NUCLEAR POWER FOR UNDER-DEVELOPED AREAS

In the fateful summer of 1945 some leading scientists met in Washington to discuss future uses of atomic energy. And one of them - Enrico Fermi, who had established the first self-sustaining chain reaction three years before, remarked: "It would be nice if it could cure the common cold". The energy of atomic nuclei does not cure the common cold, but it does perform an amazing variety of other useful functions, among them - perhaps the most important - the generation of electric power. Electricity generated from nuclear energy should be able to meet man's ever-increasing needs of power even after all the world's fossil fuels have been burnt and all the rivers harnessed for power production.

It is an exhilarating theme which can be - and often has been - elaborated with considerable force. Complexities emerge with detailed analysis, but the basic compulsions are simple and clear. And the nature of these compulsions can be seen from a few broad facts.

Civilization progresses with increasing use of energy. The energy needed for any degree of development has to be supplied by sources other than one's muscles. For many hundreds of years, this energy has been supplied by the combustion of a very limited number of substances. Not only the number but also the total amount of such substances is limited, and we are threatened with reaching a stage when the world reserves of chemical fuels will have been exhausted. The contribution that can be made by the energy of falling water in the form of hydro-electric power is imperishable but relatively small and does not relieve the gloomy prospect to any appreciable extent.

The principal chemical fuels are coal, oil and natural gas. It is possible to differ on how soon the world reserves of these fuels will be exhausted, but most experts agree that these will not last for more than a few hundred years.

The eventual need for nuclear power for the world as a whole would thus appear certain, but the specific needs of the immediate situation are not yet apparent. In other words, while the broad outlines of the need are obvious, the urgency and the manner of meeting that need will have to be ascertained for specific situations. The situations vary so widely that any firm general conclusion would be inappropriate.

Varied Situations

First, there is the difference between advanced and under-developed areas. The term under-developed, of course, does not have any invariable connotation, but it is interesting to note that consumption of energy has an unfailing correlation with the more common characteristics of economic development. In fact, the level of energy consumption may be regarded as a fairly correct index to the level of economic development. Of the total world consumption of energy at the 1950 rate of 1 Q* per decade, 37 per cent was estimated to be in the United States alone. The world's total installed electrical capacity in 1950 was estimated at 230 million kilowatts. Only 7.3 per cent of it was in the under-developed areas (which might be said to comprise most countries of Asia, most of Africa, most of Latin America, as well as a few South European countries).

Secondly, even a group of countries with a similar level of economic development would not present a uniform picture. Conditions vary from country to country, from one region to another. Among the advanced countries, for example, we have in Britain a picture of a highly industrialized economy with rapidly increasing demands for power but with poor resources for hydro-power and small prospects of any substantial increase in coal production. The United States, on the other hand, has vast reserves of coal that can be easily mined. Again, a country like Norway can depend primarily on hydro-electric power for a considerable time.

Similar differences will be found among the less developed countries also. It will be found that there are areas where the introduction of nuclear power in present conditions will be considerably more expensive than the conventional alternatives, while in certain other areas nuclear power may immediately be competitive with thermal or hydro-electric power. It is however obvious that for such reasons as very serious difficulties in the transportation of chemical fuel and the absence of hydro-electric sources, it may be impossible to develop certain areas by conventional power, and nuclear power will eventually become the only means of developing these areas.

Common Features

Despite these differences, most under-developed countries present certain common features. The first of these, of course, is the inadequacy of power consumption. Consumption of energy per capita is low, consumption of electric power per capita is very much lower. Although this is generally true of all countries, the role played by electric power in meeting the total energy needs of the less developed ones is particularly small. An overwhelming proportion of the total energy consumption in under-developed areas

*1 *Q is equal to the energy of about 33 000 million tons of coal.*

is accounted for by the combustion of fossil fuels - not so much of coal and oil, which are often scarce, as of vegetal waste. It has been estimated that about 80 per cent of the energy consumed in India is derived from the burning of cattle dung. Electric power generated from an efficient heat source can be adapted to the most varied uses and makes for a more economical use of capital and labour. Besides, many of the modern industrial processes are inherently dependent on the availability of economical electric power. Extreme shortage of power supply, even when combined with a fairly large total consumption of energy, is often a major factor in retarding industrial development.

