Petrochemicals – Viable Raw Materials for Tomorrow's Soap and Detergent Industry?

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ABSTRACT

This paper attempts to address the complex question of petrochemical raw materials' future role in supplying the soap and detergent industry. The following points are emphasized: (a) The basic resource oil and natural gas, although not in unlimited quantities as in the past, will be available in the future. (b) The petrochemical industry will continue to receive its required share of the available petroleum resources, and the detergent industry will continue to receive the feedstocks they require. (c) The cost pressures which will be impacting the surfactant manufacturers will be similar to the overall inflation rates affecting the entire economy.

INTRODUCTION

With the high degree of interest that has been focused on the oil and petrochemical industries in recent times, it is most important for the manufacturers of soaps and detergents to ask some penetrating questions about the future of petrochemicals as raw materials. This discussion will attempt to answer these questions by first reviewing the basic petrochemicals involved in surfactant manufacture and projecting growth patterns of these surfactants. It will then evaluate the competing uses for the energy contained in the hydrocarbons that serve as raw materials for petrochemically derived surfactants. A look at the value added concept as it relates to the energy sector vs. the chemical feedstock sector will serve to illustrate why we believe the chemical industry must get its share of our limited petroleum resources. And finally, the future cost projections affecting petrochemically derived surfactants will be briefly examined. In this discussion the term petroleum refers to both oil and natural gas and is used interchangeably.

BASIC PETROCHEMICAL RAW MATERIALS

There are three major petroleum-derived raw materials that serve as the basic building blocks for the manufacture of various surfactants – ethylene, benzene, and normal paraffins. Although olefins derived from wax cracking play a major role in the manufacture of surfactants in Europe, they are only a minor factor in the U.S. and, therefore, are excluded from this discussion.

The manufacturing process begins with crude oil being fed into the refinery, where it is separated into a variety of intermediate hydrocarbon fractions (Fig. 1). The intermediate fractions of interest to the petrochemical industry such as gas oil, naphtha, kerosene, etc., are further processed either through an ethylene cracker, a benzene recovery unit, or a normal paraffin recovery unit to produce the basic feedstocks for the detergent industry.

Normal paraffin is a constituent of some crude oils, and by distillation followed by mole sieve operation, it can be separated from the other hydrocarbon streams. Paraffin has some advantage as a feedstock because it can be recovered by a relatively simple process; however, it has the disadvantage of being limited to certain crudes in finite amounts and in fixed carbon chain length ratios. Ethylene, on the other hand, does not exist in the natural state and must be produced by pyrolysis cracking of a heavier hydrocarbon requiring a relatively complex manufacturing process. However, ethylene manufacture provides versatility in feedstock requirements, and it has the added advantage of being capable of producing detergent intermediates in varying carbon chain length ratios through the use of ethylene growth technologies.

CONVERSION OF BASIC PETROCHEMICALS TO SURFACTANTS

Detergent manufacturers normally would not purchase raw materials in the form of ethylene, benzene, or normal paraffin, but rather as a surfactant. The downstreaming of the petrochemical feedstock into the various surfactants usually involves several intermediate manufacturing steps and must pass through a rather complex network prior to the production of the finished surfactant. Figure 2 illustrates a simplified schematic of the conversion of these

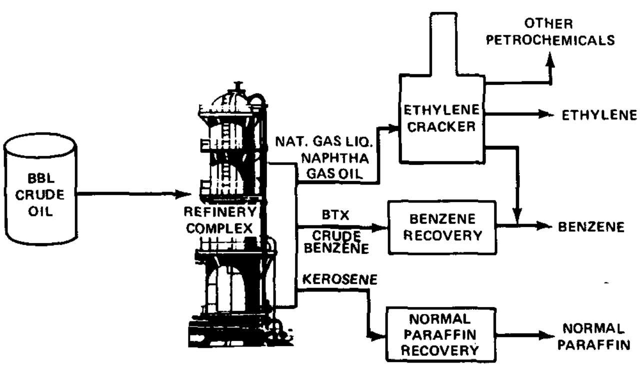

FIG. 1. Petrochemical building blocks for surfactant intermediates.

