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Symposium I

ON STRETCHING THE LAST DROP OF CRUDE OIL: A NEED FOR OPTIMIZATION OF GLOBAL PRODUCTION AND CONSUMPTION OF OIL

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CENTRAL THEME AND WORKING HYPOTHESIS

Industrial growth and quality of life in a modern society depend upon human-, energy, and material-resources. Crude oil is an important non-renewable energy and material resource. The supply of crude oil influences the economic, political and social fabric of nations. In this author's opinion, if the present industrialized society is to become a sustainable society, it must plan and execute a strategy for a transition to other forms of energy and material recycling. In order to provide the longest possible transition period for the development of new energy technology and the reorientation of social, political, and economic values, the global production and consumption of oil should be optimized. Various strategies for the production and consumption of oil are suggested in relation to the social, economic, and political framework of the U.S. This involves critical decisions for people, Government, media, industry, and educational institutions.

The fact that average oil recovery from petrolem reservoirs is about 33% necessitates greater emphasis being placed on enhanced oil recovery technology. Although other forms of energy such as coal, nuclear, solar, geothermal, etc., will play a role in extending this transition period, the author has emphasized the potential of enhanced oil recovery processes to increase the total yield from petroleum reservoirs. In view of economic, environmental, and technological limitations associated with the development of other forms of energy, the enhanced oil recovery processes offer the most promising approach for meeting the oil needs of the world in the coming decades. The priorities for various uses of oil must be defined for conservation.

Based on the author's involvement in this area over the past decade, a blue-print is offered for the optimum production and consumption of oil including desired changes in the Government energy policy, research and development planning, management philosophy, and the attitude of people towards energy and material resources.

AREAS TO BE EXPLORED AND DATA TO BE UTILIZED

Energy Consumption and Standard of Living:

Figure 1 shows per capita energy consumption in the U.S. and the world. In general, energy consumption is proportional to the standard of living. However, there are exceptions. Some countries consume more energy than others for the same standard of living.

U.S. Energy Sources and Energy Uses:

Figure 2 shows U.S. energy sources as of 1973. The major change that has taken place is that in 1973, imported oil constituted 28% of the total amount of oil used in the U.S.; whereas, in 1978, about 50%

