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ETHYLENE
BASIC CHEMICALS FEEDSTOCK MATERIAL

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FOREWORD

Ethylene ranks first in production among the major organic chemicals, and its consumption is approximately twice that of its next two contenders —propylene and benzene. The ethylene business is capital-intensive and complex, and its stakes are high and continually increasing. Unsettled conditions and problems have made it the subject of concern to the chemical processing industry.

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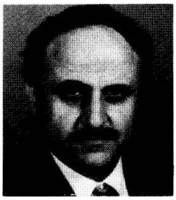
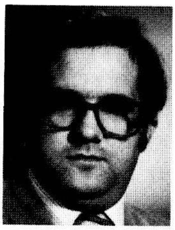


Oscar G. Farah is Manager of International Programs, Energy, Resources and the Environment Division at Metrek, a division of The MITRE Corporation. Dr. Farah started his career at MITRE in 1969 and since then has been associated with a variety of projects covering communications, transportation, and energy and the environment. Since 1974, his interests have been concentrated in the area of energy and the environment, and in 1976 he started working in MITRE's international programs. Before joining MITRE he was a research scientist at the Naval Research Laboratories (NRL) and the Carlisle Barton Laboratory of Johns Hopkins University. Prior to that he was a member of the technical staff at Bell Telephone Laboratories and the Western Electric Company. On a number of occasions he has worked as an independent consultant for the Hudson Institute, NRL, Scope, Inc., and The MITRE Corporation. Dr. Farah obtained a BS in Mechanical Engineering from Purdue University and a PhD in Electrical Engineering from Johns Hopkins University. He has published a number of papers on world energy demand and supply, energy transmission and energy conservation.

Robert P. Ouellette is Technical Director of the Environment Division of The MITRE Corporation. Dr. Ouellette has been associated with MITRE in varying capacities since 1969 and has been Associate Technical Director since 1974. Earlier, he was with TRW Systems, Hazelton Labs, Inc. and Massachusetts General Hospital. He graduated from the University of Montreal and received his PhD from the University of Ottawa. A member of the American Statistical Association, Biometrics Society, Atomic Industrial Forum and the NSF Technical Advisory Panel on Hazardous Substances, Dr. Ouellette has published numerous technical papers and books on energy and the environment. He edited the comprehensive survey, *Electrotechnology*, published in 1978 by Ann Arbor Science Publishers, Inc.

Ralph Kuehnel received both an MBA in Quantitative Methods and a BS in Accounting from the State University of New York. At MITRE, Mr. Kuehnel has been responsible for the design and development of the Metrek Model for Financial Evaluation of Boiler Conversion to Coal-Oil Mixtures. Mr. Kuehnel previously worked with public utilities and government agencies in the development of long-range utility plans. These tasks included the design and responsibility for the development of a number of computer models to assist in evaluating economic, environmental and regulatory policies related to utilities. Mr. Kuehnel has also served as financial analyst in the design of a detailed financial performance model for the cable television industry. Under the sponsorship of the Canadian Department of Communications, he directed programming and installation of this model in Ottawa, where it is now being used for policy evaluation, rate regulation and financial analysis of cable systems.



Mario Muradaz is currently working to obtain a degree in Economics from the University of Maryland. At MITRE, Mr. Muradaz has been responsible for research in support of various energy technology projects. His tasks have involved identifying pertinent energy research currently conducted at national laboratories, as well as pertinent Congressional Acts applicable to energy-related activities.

Paul N. Cheremisinoff is Associate Professor of Environmental Engineering at the New Jersey Institute of Technology. He is a consulting engineer and has been a consultant on environmental/energy/resources projects for MITRE Corp. A recognized authority on pollution control, he is author/editor of many publications, including several Ann Arbor Science handbooks on pollution and energy, such as *Pollution Engineering Practice Handbook; Carbon Adsorption; Environmental Impact Data Book; Industrial & Hazardous Wastes Impoundment; Environmental Assessment & Impact Statement Handbook*. Mr. Cheremisinoff is also Engineering Editor of *Water & Sewage Works*, an international journal.

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INTRODUCTION

This book examines the future of the U.S. ethylene industry by considering its alternate sources of supply, the expected technological improvements in its production processes, its demand growth, and its available and under-construction production capacity. This study was based on a survey of the literature and on industry contacts.

Using information on energy resources, the background necessary to permit a logical forecast of the future of the ethylene industry is presented. Two alternative scenarios are given:

1. continued oil glut and expansion of the availabiity of natural gas; and
2. business as usual, but with spot shortages and curtailments.

In either situation the ethylene industry should have no problem surviving, and its principal feedstocks will continue to be crude oil and natural gas. Principal difficulties (up to 1985) will be due to present overproduction capacity, drop in demand growth from 12% to 6.5–7% and the coming onstream of ethylene plants in OPEC countries, Canada and South America. With either scenario, the quantity of coal- and biomass-derived petrochemicals will be negligible and could provide no more than 10–15% of production by the year 2000. However, the technologies for utilizing coal and biomass cannot be neglected as these feedstocks do provide "an insurance" against possible long-term shortages. Biomass technology appears to offer an advantage to the less-developed countries that are short on capital and require labor-intensive industry.

An important threat in the background is the possible disruption of production in the oil-producing countries due to political causes. Internal unrest in these countries could cause immeasurable damage to world economies if allowed to surface. Short disruptions could be handled with minimum difficulty, but for long disruptions of supply, the total world economy would suffer.