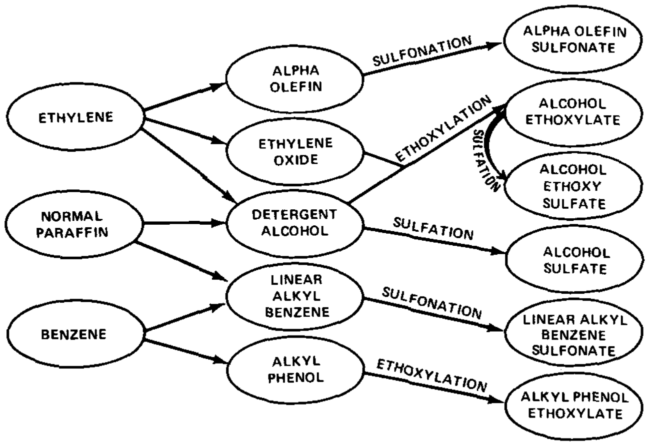

FIG. 2. Conversion of petrochemicals to surfactants.

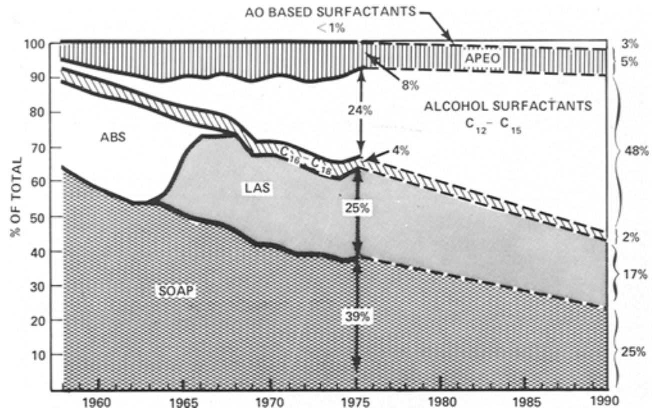

FIG. 3. Principal U.S. surfactant trends.

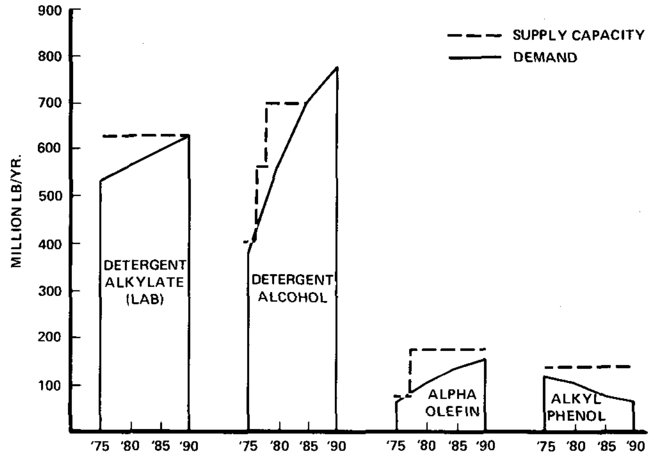

FIG. 4. Major hydrophobe supply/demand in U.S.

basic petrochemicals into surfactants for direct use by detergent manufacturers. Only major large volume surfactants derived from petrochemical feedstocks are illustrated here. Actually there are many other surfactants either now or potentially derived from petrochemicals which play important but smaller roles in the detergent industry, such as cationics and amphoterics.

Surfactant manufacturers process these large volume basic petrochemicals into intermediates such as detergent alcohols, alpha olefins, linear alkylbenzene, alkylphenols, and ethylene oxide. Further processing of these materials via ethoxylation, sulfation, or sulfonation converts them into the final surfactant products familiar to the detergent manufacturers. Full integration allows flexibility in the conversion of hydrocarbons into the basic petrochemical, surfactant intermediates, and the final surfactants themselves. This flexibility allows maximum utilization of resources and of the various by-products formed in the manufacturing process.

