INDIAN STATISTICAL INSTITUTE

FOURTEENTH CONVOCATION ADDRESS

THE USE OF HYDROCARBON SOURCES

By

S. VARADARAJAN

25 April 1980

203 BARRACKPORE TRUNK ROAD

CALCUTTA 700 035

THE USE OF HYDROCARBON SOURCES

By S. VARADARAJAN, Ph.D. (Delhi & Cambridge)

Chairman and Managing Director, Indian Petrochemicals Corporation Limited
President, Indian Academy of Sciences

Mr. President, Mr. Chairman, Professor Adhikari, Members of the Indian Statistical Institute and distinguished guests,

I deem it a great privilege and honour to be invited to present the Convocation Address and I am grateful to the Indian Statistical Institute for this opportunity to be with you.

On this occasion, I feel it would be appropriate to examine the manner in which carbon based materials, which are the basis of organic life, have been utilised in increasing the well being of man and the limitations and opportunities that would arise in the immediate future, for us in India, in the use of such material.

Use of renewable resources

The advanced civilisation of man has been characterised by the ingenious use he has increasingly made of many natural materials such as wood, leaves, cotton and jute fibres, vegetable barks and shells, animal bone, horn, ivory, silk, wool, skin and leather, all derived from plant, animal and marine organisms. These structural materials have been fashioned to meet needs of clothing, housing, transport, storage and in self-defence and conquest. A whole array of non-structural materials such as vegetable and animal colours, drugs, insecticides, poisons, surface coatings, paints, varnishes, perfumes, flavours, washing agents, emulsifiers, solvents, plant nutrients and oils for illumination have been found from renewable plant and animal sources.

Use of non-renewable hydrocarbon resources

Energy requirements, especially for transport and movement of goods, in the past had been met very largely from biological sources with domesticated animals and human labour, all again dependent on renewable carbon based nutrients. Even requirements of energy for lighting and heat were met largely from wood, charcoal and vegetable and animal oils. The use of non-renewable hydrocarbon sources such as coal for heat energy and for metallurgical processes is an important application of such source. The very large increase in the use of non-renewable hydrocarbon sources has however come about from the invention of the steam engine, and internal combustion engine and the jet engine, the last two being dependent on refined petroleum hydrocarbon oils.

The advances made in the science of organic chemistry have led to the application of coal and petroleum derived materials to applications other than energy. Firstly from coal tar, the byproduct of metallurgical coke production and from petroleum hydrocarbons, it has been possible to synthesise a wide variety of materials for non-structural uses and even for structural applications. These include synthetic dyes, pigments, insecticides, agricultural chemicals, drugs, detergents, paints as well as synthetic fibres such as polyester, nylon and acrylics and materials such as the commonly known polyethylene, polypropylene, polystyrene, polyvinyl chloride and rubber and newer materials such as polycarbonate, polymethacrylate, melamine and copolymers, ABS, and SAN. These new synthetic materials have grown in volume and variety in an extraordinary manner during the last thirty years and have helped to conserve land and water resources for essential food production and to inhibit the rapid depletion of forest wealth, animal and bird life and marine organisms. It is estimated that the world production of these synthetic materials amounts to about 250 million tonnes annually and they use about 7 per cent of the total petroleum oils consumed yearly.

Use of hydrocarbon resources for nutrient needs

With the growth in world population and the rapidly escalating needs for food, modern agricultural practice has introduced the application of nitrogenous fertilizers in the form of ammonia and urea on a very large scale. The production of such fertilizers is today wholly dependent on non-renewable hydrocarbon resources such as coal, natural gas or petroleum naphtha and fuel oil. Although the product ammonia contains only nitrogen and hydrogen as constituent elements, carbon fossil hydrocarbon is used to remove oxygen chemically from air and from water to give nitrogen and hydrogen needed for ammonia synthesis. Approximately 60 million tonnes (expressed as N) of fertilizers are produced annually in the world today and a rapid increase in the next twenty years is assumed as the prerequisite for food production.

