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A CATALOGUE OF ALTERNATIVES

by S. A. Sanni

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EVERY INAUGURAL LECTURE, by definition, heralds the start of something new, and this would apply even if I were but the latest in a succession of holders of the Chair of Chemical Engineering at the University of Ife rather than the first. In fact, Chemical Engineering is not only a new discipline but also a new kind of profession in this country. If this had been one of several inaugural lectures in Chemical Engineering, you might have expected my lecture to set out my personal view of the subject and of its teaching; and this I hope to do to some extent. But as this is the first inaugural lecture in Chemical Engineering in Black Africa, you will wish perhaps first to know something of what the subject is really about.

Let me begin by reminding you of the extent to which our lives are nowadays dominated by the critical relationship between Engineering and the society. Its effect is so all-pervading that we are liable to develop a kind of protective blindness to it, in the same way that if we wear red coloured glasses we become, after a while, unaware that the world appears to be particularly red in colour.

There is no doubt that we live in a scientific age. More to the point of course, is that what has, for better or worse, changed the world out of recognition is applied science, and particularly engineering. The critical factor in producing this change is the scale of application. Engineering has its biggest effect socially when it affects us as individuals. We are all aware of Mechanical and Electrical Engineering: they are brought home to us, literally, in our cars, radio, washing machines and our television sets. The effects of Chemical Engineering are less obvious but are just as pervading. The average householder may not realise that, apart from the main structure of his house, almost every material in it is the product of Chemical Engineering–the soaps, detergents, plastic ware, paint, electrical insulation, synthetic clothes, margarine and cooking oil, salt, sugar, milk, spirits, medicines, petrol–and so the list goes on. These domestic examples may seem trivial but behind them lies an industry employing about ten million people all over the world, and we see here the first stage of the relationship between Chemical Engineering and society.

Although chemical engineering is usually thought to have originated in modern times, many of the processes associated with this discipline were developed in antiquity. Filtration operations, for example, were carried out 5,000 years ago during the third Egyptian dynasty. At that time, grape juice was filtered through a cloth bag which was an undertaking requiring a great deal of strength and acrobatic dexterity. During the same period, salt was recovered from sea water by the combined operations of fluid flow, evaporation, crystallisation and sedimentation, with the necessary heat supplied by the sun. This discontinuous batch process, practised for many centuries prior to 1550, is still in use. The great awakening of science in the sixteenth century was followed in the seventeenth century by an unprecedented advance in mathematics. By the later part of the eighteenth century a great store of knowledge had been accumulated. It needed only practical mind and a culture hungry for useful products to apply this knowledge. The time was then ripe in England, for it had become a powerful nation with access to large sources of raw materials. In 1887, George Davis started the first course in Chemical Engineering at Manchester Technical College, and he wrote the the first book in 1901.

The first four departments of chemical engineering in the United States were established at the Massachusetts Institute of Technology in 1888, at the University of Pennsylvania in 1892, at Tulane University in 1894 and at the University of Michigan in 1893. Chemical Engineering education was fortunate to have evolved in an era of increased interest in the fundamentals of science. All early curricula in the United States required thorough study of chemistry and physics. This was supplemented by mechanical engineering and some descriptive lectures on equipment and processes. The chemical engineering curriculum of today is strong in the fundamentals of chemistry, physics and mathematics. The instruction in chemical engineering science is divided into applied physical chemistry and unit operations. More recently, basic scientific principles underlying several unit operations such as momentum, heat and mass transfer have been stressed.

I have so far stressed the development of chemical engineering education and practice because, it is in education that the central ideas of a profession can often be seen most clearly, and it is where the success of a profession rests. This historical resume was given in order to provide the insight necessary for a logical development of the definition of chemical engineering, its goals and philosophy.

Chemical engineering comprises those activities which apply science to problems related to the economic production of useful things by processes involving chemical or physico-chemical phenomena in one or more steps. This definition emphasises the broad horizons of the chemical engineering profession, and places no limits on the scientific knowledge to be used or on the type of work a chemical engineer may do. There are five types of activities in chemical engineering; research, design, production, sales and management. The work of an individual chemical engineer may overlap two or more of these activities, and the emphasis depends on his taste and personal qualities rather than on his technological ability. Common to all these activities is the ultimate result of their efforts—the economic production of useful things. To the researcher this goal may be distant, but it is real and essential if his contributions are to find uses. To the man in production or design it is quite tangible. The distinguishing quality of a chemical engineer at any technical effort is his sense of the urgency of man's needs and his willingness to compromise theory with reality in satisfying these needs.