Nonintegrated surfactant suppliers, such as sulfators and ethoxylators, however, also play a key role in this network as they provide manufacturing specialization in either the production of the hydrophobe or of the ultimate surfactant.

SURFACTANT TRENDS

Changes in the market share for various surfactants in recent history and our projections of anticipated growth in the U.S. market have been combined in Figure 3. Several significant changes can be noted. There has been, and it is projected to continue, a loss in market share for natural soap. In the mid-1960s the switch occurred from branched alkylbenzene sulfonates (ABS) to linear alkylbenzene sulfonates (LAS) because of the latter's improved biodegradation properties. In the same time period there was very rapid growth in the demand for the detergent range alcohol-based surfactants. This increasing market share can be attributed to major reformulation trends, as the detergent manufacturers accommodate the changes in the laundry wash conditions and the continuing interest in providing the most environmentally acceptable products.

Natural soap will probably sustain its present level of production, while LAS is projected to have a slight annual growth rate of about 1% AAI (average annual increase). However, both soap and LAS are expected to lose market share to C_{12}-C_{15} alcohol derivatives which are projected to continue their significantly rapid rate of market penetration. Alpha olefin-derived surfactants are expected to achieve a 2-3% market share by 1990.

Products which are not expected to grow, and in fact should decline in usage, include alkylphenol ethoxylates and tallow alcohol sulfates (C_{16}-C_{18} alcohol-based).

SUPPLY/DEMAND PROJECTIONS

Figure 4 shows the U.S. supply/demand projections for the major hydrophobes through 1990. These projections are based upon the growth rates in the previous section, thus any change in these rates obviously affects the timing and/or need for additional capacity, the development and introduction of substitute surfactants, and/or changes in the detergent formulations. With this caveat, it is projected that recent expansions in the C_{12}-C_{15} alcohol production facilities should be adequate to fulfill the demand into the middle 1980s and that existing LAB capacity should be sufficient through the period under review.

To address the question concerning capacities for the basic petrochemicals, requirements for surfactant intermediates are compared in Table I to the total demand projections for these petrochemicals in the U.S. The 1990 requirement of 770,000 metric tons of ethylene is impressive; however, it is placed into somewhat better perspective when realizing it represents just 3.5% of the industry's total ethylene capacity. This is the same proportionate volume that was utilized in surfactant manufacture in 1975.

Surfactants represent the major outlet for normal paraffin, thus the percentage of total production is high; however, the increased volume required to meet the 1990 demand is small. Benzene use will drop to about 1.5% of its total production by 1990.

TABLE I

Basic Petrochemicals for Surfactants vs. Total U.S. Production

	1975		1990	
	MM lb to surfactants	% Of total production	MM lb to surfactants	% Of total production
Ethylene	770	3.5	1,700	3.5
Paraffin	550	80	660	70
Benzene	260	3	310	1.5

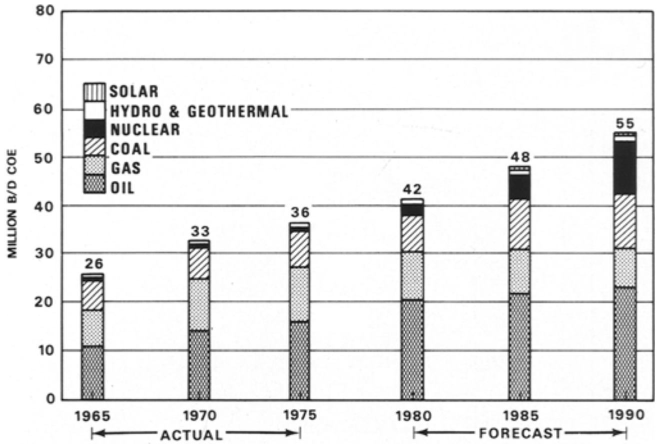

FIG. 5. U.S. energy supply by primary fuel source.