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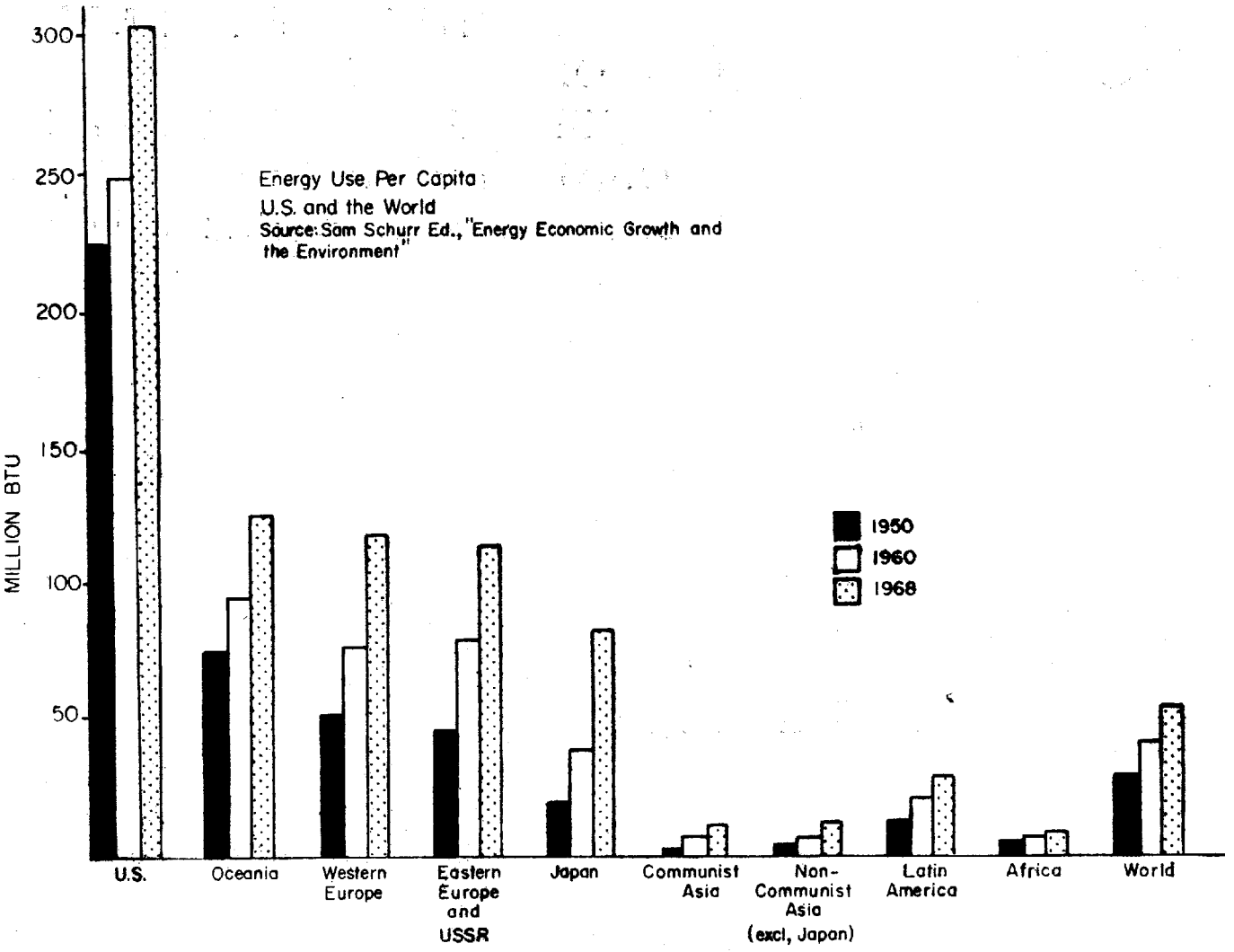
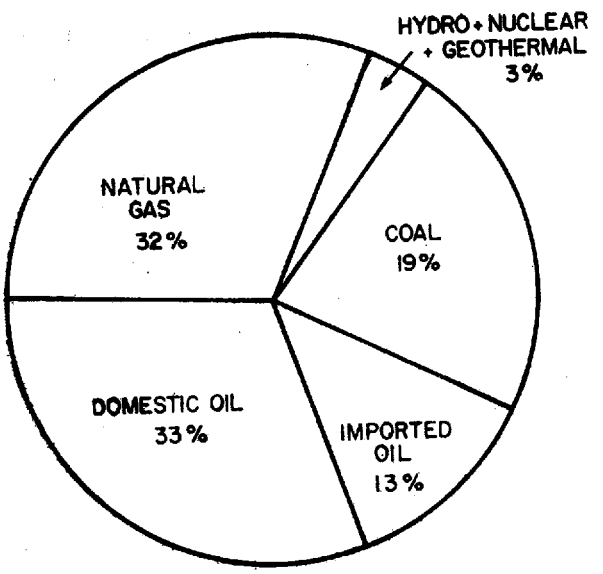


Figure 1



U.S. ENERGY SOURCES 1973

Figure 2

of the total oil consumed was imported. Figure 3 shows U.S. energy uses. It is obvious that oil provides a major energy need of our society. This raises the question of world and domestic supply of crude oil.

Oil Production, Consumption, and Reserves of the World and the U.S.:

Analysis and critical review of data reported in literature show that the annual production rate of crude oil in the world is about 22 billion barrels (bbl). This corresponds to about 60 million bbl per day world production. The world consumption of oil is about 54 million bbl/day. The recent shutdown of oil production in Iran wiped out this surplus.

The annual consumption of crude oil is about 7 billion barrels in the U.S. corresponding to about 20 million bbl/day. Thus, the U.S. having 6% of the world population, consumes 33% of the world's oil production. About 50% of its crude oil is imported. With the current OPEC price, the cost of imported oil is about 145 million dollars per day.