Secondly, the distribution of power supply within an under-developed country shows a striking imbalance. The generating capacity and the supply are almost entirely confined to large cities or ports. As a result, the level of development of certain urban areas bears no relation to the backward economy of vast rural areas. The social consequences that flow from such economic imbalances are none too happy.

Another important feature is the absence of concentrated demand. Demand is dispersed over a wide area and at no point except big cities is it sufficiently large to justify the construction of a major plant. Over the rest of the country, there are only tiny pockets of actual or potential consumption, separated by vast stretches of backward rural area that has little use for electricity in present conditions.

A Vicious Circle

It would be clear that all these factors constitute a vicious circle. Lack of power limits industrial development and lack of development limits the demand for power. Absence of demand over large areas separating power-consuming pockets makes it necessary to have either many small generating plants or a few large plants with wide-spread transmission lines. Both push up the total generating cost and consequently the price per kilowatt-hour. And the high cost inhibits wider or increased consumption. The demand remains low, or totally absent over wide areas.

While conditions for an adequate power supply increase with greater industrialization, an increase in supply itself tends to promote industrial development. Besides, the demand for electricity, not only by industry but also by the ordinary individual consumer, tends to increase with its availability. In a report* to the Economic and Social Council, the United Nations Secretary-General observed: "Because of the wide range of its uses the existence of a supply of electricity is apt to create its own demands and the need for an extension of its supply. All over the world, therefore, countries in evaluating their future demand for electricity, must take into account both its basic role in providing essential power for specific industrial and agricultural developments and the dynamic nature of the demand for it in the process of economic and social growth". The report also observed that the method of producing electricity from nuclear energy "is only on the threshold of its application" and "how rapidly the use of atomic energy will go beyond the threshold depends very largely upon the extent to which that energy may be economical under specific conditions".

The factors that enter into the economics of nuclear power generation are quite complex. Despite the high potential energy yield of nuclear fuel, one element in particular tends to keep the cost of power at a relatively high level. That is the capital investment for equipment and structures. A nuclear power plant involves complex and extraordinarily precise engineering construction, the use of special and relatively rare materials and elaborate arrangements for safety. All these have a direct bearing on cost. On present showing, capital costs are considerably higher for a nuclear plant than for a coal-fired thermal station. And construction costs per kilowatt of installed capacity is likely to be much higher for small than for large reactors.

Fuel costs, on the other hand, are expected to be lower for nuclear plants than for thermal stations - because of the much higher energy yield of nuclear fuel. And fuel costs are not likely to be substantially higher in small than in large reactors, particularly if the processing of fuel is done in large, central processing plants.

The cost of power will be affected also by the load factor of the power reactors. A higher load factor reduces cost. In other words, the cost per unit of power generated falls as the time during which the plant operates at full power increases.

Economics and Technology

Considering the net effect of the various economic and technological factors, some experts have doubted whether the utilization of nuclear power in the less developed areas would be feasible or profitable in the immediate future. Higher capital costs, the large power output of the existing reactor types, the need for a large, steady industrial load or of a grid - these are factors which, in the opinion of some, make the use of nuclear power uneconomical in under-developed areas. On the other hand, other experts have pointed out that in some of the under-developed areas, there is a strong case for immediate recourse to atomic power. As Dr. Homi J. Bhabha (India) observed at the Second Geneva Conference on the Peaceful Uses of Atomic Energy, conditions in certain under-developed areas show that a negative conclusion is not generally applicable.