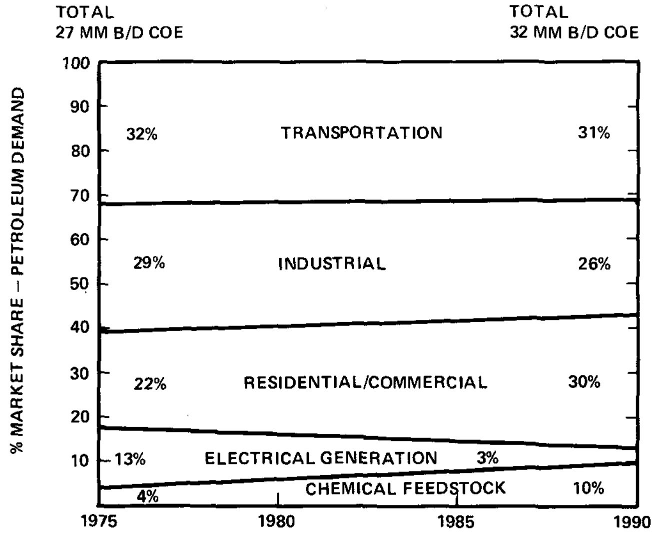

FIG. 6. U.S. oil and gas demand by market.

In general, since the amount of petrochemical required for surfactants is small relative to the total petrochemicals market, it is reasonable to assume that the demand will be satisfied if the petrochemical industry can successfully compete for the required petroleum resources.

ENERGY OUTLOOK

Energy supply/demand considerations will now be examined in order to evaluate petrochemical feedstock availability for the surfactant manufacturers to sustain the growth of the detergent industry. This question cannot be answered simply because it is part of the complex social-political problem of competing uses for the world's supply of oil and natural gas. In order to discuss this problem in a manageable form, we will focus on the situation in the U.S. In this paper a barrel of crude oil equivalent (COE) is used as a yardstick for comparing amounts of different forms of energy. One barrel of COE corresponds to about 5.8 million British Thermal Units (BTUs).

Figure 5 depicts history and a projection of the various energy sources to satisfy the total energy demand in the U.S. The energy demand will continue to increase, but the rate of growth will decline from 5% AAI (1965-1970) to less than 3% AAI by 1990. The principal area of interest, relating to the availability of petrochemical feedstocks, is the supply of oil and natural gas. We do not forecast an appreciable increase in their availability between 1980 and 1990 from a level of ca. 30MM B/D COE. This underscores a clear need for the prompt development of alternate energy sources, and we expect significant growth in nuclear energy and increased coal production through 1990. Commercialization of solar energy sources should also begin to play a small but important role in satisfying the energy demand by 1990.

The key point being made from this forecast is that while the total energy consumption will continue to increase at a rate of almost 3% per year, the oil and gas available will remain relatively constant through the period. This obviously means that the various end uses or markets that depend on the oil and gas as a raw material or for its energy value will be competing for their share of these limited natural resources.

DEMAND FOR OIL AND GAS BY MARKET SECTOR

A closer analysis of the various markets that depend on natural gas and crude oil (Fig. 6) indicates that some significant shifts in market share are anticipated by 1990. To understand why these shifts are projected there are two major factors that must be considered. The first is the economic alternatives available to each market sector, and the second is the ultimate value which is added to the crude oil and natural gas when consumed in each of their sectors.

Let us first consider what alternatives might be available to each of the market sectors. The transportation sector in the U.S. economy has limited viable alternatives through 1990, but the share of petroleum consumption is expected to decline slightly due to moderation in demand resulting from continued improved mileage in gasoline-powered vehicles. In the industrial area, conversion from oil- or gas-fired boilers to coal-fired boilers for steam generation is expected to occur on a limited basis. This conversion, coupled with industry's efforts to become more energy efficient, is expected to result in a decreased share of the consumption of the available oil and gas by this sector by 1990.