It can be said that the chemical engineer's traditional role is that of the wrestler with reality, the prime contributer to production even when understanding is lacking, the inventor, and the voice of technological urgency. The role of chemical engineering is lofty and challenging. Our methods must seek to achieve the refinement of scientific pursuit without assuming the traditional goals of pure science itself. Our role as engineers must live and grow for the good of the society.

One of man's distinctive talents is his ability to make decisions. Chemical engineering as a profession has made full use of this talent. The chemical engineer's daily decisions must deal with the practicalities of the real world and the consequences of these decisions are continuous tests of their validity. In this respect he is a pragmatist, for he applies the criterion of "will it work" to decision making efforts, and he depends on the practical consequences of his decisions for a measure of their success. In predicting these consequences with a satisfactory degree of probability, he must lean heavily on his own experience and that of others. The chemical engineer has been successful because, motivated by urgency, he has accepted the inadequacies of any decision making processes and has tried to make the best decisions possible, because in engineering action is imperative.

The highest purpose a free man professes is a search for meaning in life. Having found meaning in life, we need only to relate that meaning to our profession, for man's work is the tool through which meaning is expressed and through which the early goals related to this meaning are attained. The question remaining then is what does chemical engineering as a profession offer as a tool for implementing man's highest values and most sensitive apprehensions of reality as a whole? One immediate answer lies in the definition of chemical engineering which was discussed earlier. By assuming a decisive role in the economic production of useful things, the chemical engineer provides not only the needs for survival but also many added amenities which ultimately yield the leisure needed, before anyone can think beyond his physical self. In the less developed areas of the world, these contributions have unbelievable power for good. Industrialisation holds not only the key for survival in the northern world but the key to an era of greater human dignity.

On a more abstract plane, chemical engineering can also satisfy the urge to fathom the unknown and do so better in some ways than pure science. Pure science, and rightfully so, must remain tenaciously committed to a goal of ultimate understanding. Chemical engineering, with its sense of urgency for use in our times, can roam freely in the unknown, picking here, discarding there, and finally emerging with a workable idea, a new invention, or a radical concept. In the urgencies of today's problems, understanding and lasting values can be found which will ultimately lead to man's control of nature in accordance with the highest spiritual perceptions.

I referred at the beginning of this lecture to the all-pervasive and growing infiltration of the products of engineering and technology into every home, and to the fact that our lives are more and more conditioned by engineering and technology. This is particularly true of the so-called Less Developed Countries. Consequently, indiscriminate pursuit of advanced technologies by these countries without adequate attention to the human and environmental problems are giving rise to a number of social and psychological maladies, the gravities of which are evident in our craze for imported products.

Technology is a basic resource for development. However, compared with other resources, such as finance or manpower, technology tends to be relatively neglected at the national policy level. Most developing countries like Nigeria, formulate and implement overall national policies, often very elaborate, to guide the way in which other resources are created, acquired, distributed, and used in the process of development. But we have never devoted an equivalent effort to the national management of the crucial resource of technology. This relative neglect of technology is most evident in relation to imports of technology. This is particularly curious in the light of the fact that, an overwhelmingly large proportion of the technology needed to develop production in key areas of our nation is acquired from overseas. So, while the financial and manpower resources are largely under the general influence and control of the local economic, social and political system, technology is largely a foreign resource. What this technology consists of, where it comes from, what it costs, what economic and political constraints come with it, how useful it is, and who gets what benefit from its uses are all issues which can be largely determined outside the society which acquires and uses it. The extent to which this is so will depend on whether there exists any systematic local policy on the importation of technology, and on the nature of the structure of such a policy.

A growing number of development experts and technology policy-makers are beginning to question the wisdom of massive technology transfers from the industrialised countries to the developing nations. The large-scale capital-intensive technologies developed in Europe, North America or Japan may well be very efficient, but their introduction into poorer, less developed nations often creates more problems than it can solve. They are usually very costly relative to the income of the local population; they require an educational and industrial infrastructure which takes decade to build up and their disruptive social consequences tend to be much more sudden than in their country of origin. But perhaps most important of all, their introduction often inhibits the growth of the indigenous innovative capabilities which are necessary if development is to take place.