Experts are however agreed that nuclear power generation in most of the under-developed areas could only begin with small or medium power reactors, because only in very few areas is the demand for power large and concentrated enough to justify the construction of a big plant. That raises the technological problem. At the Second General Conference of the International Atomic Energy Agency, Sir Edwin Plowden (UK) remarked: "Interest in small power

*Economic Applications of Atomic Energy, *United Nations, 1957*

reactors is understandable but the fact is that nowhere in the world has a small reactor yet been designed to supply amounts of power appropriate to the needs of such (i.e. the less developed) countries at an economic price. Small reactors that are economic will certainly be developed in time, but the scientific and engineering problems are formidable. Until solutions are in sight, the most useful help the Agency can give to the less developed countries is to concentrate on what is practicable in the immediate future, and in particular to promote opportunities for training their scientists and engineers so that they may be ready when the time comes".

It is to be hoped that the time will come soon, and in the meantime there is need for a detailed evaluation of the entire problem. In evaluating the needs of the less developed countries for nuclear power and in determining how and to what extent these needs can be met, the fundamental questions to be decided are: (a) to what extent can the total power needs of these countries be met by conventional (thermal and hydro) means, (b) in which sectors would it be immediately possible - from both technical and economic points of view - to generate power from nuclear energy, and (c) in which areas would it be imperative to resort to nuclear power in the immediate future.

Small Reactors

Knowledge about the technology of small reactors is still limited because a great deal of effort is concentrated on developing large power reactors, and operating experience is lacking. At the same time promising lines of research have been reported in some countries, and there is now an urgent need for a thorough and careful study of the subject as a whole. Similarly, in the field of the economics of nuclear power, there is need for a more detailed and systematic study than has hitherto been made.

Guided by these considerations, the IAEA Second General Conference recommended a survey of the nuclear power needs of the less developed countries, a study on a continuing basis of the technology and economics of small and medium power reactors suited to these countries, dissemination of the information obtained and assistance in training personnel in the technology and economic utilization of such nuclear stations. And on the basis of this recommendation, the Agency has initiated an integrated two-year programme of work for examining the possibilities of utilizing nuclear power in under-developed countries.

In carrying out this programme, the Agency is seeking potentially promising cases in which nuclear energy can yield necessarily limited but early benefits. That would help an assessment of the technical and economic possibilities of small and medium reactors in specific situations. It would also enable under-developed countries to compare and ascertain whether nuclear energy can provide an early solution to some of their pressing power problems.

Needs in Specific Situations

In most of the less developed countries, the most acute short-term needs for power appear to be linked with definite utilization, for instance in connexion with some mining or industrial activity, or with domestic electricity for use in one particular area where there is little prospect of help from an existing grid system or expansion of inter-connexion, at least for some years, and where development is impeded by high costs of conventional power, especially fuel costs. Again, in most cases the net electrical capacity of any one of the power units needed will not be large, probably not more than 50 mw. Of course, situations may be found where a grid system exists and larger power stations may prove more economical. At the same time, the technical requirements of the various types of reactors which may prove promising for that purpose will also have to be examined. This will call for careful analysis of the development of small and medium power reactors, with special reference to their adaptation for use in the less developed areas. The factors to be considered include ease of transportation and installation, long life, reliability, safety, resistance of equipment to climatic conditions, simplicity of functioning and maintenance, etc.

With these technical studies, evaluation of the elements for the costs of installation and operation of nuclear power plants will have to be undertaken. It will be necessary to take particularly into account the possible variations of these costs when applied to specific situations in the less developed countries. IAEA is already receiving the collaboration of the UN regional Economic Commissions in determining the relevant data on conditions prevailing in their special areas.

The first three phases of IAEA's work programme are: (i) studies on the technical suitability of reactors with a power level of up to 50 mw; (ii) economic studies in regard to reactor systems, including a systematic analysis of power costs; and (iii) selection of characteristic situations that appear to favour utilization of nuclear power.

Survey in Latin America

The Agency has already initiated preliminary investigations and technical studies in this field. A survey of special interest in this connexion will be carried out by an Agency mission which will shortly visit Argentina and Brazil to explore the possibilities of economic production and utilization of nuclear power at specific locations. The locations suggested in Argentina are Buenos Aires and its vicinity, and the Patagonian area. In Brazil, the proposed locations are at the mouth of the Parahiba River, about 200 km north-east of Rio de Janeiro, and at the mouth of the Iguape River, on the coast of the State of São Paolo, about 160 km south-west of the city of Santos.