Conversion of residential and commercial heating systems from oil and gas to other forms of energy, however, is too costly to be economically practical or environmentally viable in the case of coal. Solar energy should begin to impact this sector near the end of the period. Under the circumstances the total petroleum consumed by the residential/commercial sector is projected to increase from a 22% to a 30% share by 1990 because of the relative inflexibility for conversion to other energy sources.

The electrical generation segment, because of the relative ease with which it can convert to other sources, is expected to have the largest change. Nuclear and coal facilities are already economical and in widespread use in the U.S. Further government action is expected to encourage the conversion from petroleum-based facilities to coal or nuclear facilities. The changes would result in a projected market share decline from 13% to only 3% by 1990.

For the chemical feedstock sector the only alternative available is coal, but we do not expect it to be technically or economically viable on a wide scale before 1990. During the period, however, the overall demand for petrochemicals is expected to grow at about 5.5% AAI through 1990, thus if this demand is satisfied, the chemical feedstock sector must more than double its consumption of oil and gas resulting in an increased market share from 4% to 10%.

Thus, the residential/commercial sector and chemical feed sector are expected to increase their share of petroleum consumed at the expense of the electrical power generation sector, the industrial sector, and to a smaller extent, the transportation sector. However, the concept of available alternatives does not fully explain these changes. For example, why is the chemical feedstock sector projected to get a significantly larger share of the available hydrocarbon resources while the transportation sector stays constant

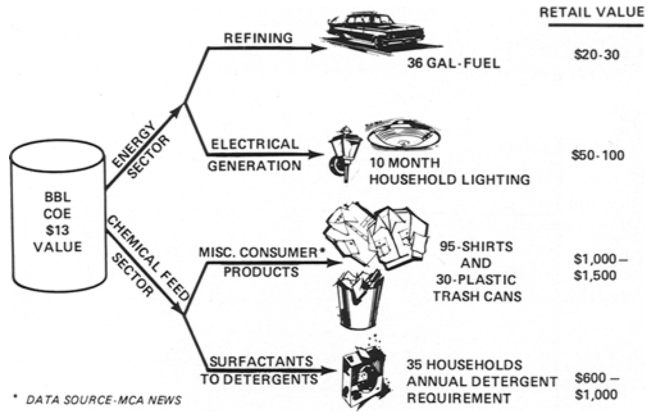

FIG. 7. What can be done with a barrel of crude oil.

even though neither one has a viable alternative? A partial answer to this question lies in the value added concept and which sector has the ability to outbid the other in an auction for a limited resource, assuming minimal government intervention.

VALUE ADDED CONCEPT

Value added will be defined here as the difference between the cost of a crude oil equivalent and the price the consumer is willing to pay for the product that is derived from the crude oil. Value is added in the form of manpower, material, equipment, and profit at each step of the manufacturing process. For example, an integrated chemical company adds value as it converts the crude oil into petrochemicals and then into surfactants. The detergent company adds value as it formulates and packages the detergent. Still more value is added in marketing and distribution before the consumer pays for the product. He is actually paying for a small amount of contained crude oil, plus all of the manpower, material, equipment, and profit that is required to convert that crude oil into the finished product available to him.

ALTERNATE USES FOR A BARREL OF CRUDE OIL

The value added concept as applied to alternate uses for a barrel of crude oil equivalent is illustrated in Figure 7, which depicts various options available for consuming this resource. One barrel of crude oil equivalent, valued at ca. \$13, can be converted into 36 gal (145 liters) of motor fuel having a retail value of about \$20-30 and providing enough energy to drive a passenger car about 800 miles. This same volume of oil, used in an electrical generating plant, produces enough electricity to satisfy the lighting requirements of an average household for about 10 months, accounting for about \$40-100 of that household's utility bill for that period of time. Feeding this same barrel of COE to a petrochemical plant instead of to the energy sector produces a wide variety of products with at least an order of magnitude increase in value added. That one barrel of crude oil equivalent provides enough raw material to make 95 white shirts with 65% polyester content and 30 plastic trash cans with a combined approximate retail value of \$1,000-1,500. If instead it was converted to surfactants, it would provide enough raw material for detergent manufacturers to satisfy the annual laundering requirements for about 35 households with a retail value of about \$600-1,000.

