, particularly in the U. S. The additional volumes which will be consumed in this sector in the U. S. will be quite large, but the annual average growth rate here will be somewhat lower than the growth rates anticipated abroad.

2. There are no new technological developments in sight which seriously threaten hydrocarbon fuels in the transportation market in the foreseeable future.

3. There may be shifts in demand away from gasoline toward middle distillates in the U. S., but any such shifts are expected to be gradual and are not expected to affect the overall demand for petroleum significantly.

Industry and Power Plant Use

General industry and power plant use constitute a second market for oil. Most of the petroleum fuel supplied to this market is in the form of heavy fuel oil. In the U. S. oil is not a major factor in this segment. It accounts for about 7 per cent of the steam electric power plant fuel used by utilities and about 13 per cent of the manufacturers' heat and power market. In addition to these uses, oil will be of increasing importance in specialized industrial uses. For example, a pound of oil can displace 1.6 pounds of coke in blast furnaces with significant savings. Ore reduction and fertilizer manufacture also represent large potential markets for oil.

The future of oil in the industrial markets of the U. S. is determined by factors other than technology of utilization, however. The domestic production of heavy fuel oil is declining as refiners continually improve their yield patterns and it is now equal to only about one half of domestic consumption. Imports of heavy fuel oil, which make up the balance, are limited by the Oil Imports Administration in such a manner that the total domestic supply of heavy fuel oil has been held fairly constant since the inception of the program. It is, of course, impossible to project with confidence the import policies of the future, but it is clear that if the controls limit the supply to a fixed level, as they have in the past, they will serve to prevent increased industrial oil consumption in the U. S. as a result of either normal growth or of new technology. Furthermore, widespread improvements in transporting coal will probably result in some further reduction in delivered coal prices which will make coal more competitive. Abroad, however, there is quite a different story. Oil will be increasingly important to general industry and, for the foreseeable future, rapid expansion in the generation of electricity will increase the demand for oil despite probable nuclear developments. Coal costs will continue to rise in Europe and there is some hope for reducing the punitive excise taxes levied against heavy fuel oil in much of Europe today. As a result, oil should become increasingly competitive outside the U. S.

Residential and Commercial Consumption

The residential and commercial sector is another major petroleum market. Gas dominates the space heating component, however, and electricity is the major factor in the air cooling segment. Oil--largely in the form of middle distillates --supplies about one third of the total energy consumed in this market.

Oil's share of the space heating market is under attack by both natural gas and electricity, particularly in multi-unit dwellings. Natural gas has accounted for most of the growth of this market in recent years but electricity is a growing threat to both gas and oil. More new homes were heated by gas than electricity last year and more were heated by electricity than by oil.

Further threats to oil's position in the residential and commercial market are posed by research on thermoelectric heating and cooling and on gas-fired absorption cycle combination heating-cooling units. On the other hand, oil's position is being strengthened by research on oil-fired absorption cycle units and hydrocarbon fuel cells which can be used to supply electricity to individual residences or to groups of consumers in limited areas.

A significant technological breakthrough would be required before any of these potential new uses would be able to alter utilization patterns appreciably and it

is not at all clear today what the net effect on petroleum demand is likely to be. It is also worthwhile to note that given the assumption of adequate resources and no significant changes in relative prices, there is no overwhelming national urgency for conducting such research as far as civilian uses are concerned.

Total Petroleum Demand

Most students of the petroleum industry are in agreement that if there are no unforeseen technological breakthroughs by oil or by competing forms of energy and if relative energy prices remain essentially unchanged, petroleum demand will grow in the United States at 2 to 3 per cent a year over the next decade or two. In foreign areas, where the growth potential is greater and where supply is less likely to be directly limited by import controls, petroleum demand already exceeds that of the U. S. and annual growth rates will be about twice as great as those expected in the U. S.

ADEQUACY OF SUPPLY

The demand projections of the previous section are predicated on the assumption of no change in relative prices. If, however, petroleum resources should prove inadequate to meet expected demand and if prices should rise, the future demand patterns would diverge from the projected levels. It is important, therefore, to balance projected demand against the resources which can be made available during the period in question.

If the domestic consumption of petroleum products should grow at the indicated upper level of 3 per cent a year, total consumption would exceed 100 billion barrels during the next twenty years. The resulting draft on domestic resources would depend on the administration of the import control program and the amount of natural gas liquids produced, but it is not unreasonable to assume that the projected demand pattern implies the production of 70 to 80 billion barrels of domestic crude oil during the next two decades. The domestic industry had not produced quite this much oil after the first century of its existence. Is it likely that it can produce this huge quantity in the next twenty years or are the pessimists, who feel this is an impossible burden, correct? Even if it is physically possible to produce this volume, can it be done at competitive prices? Given the assumption of an unchanged import program, these questions must be answered in the affirmative if the preceding demand projection is to be accepted.

One's answer to these questions depends on his estimate of the petroleum content of known petroleum reservoirs and those to be discovered during the forecast period, on the quality of these reservoirs and on future developments in techniques of production.