Hydrocarbons in metal production

Coal and coke have been employed for several thousand years in the production of iron and non-ferrous metals such as copper, zinc, lead, nickel and tin, these in turn have led to the production of steel as well as a whole range of alloys with many desirable qualities of high strength, malleability and resistance to corrosion. Modern industry, transport and communication systems depend wholly on the advances in metallurgy. The level of industrial development achieved in any country is today measured by the variety and quantities of metals and alloys that are produced. All national plans for development, including our own, forecast higher metal and alloy production and would need very large scale use of non-renewable hydrocarbon resources.

World energy crisis

The indiscriminate use of hydrocarbon, especially petroleum oils, during the last twenty years has focussed attention on the high rate of their depletion and the possible consequences. Limits to production are being reached and costs have risen in an exponential manner. During the last ten years petroleum prices have increased 3000 per cent. Future continued availability of these is in question and there is wide turmoil. We in this country are also affected by these changes and it is therefore pertinent to study the dimensions of the problem and of the possible avenues for relief.

Hydrocarbon usage in India

India has a long history of the use of wood, charcoal, and coal as energy sources. Due to the relative abundance of oil seeds, in the early part of the century, vegetable oils were used as sources of illumination and of energy for heating.

The first discovery of oil was made in 1867 at Makum in Assam. Other fields were identified twelve years later, and in 1921 oil production amounted to 14,000 tonnes. Oil and gas were found in Gujarat during 1958–60 and additional wells were found in 1963. We were fortunate in finding oil and gas offshore in 1974 in Bombay High.

Production, imports and consumption of oil products have shown a steady increase. Table 1 gives a picture of the trend :

Table 1

Oil and oil products

Production, imports and consumption in million tonnes in India

Year	Production	Imports	Consumption
1950	0·1	3·2	3·3
1955	0·7	4·7	5·4
1960	0·5	7·5	8·0
1965	3·0	9·4	12·4
1967	5·7	8·3	14·0
1970	6·8	12·2	19·0
1972	7·3	15·4	22·7
1973	7·2	16·5	23·7
1974	7·5	15·5	23·0
1976	8·7	16·2	24·9
1979	15·0	17·0	32·0

Recent experience shows that consumption is increasing at a rapid rate. While it was earlier planned to contain annual rate of increase to 8 per cent, recent increases have ranged from 15 to 20 per cent. In the absence of adequate supply of alternatives such as firewood, coal and electricity, petroleum hydrocarbon products consumption is increasing. Domestic production is expected to increase to about 20 to 22 million tonnes of oil. Inspite of the increase in domestic oil and gas production, imports of oil and oil products are likely to increase further in the coming years and the total consumption of petroleum oil products may increase in excess of 37·5 million tonnes in 1983, envisaged in the draft sixth Five Year Plan. It is also likely that the demand may be approximately 50·0 million tonnes by 1987. The sector-wise consumption is as follows :

Table 2

Sector		Percentage
Transport	...	33
Industry	...	28
Agriculture	...	10
Domestic	...	14
Power generation	...	7
Miscellaneous	...	8

Coal, which is the more abundant hydrocarbon resource, is also produced at an increasing rate as can be seen from Table 3.

Table 3

Year	Production in million tonnes
1951	35
1961	56
1975	88
1977	101

It is estimated that the demand would increase to about 145 million tonnes in 1983 which would be met by local production. Of this the major uses are for power generation (53 MT) and for steel production (32 MT).

Indian requirement in the world context

Indian usage of non renewable hydrocarbon resources as yet remains quite small, compared to the developed world, as can be seen from Table 4.

Table 4

Use of non-renewable hydrocarbon resources in million tonnes oil equivalent

Item of use	World	USA	India 1980	India 1987 (est.)
Energy	5000	2000	110	145
Nutrient Nitrogen	60	30	2	7
Carbon Chemical Feedstock	500	250	2	4

It can be readily seen that while our consumption is by no means small in relation to our local production and foreign exchange resources for imports, they remain quite low in comparison with a high energy based nation such as the United States of America, with a population of one third that of India. The current imports of oil and gas in the United States represent about 500 million tonnes per annum, whereas Indian imports of oil and oil products are approximately 18 million tonnes. While conservation measures would be necessary, it is difficult to curtail consumption and imports in India, without seriously effecting many sectors including agriculture, industry and transport. Already the foreign exchange outflow on account of oil imports is estimated to be in excess of Rs. 5000 crores for meeting the needs of the year 1980. During the next seven years, unless large new oil and gas sources are quickly discovered and exploited, even at current prices imports of oil and oil products may need Rs. 10,000 crores annually.