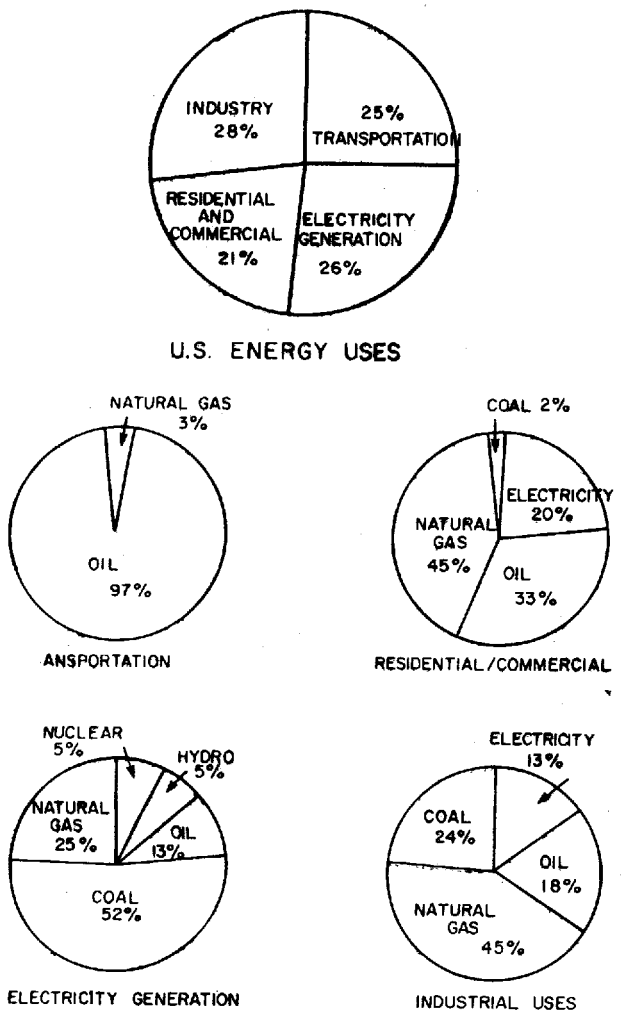


Figure 3

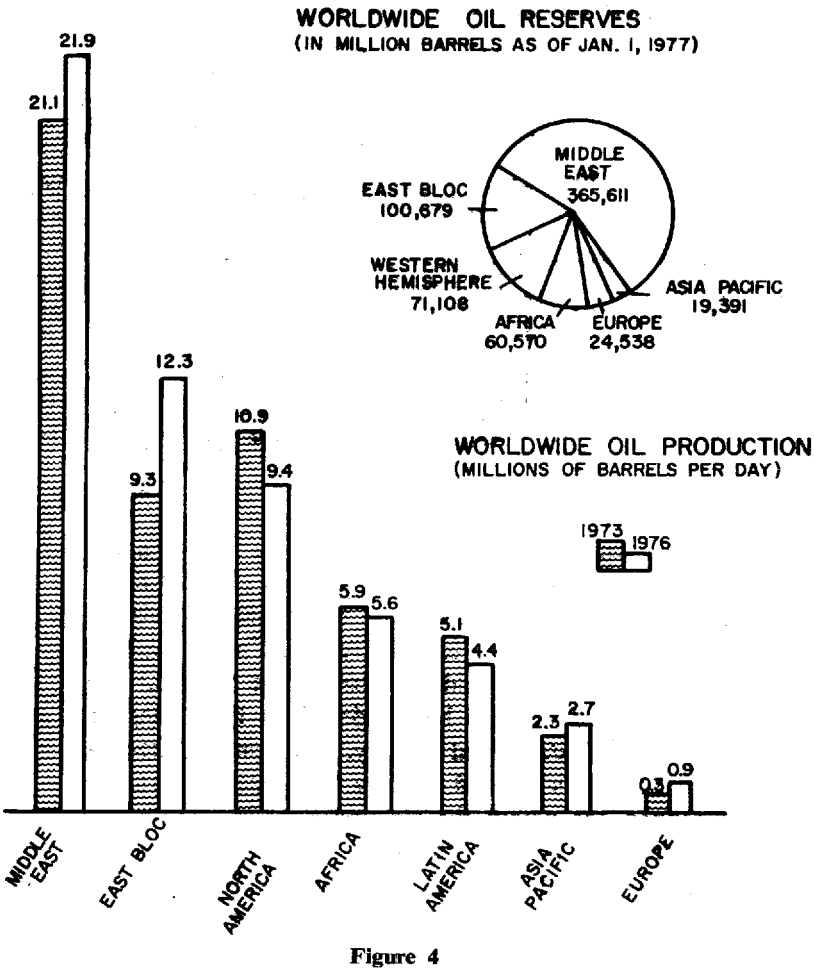


Figure 4

Figure 4 shows the oil reserves and production in various parts of the world. The world oil reserve as of January 1, 1978 is estimated to be 641.6 billion barrels. At the present rate of world consumption, this reserve would last only 29 years. The U.S. oil reserve as of January 1, 1978 is estimated to be 28.5 billion barrels. With its annual consumption of 7 billion barrels, this would be equivalent to four years supply.