One highly competent authority has estimated that the domestic industry can develop at least 70 billion barrels of reserves in the next two decades from fields which have already been found and from fields which will be found on acreage which is already partially explored and is currently under lease(4). I see no reason to challenge this view. It must also be kept in mind that the nation's potentially productive sediments are far from explored. Another authority has estimated that less than one fifth of the nation's potentially productive sediments have been explored with any degree of thoroughness(6).

It would be most unwise to write off in advance these unexplored sediments as unproductive. Many potentially productive areas have been subject to little if any reconnaissance exploration. Furthermore, the sensitivity of our existing exploratory tools is such that we are frequently unable to locate valuable deposits by surface efforts alone. In particular, we are generally unable to locate strat-

igraphic traps through such surface efforts and some of the world's largest known fields have been found in such traps. As we extend our efforts to the largely unexplored areas, as we gather additional information through drilling in all areas, and as we continually improve the accuracy of our geophysical equipment it is almost inevitable that we shall discover additional large volumes of oil. Furthermore, there is every reason to believe that we shall be able to continue the long evident trend of increasing recovery of oil in place.

There is thus no convincing evidence that a physical scarcity of resources will inhibit petroleum production in the foreseeable future. Oil whose presence is already known or whose existence may be logically inferred is adequate for twenty years of consumption. In addition much more oil, whose existence can only be conjectured today, will undoubtedly be found or made available through improved recovery. To the extent that such oil becomes available, the period when physical scarcity will begin to inhibit consumption will be deferred into the unascertainable future.

The oil shale deposits in the U. S. and the tar sands in Canada provide further assurance that resources will not be a limiting factor on petroleum utilization in the foreseeable future. Not only are these resources immense in terms of oil in place, but large volumes of oil can probably be produced from them profitably at prices which are nearly competitive with crude oil.

Resources outside the U. S. are even more plentiful relative to demand than in the U. S. Thus there is less likelihood of shortage abroad than in the U. S. Furthermore, the discussion of U. S. resource adequacy assumed continuation of import regulations similar to those in effect today. If for some reason oil should not be found in anticipated volumes in this nation, import controls could be relaxed. Total free world resources are undoubtedly quite adequate to meet all anticipated demands over the foreseeable future.

Although resources in total may not serve to limit utilization it is possible that exploitation of increasingly inferior resources in certain areas such as the U. S. could lead to rising costs which would, in turn, inhibit demand in those areas.

In the U. S., for example, there has been a clearly discernible pattern of drilling to greater depth and moving toward less accessible deposits--notably those under the Gulf of Mexico and the West Coast offshore. Thus, it might be presumed that increasing costs of production might soon lead to higher prices which would be a limiting factor on utilization even if physical presence of resources were not an applicable constraint.

Although the hypothesis of increasing unit costs resulting from depletion of the more economical resources appears reasonable on the surface, an important recent study by Resources for the Future casts serious doubt on its validity(2). Improved technology in exploration and production have, according to this study, more than offset those factors which otherwise would have led to rising costs. There is no evidence of a reversal in this trend as of today and no logical reason to posit one in the foreseeable future. Accordingly, it appears likely from what we know today that petroleum prices will not rise relative to all other prices in the forecast period. This conclusion is reinforced by the fact that shale oil would probably come into production quite rapidly were crude oil prices to rise appreciably. Thus the magnitude of our crude oil resource base combined with potential competition from shale oil and other fuels will quite probably serve to keep crude oil prices from rising appreciably in the U. S.

One potential threat to oil markets--and a further safety factor for hydrocarbon consumers--is the production of liquid fuels from coal. Research is

currently underway to develop economical techniques for producing such fuels from coal. To the extent that this research is successful it will, of course, reduce the demand for crude oil. There have been some interesting recent developments in coal liquefaction but, nevertheless, at present there is no convincing evidence that coal will displace any significant volume of petroleum in the liquid fuels market. This view is apparently fairly widespread since very few companies believe such research is sufficiently attractive to warrant the use of their own funds and the bulk of the work being done in this area is under Federal contract. Coal liquefaction is an interesting speculation but, given the information available today, it does not appear to pose a real threat to oil in the foreseeable future. Furthermore, if adequate supplies of all fuels will be forthcoming at no significant change in real prices over the foreseeable future, then there is little, if any, economic justification for federally sponsored research in this area.

CONCLUSIONS

The demand for petroleum products in the U. S. will probably grow at a rate of 2 or 3 per cent a year. Abroad, the annual growth rate will be perhaps twice as great as the rate in the U. S. Resources will not be a limiting factor either in the U. S. or the free world and there should be no significant shift in relative fuel prices in the foreseeable future.

It is unlikely that oil demand will be increased appreciably in the U. S. through research in utilization. Research on improved exploratory and productive techniques will probably have a greater influence on domestic oil demand than will research on oil utilization. Research on new uses is likely to have a much stronger influence on foreign utilization, however, than is the case within the U. S. The changes in oil utilization which appear most probable will not alter the growth rate of oil demand in the U. S. so much as its composition.

Finally, some research is being conducted today on the supposition that crude oil is in limited supply and hence that refined product prices are likely to rise in the near future relative to prices of competing fuels. Those undertaking research on these grounds are likely to be disappointed just as they have been in the past. Such research may represent an interesting speculation, but there is no overwhelming national urgency or profit incentive to develop substitutes for crude oil and its products.

LITERATURE CITED

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