Energy needs for the production of nutrient nitrogen

In recent years there is a concerted drive towards increased food production, and a great deal of success has been achieved. The target of food production for 1983 is 146 million tonnes and it is visualised to be 187 million tonnes in 1993. There has been a large increase in nitrogenous fertiliser usage in recent years. The demand for Nitrogen is expected to be 5.3 million tonnes in 1983 and 8.0 million tonnes in 1988. Production may rise from about 2.0 million tonnes currently to 3.9 million tonnes in 1983 and to 6.0 million tonnes in 1988. These would require large capital outlay, imports as well as use of coal, gas and oil hydrocarbon resources.

While success in food production and nitrogenous fertilizer application are laudable, it is possible that there may be an over-emphasis on fertilizer use. It is seen that for Indian production of foodgrains which may represent about 5 per cent of world food production, the nitrogen fertilizer usage in India would be about 10 per cent of world usage. Indeed for 20 to 25 per cent increase in foodgrains production from the current level of 125 million tonnes, the additional Nitrogen fertilizer usage envisaged is of the order of 70 per cent. It is possible that considering the increasing cost of fertiliser Nitrogen and its dependence on hydrocarbon resources, a study on the optimum use of fertilizers would be rewarding. It is also likely that other inputs may give a better benefit to cost, after a certain level of Nitrogen input has been reached.

Hydrocarbon resources for production of structural materials

The production of metals from oxide or sulphide ores require reduction with coke usually at high temperatures. The energy requirements for these processes are therefore quite large. On the other hand, the production of synthetic hydrocarbon based polymers generally uses substantially less energy and total hydrocarbon. Table 5 gives a comparison of energy needs for production of different materials in terms of unit weight and unit volume of materials :

Table 5

Energy requirement in the manufacture of materials

Material	Tonnes of oil equivalent per tonne of materials	Kilocalories per cubic cm. of materials
Aluminium	5.6	158
Steel	1.0	82
Copper	1.2	112
Paper	1.4	12
Cellophane	4.4	17
Polyethylene	2.2	22
Polystyrene	3.2	36
PVC	1.9	28
HDPE	3.3	24
Polypropylene	2.5	24

The unit volume comparison is valid as these materials used vary widely in specific gravity and the end use is based on mechanical strength per unit surface area. The following Table 6 further illustrates the lower energy needs in the use of such polymers.

Table 6

Energy content of some end products total energy in tonnes of oil equivalent

End Product	Traditional Materials	Polymer based materials
Bottles (1 litre)	Glass, 230 per million	PVC, 97 per million
Container	Tinned steel, 75 per million	PVC, 81 per million
	Aluminium, 142 per million	
Drainage Pipe (4 inch)	Cast iron, 20 per KM Clay 5 per KM	PVC, 4 per KM
Fertilizer sacks	Paper, 700 per million	LDPE, 470 per million
Shirts	Cotton, 1 per thousand	Nylon, 2 per thousand

The above show the need for a serious examination of the continued use of metals, glass and even paper as structural component materials at a time when there may be limitations on account of energy availability. It is also known from recent advances in material science that it is possible now to use new polymers such as polyamide, polysulphide, polysulphone, polybenzimidazole, polycarbonate, polyfluro hydrocarbons as well as polymer fibre reinforced materials in the creation of very high strength materials, having additional desirable properties such as electrical and thermal insulation, transparency, resistance to abrasion, corrosion and stress cracking and ability to maintain low wear in friction. These engineering materials are now finding extensive application in aircraft, automobile, industrial machinery, mining and electrical power and transmission. In our own long-term planning, there is clearly need for examination of priorities for the use of hydrocarbon energy sources in materials production.