Three basic questions regarding the oil outlook for the coming decades must be asked:

* At what rate will oil consumption by the world and the U.S. increase or decrease?
* What increase in oil reserves might occur due to new oil field discoveries?
* What increase in reserves could occur due to employment of enhanced oil recovery technology?

With the present world situation and the current state of science and technology, it does not appear that the demand for oil will decrease in the coming years. Future discoveries of oil will most likely occur in hostile environments (e.g., greater ocean depths). The cost of production and transportation of this oil will be much higher. A more promising approach is to improve the total yield from a reservoir (average oil recovery with current production technology being 33%). The tertiary oil recovery processes and their future development can increase the average oil recovery from 33% to 60%, almost doubling the ouput of oil.

Successful employment of tertiary oil recovery processes is, however, not strictly a technological problem, but involves politics, pricing, and public opinion, as well as geopolitical conditions. Figure 5 illustrates the U.S. crude oil "barrel" as of January, 1974, indicating the enhanced oil recovery potential.

A Strategy for Enhanced Oil Recovery from Reservoirs:

In general, people are not well-informed about the production aspects of oil. Figure 6 schematically shows a 3-dimensional view of a petroleum reservoir.

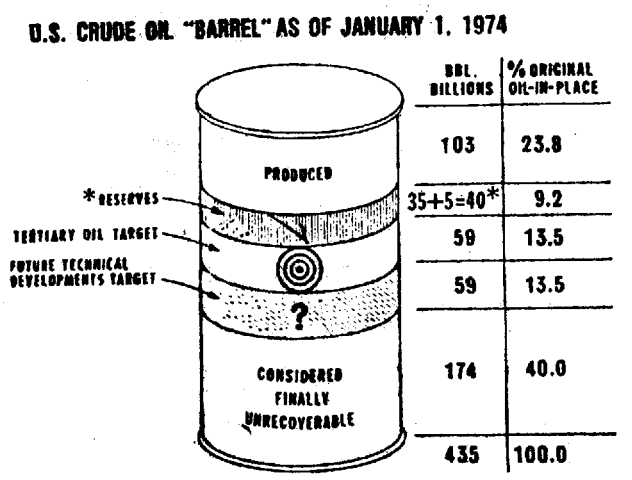


Figure 5

Oil, gas, and brine are found to coexist in the pores between sand particles and minerals. Oil flows through sandstone or limestone rocks. Such oil-bearing zones could be 10 to 100 feet thick and could be located several thousand feet below the ground. The production of oil can be divided into three stages: primary, secondary, and tertiary. In primary production, the oil is pushed out by natural pressure of entrapped gas within the reservoir, When oil production declines, water is injected into the reservoir to push oil toward production wells. This constitutes secondary recovery . When no oil comes out at the end of the secondary stage, tertiary techniques can be employed to recover additional oil.

For secondary and tertiary oil recovery processes the five-spot pattern of wells can be used. Water or surfactant solution is injected in the central well, and the oil is pushed toward the production wells (Figure 6). The author has shown by laboratory experiments

DISPLACEMENT OF OIL IN PETROLEUM RESERVOIRS BY WATER OR CHEMICAL FLOODING (FIVE-SPOT PATTERN)

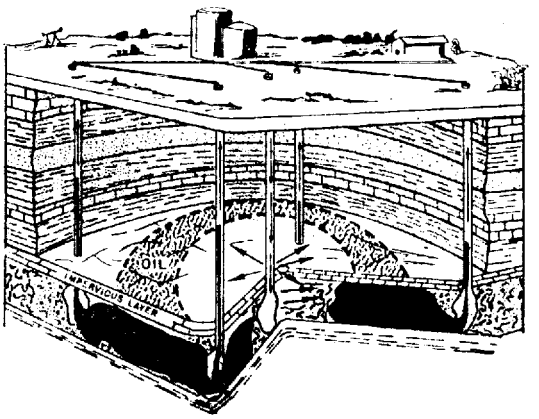


Figure 6

that 16% more oil can be recovered by injecting water containing a specific salt concentration (depending upon the crude oil).