Since the petroleum component of these synthetic materials is such a small percentage of the total retail cost, it stands to reason that the petrochemical sector should be able to outbid the energy sector in an auction for the limited petroleum resources. For simplification, this example assumes that the crude oil equivalent is all converted into ethylene. In an actual petrochemical plant a

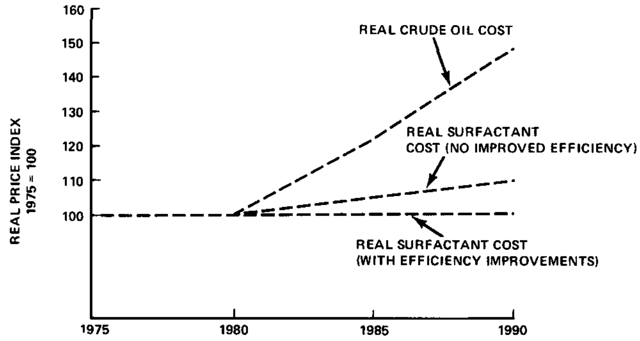

FIG. 8. Surfactant cost projection.

wide range of petrochemicals including propylene, butadiene, benzene, etc., is produced. These petrochemicals are then converted into an even wider range of finished products including plastics, paints, fertilizers, fibers, detergents, and even aspirin. All of these products (and many more) were produced in 1975 while using only 4% of the U.S. supply of oil and gas as chemical feedstock. The value added to that barrel of crude oil equivalent by these petrochemical products is truly staggering compared to the value added in the energy sector. In a report to the Petrochemical Energy Group in 1973, Arthur D. Little, Inc. estimated that a sustained 15% reduction in the output of the petrochemical industry could result in a loss of 1.6-1.8 million jobs in consuming industries and a loss of domestic (U.S.) production valued at 65-70 billion dollars annually. This economic reality should assure that the petrochemical industry and thus the surfactant/detergent industry continue to receive their required share of the limited petroleum resources.

COST PROJECTIONS FOR SURFACTANTS

In order to project prices detergent producers will have to pay for their surfactant raw materials in the future, the individual cost pressures must be isolated. In breaking down the cost buildup, 15% of the surfactant cost is directly related to the contained energy in the raw material, which is essentially the petrochemical feedstock. Another 10% of the cost is directly related to the required manufacturing or processing energy. These two cost portions, totaling 25% of the surfactant cost structure, are directly related to the future price of a barrel of crude oil. It follows then that the remaining 75% of the surfactant cost is not directly related to crude oil prices, but is more influenced by other factors such as the cost of labor, cost of capital, etc. With this cost relationship in mind, it is possible to look at some projected cost increases out through 1990. There are many economic scenarios forecasting crude oil pricing. Our scenario (Fig. 8) is based upon a consensus of several others, and projects oil pricing to increase in line with inflation until 1980 and then at ca. 4% per year above inflation (i.e., 4% "real" dollar increase) between 1980 and 1990. If this price projection is applied to the surfactant cost analysis, it means that three quarters of the surfactant cost will increase with the overall inflation of the economy, while one quarter of the cost will be directly affected by the 4% per year real increase in crude oil. These factors when combined result in a forecast of surfactants based on petrochemical feedstocks increasing at a rate of ca. 1% per year higher than the overall economic inflation rate between 1980 and 1990. This analysis assumes that technological improvements, economics of scale, learning curve efficiencies, etc., do not offset the escalating crude values. However, there is a high probability that some of these improvements will take place, thus offsetting the rising cost of crude oil, and resulting in a constant price in real monetary terms (after adjusting for inflation) through 1990.