The mission will evaluate the information already

collected by the national authorities and gather additional information that may have a bearing on cost factors. It will assess the progress made in the generation of electricity in the vicinity of the proposed locations, assist in making a preliminary assessment of future power needs and suggest steps for meeting those needs. In particular, it will consider the special problems of installing nuclear power plants at the suggested locations.

The survey in Latin America will be only a part of the extensive studies that IAEA is carrying out. The studies initiated under the three phases of the Agency's work programme in this field are being carried out concurrently and are expected to be completed by September 1959. The Agency will then start further specific studies, both technical and economic, in relation to selected situations. The results of these studies will be available in time for a major conference on small and medium reactors scheduled for 1960.

The findings from these studies are clearly not meant to answer all questions that may arise in the process of utilizing nuclear power in the less developed countries. Indeed, it would hardly be possible to answer all questions at the same time. It would be more realistic to tackle the problem piecemeal, ensuring, however, that one step leads to another in a logical sequence of development. The studies initiated by the Agency constitute the first major step in that direction, and their outcome will help in outlining the kind of initial practical action that will be needed.

SURVEY IN SOUTH-EAST ASIA

Technical assistance to atomic energy projects in different countries, particularly the less developed ones, is one of IAEA's principal functions. Before such assistance can be fruitfully rendered, the Agency has to study the needs and possibilities of development in these countries and decide on the lines of effective aid. Many countries have asked the Agency to assist them in evaluating their needs and conditions relating to atomic energy, to advise them on the best methods of advance and to determine how the Agency can be of assistance. Apart from direct benefit to the countries concerned, such an approach makes for better co-ordination of the Agency's activities and better utilization of its resources.

To this end, IAEA has already sent some preliminary missions to different areas and more are expected to be sent out in the future. One such mission has just completed a survey in China (Taiwan), Japan, the Republic of Korea, the Philippines and Viet-Nam, and another is visiting Argentina, Brazil and Venezuela this summer.

Earlier this year, an Agency mission visited four countries in South East Asia: Burma, Ceylon, Indonesia and Thailand. It consisted of eight members, four of whom were experts made available by Member States for this purpose,* while the others were chosen from the Agency's own staff. The work of the mission is recorded in extensive individual reports and in various notes and documents collected by the mission. These will be of value not only to the Agency and the countries concerned but to all interested in the utilization of nuclear energy for the peaceful progress of the less developed areas of the world. A brief, and necessarily incomplete, summary of the main observations and conclusions is contained in the following paragraphs.

In each of the four countries, the mission held detailed discussions with scientists and officials, collected information and exchanged ideas. Besides general discussion, consultations were held in small working groups on specific topics and problems. The members of the mission also visited atomic energy centres, other scientific and technical organizations, educational institutions as well as sites of actual or possible projects.

The reports of the mission can be considered under three broad heads. They contain, in the first place, a general description of the atomic energy programmes of the four countries, covering both current and planned activities. Under the second head can be considered the mission's comments and recommendations. Thirdly, the reports contain lists of specific requests for Agency assistance made by these countries after discussions with the mission.

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* *They were:*

Hugh Belcher (UK) Expert on the medical uses of radioisotopes; Head of the Radioisotope Laboratory of the Post-Graduate School at the Hammersmith Hospital, London;

Georges Bigotte (France) Specialist in geology and geological engineering; holds a senior position in the French Atomic Energy Commission;

Maheshwar Dayal (India) Design Engineer at the Indian Atomic Energy Establishment at Trombay;

Oleg Kazatschkovsky (USSR) Expert on the physics of experimental power reactors; worked at the first USSR atomic power station.

The mission was led by Dr. Vladimir Grigorieff of IAEA's Division of Exchange and Training of Scientists and Experts.