Biological Fixation and Utilisation of Nitrogen

A large proportion of nitrogen nutrition required for green plant growth arises from biological fixation of nitrogen by microorganisms such as Azotobacter, Clostidium, Klebsiella and Citrobacter and the symbiotic organism Rhizobium. The increased use of such organisms in agricultural practices would be of value. It is also possible that through modern advances in recombinant DNA, the nitrogen fixing properties could be transferred to green plants, thus reducing the need for application of synthetic ammonia fertilizers. It would be worthwhile to make a substantial research effort in this area in this country.

It is also well established that the application of external ammonia fertilizer inhibits the action of nitrogenase, the enzyme responsible for biological nitrogen fixation by soil micro-organisms. The dimensions of this loss are not known and require study. Likewise it is also known that a proportion of ammonia applied as fertilizer is converted by some organisms in the soil to nitrogen gas thus removing the use of ammonia as plant nutrient. This may amount to 30 per cent. There is evidence that the application of some Indian oil cakes derived from minor oil seeds could reduce such losses by denitrification and this bears closer study.

There are also a number of studies in other countries on nitrogen fixation by catalytic processes and it will be worthwhile to commence research on such methods, even though they are currently exploratory in nature.

Hydrocarbon substitutes from renewable resources

Photosynthesis by green plants remains the only pathway by which carbondioxide, the output of animal systems and of industrial energy used by man, gets reconverted by the use of solar energy to food and hydrocarbon energy sources. Improved agriculture, cultivation of rapidly growing plants, the installation of energy forests and algal ponds are all current attempts towards better use of photosynthesis and these should be pursued. Nine tenths of photosynthesis still takes place on the surface of the sea. It is estimated that the annual production of carbon by photosynthesis on land is 20,000 million tonnes and all carbondioxide is cycled once in 300 years. A more efficient harvest of marine green plants would also be useful and other methods of substantially improved photosynthesis to give higher yields of sugar and starch would be worth pursuing.

While starch and cellulose from green plants are both made up of glucose molecules, man and birds and most animals depend for their food and energy on the consumption of starch. Starch is also readily converted by chemical and enzyme processes to glucose and alcohol. Considerable effort is being made to convert cellulose into glucose or other readily usable organic substances, which could be the basis of fuel or chemicals. The enzyme cellulase has the ability to digest cellulose but as yet economically viable processes for using this route are not available. There is a recent announcement regarding efficient chemical conversion of cellulose to glucose, by the use of an extruder normally employed in plastic processing, and if confirmed this opens large possibilities for the production of glucose and alcohol from abundant biological materials such as bagasse, wood pulp and saw dust. As a country with sunshine and water, we should forge ahead in developments of this type, which ensure plentiful renewable hydrocarbon resources.

Conclusions

The energy crisis coming from the large scale use of scarce non-renewable hydrocarbon fossil resources has given us warnings about following a life style based on high consumption of such resources. Fortunately, however, our addiction to these is not anywhere as deep as those of the developed countries. In the short term it is necessary to depend on such resources and ensure their minimum availability for development. However other options such as the development of nuclear energy need to be pursued vigorously.

There are however also possibilities for reducing the use of such non-renewable resources for meeting nutrient nitrogen needs through a greater understanding of the biological phenomena concerning nitrogen fixation and utilisation. There is a clear need to examine the use of new synthetic materials in place of metals needing high amounts of energy for manufacture. Finally, better use of renewable resources such as cellulose offer excellent alternatives to fossil fuels.

All these and more require, in my view, the renewal of our faith in our scientific abilities and excellence and in original approaches to meet our needs. The Indian Statistical Institute has a tradition of originality and daring and it is incumbent on all of us to carry through the spirit of Professor Mahalanobis in the assessment of our strengths and their application in novel ways to the solution of our problems. I am sure members of the Institute and the Alumni would continue to make outstanding contributions by thought, precept and action in cultivating the spirit of scientific adventure in the service of fellowmen. I wish them every success in this quest.