For tertiary oil recovery there are two major groups of processes: thermal processes and chemical flooding processes. The author has shown by laboratory experiments that almost 95% of total oil can be recovered from sandstone if the process is applied at earlier stages. The total yield of oil is greater if the tertiary process is applied immediately after primary production, bypassing secondary stage.

Policy Decisions by Government and Industry :

* The gap between the price of domestic and imported oil is questionable and controversial. The price of oil should be such that it discourages waste, but still provides for the basic needs of citizens.

* Oil companies spent $ 14 billion in 1976 for exploration and production of oil. Government and financial analysts estimate that the companies should spend $ 20-26 billion/year for exploration and production of oil through the early 1980's. Government must provide greater incentives for increased exploration, production and enhanced oil recovery technology.

* The successful application of tertiary oil recovery processes is not only a technological problem, but also involves Government oil policy, regulatory control, and oil industry's management philosophy.

* Oil production is a complex, high-risk business, requiring large capital investment. Technologically, it embraces various disciplines. However, economics is of paramount importance. Reasonable profit is a prerequisite to any business. Nevertheless, the oil industry must not be allowed to invest its profits in acquiring other industries not related to energy production. Emphasis on technological innovation must continue for other processes to produce oil such as synthetic crude from coal, shale oil, or vegetation.

* The exploration and production of oil brings into focus the importance of academic institutions as the breeding ground of new knowledge. Much more research involvement by academic institutions in this area should be supported by Government and industry. This will also shorten the lag time for transferring research into application.

* The management must implement a policy of maximizing oil output from a reservoir by apply-

ing tertiary methods in place of secondary even if it requires a large investment of capital sooner.

A Strategy for Conservation of Oil

The task of minimizing oil consumption requires input and cooperation of Government, media, people, industry, and educational institutions. Governments and media should take leadership in fostering awareness among people about the limited supply of energy and material resources. The Government's energy policy should:

* give the highest priority to those uses of oil which meet basic human needs.
* provide economic incentives to people and industry for conservation of energy
* curb waste of energy by imposing economic disincentives.
* provide economic incentives to industry for development of alternate energy sources.
* reduce the funding level of newer highways in favor of mass transit facilities.

Other segments of society can contribute significantly toward the goal of oil conservation as follows:

* The media should inform and educate people as to the national and international consequences of the dwindling oil supply.
* The industry must strive for innovation to conserve the energy and material resources.
* The auto industry must produce safer, lighter, and more efficient cars to conserve human-, energy- and material-resources.
* Careful assessment of the environmental impact and conservation of energy and material resources in technological processes must be conducted.
* Educational institutions must redesign their curricula to develop a new generation of people who are energy-conscious.
* More efforts should be directed by investigators in academic institutions toward problems related to the finite energy and material resources.
* The development of new communities using bold and innovative architectural designs. Residential homes, schools, parks, offices, and industrial areas should be within a five-mile radius so as to be within bicycling or walking distance. These could be surrounded by farms and ecologically balanced natural environments. The growth of new communities must be well-co-ordinated joint ventures of Government, industry, academic institutions, and people.
* In view of the depleting reserves of oil and material resources, the society must reorient its social, economic, political, and ethical values.

RELEVANCE TO THE GROWTH POLICY DEBATE

The following are the major points relevant to the content of this paper.

* Industrial growth vs. limited supply of oil.
* Government energy policy and the oil conservation and production measures.
* Corporate decisions and management philosophy on short-term profits vs. long-term gains in total oil yield from reservoirs.
* Reorientation of our social, economic, political, and ethical values.
* Geopolitical impact of limited oil supply and technological development of both developed and developing nations.

IMPLICATIONS IN POLICY AND ACTION

The following are the major implications of this paper for future policies and actions by various sectors of society.

* Reshaping the future direction of economic, industrial, community planning, educational, and political activities.
* Development of energy and material conscious societies.
* Emergence of new management philosophy with emphasis on optimization of energy and material resources.
* Establishment of international institutions, e.g., an international oil bank similar to World Bank to provide short-term loans of oil to nations under emergency situations in the framework of fairness and human growth.
* Maximization of the transition period for development of other sources of energy and a shift from oil-based technology.
* Reevaluation of social, economic, political and ethical values. What may be considered a necessity by an individual, a society, or a country may be looked upon as a luxury by another in our disparate and imperfect world.
* Implementation of strategies outlined in this paper would contribute toward an orderly transition of life-style, political, economic, and social values without trauma of domestic or international instability.

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