Alternate sources of supply are being developed: the heavy oils and tar sands of Canada and Venezuela; the oil resources of Third World countries; the immense reserves of natural gas in geopressured reservoirs in Louisiana and Texas; and the oil reserves of Mexico and China. But under present, nonwar conditions, development of these resources will be slow because survival is not at stake. With the passage of the modified Carter energy bill, new economic conditions now exist in the United States that are conducive to increases exploration, and future availability of feedstocks appears somewhat assured.

The principal difference between the two hypothesized scenarios is the cost of feedstock. In an oil glut and expansion situation, the cost should decrease in real terms; with business as usual but curtailment, the cost would increase. The cost increase should be modest, unlike that of 1973–1974, and will effectively be healthy on the supply situation. Some of the more expensive oil and gas resources would become economical, e.g., tertiary recovery, the oil shales, tar sands, etc.

To help ensure the survival of the ethylene industry it should continue (1) to be prepared to accept a range of feedstocks; (2) to develop preconditioning technology to hydrogenate the heavier fractions to increase ethylene yield; (3) to develop new processes to crack crude directly that can accept a range of fractions; and (4) to maintain a healthy R&D program in alternate raw materials (coal and biomass).

OVERVIEW

The U.S. Chemical Processing Industry market conditions, and specifically those for ethylene prior to the fourfold increase in oil prices, were as follows:

1. Ethylene had been and still is so basic to the petrochemical industry that its rate of growth had been correlated with the growth rate of the Gross National Product (GNP). In the 1960s, ethylene growth rate was 3–3.5 times that of the GNP. Between 1960 and 1974 the growth rate of ethylene demand averaged 12%.
2. The demand for ethylene appeared to be unlimited as most natural products such as wood, paper and metals were being replaced by plastics, which were ethylene derivatives.
3. Natural gas, which had been the principal feedstock in the production of ethylene, was becoming scarce, and planners were having serious doubts about the reliability of supply; the relatively low price of natural gas, which

was set and regulated by the U.S. government, made it uneconomical for the natural gas industry to look for new sources of natural gas in the United States.

4. The technology for production of ethylene from crude oil was available and was widely used in Europe. The conventional process consisted of cracking the crude to produce naphtha and using the naphtha as a feedstock for producing ethylene. Naphtha cracking produced a range of additional coproducts that had to be disposed of. Although the crude oil route was more expensive than the natural gas route, the coproducts were valuable to the refiner.
5. The technology for producing ethylene and the economies of scale had reached a point where small ethylene plants were no longer economical and the size of an economical world-size ethylene plant was now on the order of one billion lb/yr.

Faced with these facts and taking into account the long planning and construction lead times, the CPI went ahead bullishly with major expansion plans. (It is the opinion of some CPI experts that the CPI industry did foresee the slump in ethylene demand; however, because of the expected increases in capital costs to construct ethylene plants, the oil companies deliberately opted to increase their capacity and overbuild before construction costs skyrocketed.) The scarcity of natural gas forced the shift to crude oil, and chemical companies, which owned the majority of the natural gas-based ethylene plants, found the ownership of these plants unattractive because they had to market a range of coproducts. The oil industry, which already had markets for these products, took over the production of ethylene. Union Carbide, in cooperation with Kureha Chemical Company and Chiyoda Kako Kensetsu of Japan, chose to develop a process of cracking crude oil directly to produce ethylene using a new Advanced Cracking Reactor (ACR).

Then came the unexpected fourfold oil price increase and general slowdown of the economy in 1975. Today, with prices somewhat stabilized, the demand for ethylene is rising, but seems to have stabilized at slightly more than twice the GNP growth rate.

If one were to ask CPI experts their opinion on the future of the ethylene business, one would be surprised by the diversity of opinions received. For example, the marketer would paint a gloomy picture of this future based on the available overcapacity for ethylene production; the marketing researcher or planner would argue that based on present growth rates, at least 20 new world-size plants would be required by 1985; the supply specialist would insist that ethane/propane are no longer available and it is necessary to switch to oil; while the explorer would counter that twice the U.S. coal reserves in gas is available in the geopressured reservoirs of Louisana and Texas; also, the researcher would maintain that shale or lignite would provide excellent feedstock for ethylene production when using a transfer line or riser for cracking; and finally, the refining and production specialist would stress that the naphtha route is unattractive because as more severe reforming is used to increase the yield of gasoline, naphtha yields would decrease. Finally, the coal and biomass advocates would insist that future petrochemicals should come solely from their respective raw material.

CHAPTER 2

TECHNOLOGICAL IMPROVEMENTS IN ETHYLENE PRODUCTION

INTRODUCTION

The CPI is continuously conducting research and development to find more efficient processes. Because of the large capital investments required to construct world-scale plants and the narrow profit margins, a new plant must be of the most efficient, highest yield design. In ethylene production, improvements can be classified into two general areas.

Improvements of Conventional Processes

These improvements are made gradually, and the resulting yields inch up slowly. The improvements are generally minor and time consuming. In ethylene production, ethylene is conventionally obtained by pyrolysis of hydrocarbons. High selectivity for the desired olefins and diolefins and minimum coke production can be achieved by operating at high temperatures, short residence times and low hydrocarbon partial pressures. Hence, the components that have the most effect on ethylene yield are the reactor and the quenching unit.

Pyrolysis takes place in the reactor, which is essentially a heated vessel. The upper temperature limit is set by the material from which the vessel is made. Uniform temperature in the vessel is essential to ensure isotropic pyrolysis and minimum coke deposition. For this reason, the tubular reactor has emerged as the most effective design and can be used at elevated temperatures to achieve high-severity pyrolysis with naphtha feedstocks. Pyrolysis temperatures up to 1000° C can be achieved with presently