What are erroneously regarded as symbols of development, for example, steel mills, chemical plants, automobile assembly plants or squadrons of military aircraft, can be purchased on the international market, but development is a complex social process which depends largely upon the internal innovative capabilities of a society. Importation of foreign ideas, values and technologies have a major part to play on development, but few societies in history have developed exclusively on the basis of such imports. One of the major problems facing the developing countries is their inability to create, nurture and rehabilitate their internal capacity to invent and innovate. As far as technology is concerned, this implies not only the inability to make greater selectivity in the choice of imported equipment, plants and methods of production, but also, and this is very important, the invention and diffusion of new types of technology and new forms of organisation which are better suited to local conditions. The technology which meets this requirement can be described as "appropriate", "low cost" or "intermediate" technology. Rather than try here to give a standard set of debatable definitions, it is perhaps more appropriate to discuss the main concepts comparatively.

When speaking of low-cost technology, one is focussing attention primarily on the economic dimension of innovation. The concept of intermediate technology on the other hand belongs more specifically to the level of engineering. Appropriate technology, which tends to be somewhat more popular than low-cost intermediate technology, represents what one might call the social and cultural dimension of innovation The idea here is that the value of a new technology lies not only in its economic viability and its technical soundness, but in its adaptation to the local, social and cultural environment. Assessing the appropriateness of a technology necessarily implies some sort of value judgement both on the part of those who develop it, and those who will be using it, and when ideological considerations come into play, as they often do, appropriateness is, at best, a fluctuating concept. Appropriate technology is very close to but not entirely identical with intermediate technology; and low-cost technology does not necessarily always meet the criterion of appropriateness. In fact, each of these concepts might be viewed as a set of overlapping but nevertheless distinct areas, the frontiers of which are rapidly changing under the impact of recent experiments, new innovations and progressive changes in perspective. For this reason, the terms "appropriate", "low-cost", and "intermediate" can for the moment be used almost interchangeably, and the choice of one term in preference to another is a reflection of differences in emphasis rather than of fundamental difference in nature.

One important factor is the distinction between *hardware* and *software* technology. This distinction is just as important in appropriate technology as in modern large scale technology. Technology invariably suggests the idea of *hardware* be it in the form of factories, machines products or infrastructures for example, roads, water distribution system, storage facilities to mention a few. Hardware is something visible, and even if it is not understandable, it stands out very conspicuously. Technology however goes much beyond the *hardware*. It comprises of what can be called, by analogy to the computer industry, the *software*. This includes such immaterial things as knowledge, know-how, experience, education and organisational ability. The countries which today are highly industrialised owe their development not merely to the invention and widespread application of new types of machinery, from the steam engine to the electronic computer, but also to major innovations and gradual improvements in their organisational ability and institutional infrastructures. The importance of these none-material innovations often tends to be underrated by historians of technology. Some of these innovations may seem trivial, but development is a process which consists of thousands of small improvements and modifications in software, rather than in sudden and massive leaps forward in hardware. The history of China, Imperial Rome or late Medieval Europe suggests that the ability to invent and develop new types of hardware alone is not sufficient to generate the equivalent of an industrial revolution. What is required is an entrepreneural class and perhaps even more important, a system of values—cultural, social or religious—which can legitimise and encourage social and economic changes.

The problem facing the developing nations are not very different. The range of new hardwares available to them in advanced countries is so wide and increasing so rapidly that it could, in theory if not in practice, meet a large part of their immediate needs. What is really lacking is the software, and this is perhaps the area where the appropriate technology exponents have the most to contribute. Hardware and the technical ability to produce it in an imitative way can generally be transferred from one country or culture to another. Organisational forms and social values are, by contrast, much more culture-specific and hence generally more difficult to transpose deliberately from one society to another.

American technology symbolises the large scale approach to which many developing countries are seeking an alternative. However, in its early years, the United States was in many respects a developing nation. There are many lessons to be learnt from the United States technological development, which was, by any standard, one of the outstandingly successful national experience in technology. Twenty-five years after the Declaration of Independence, the United States still had to import such things as nails, axes, and cloth from England. Many American leaders, for example, Benjamin Franklin and Alexander Hamilton among others, realised the dangers of the situation, and tried in their own way to promote what today would be called industrial independence or technological self-determination. Conditions were however unfavourable. The manufactured goods imported from Britain were much more competitive than American products, and they were often sold at dumping prices. Protective tariffs were of little avail. America had very few industries and those which existed were quite unable to meet the needs of a rapidly growing population. But things were to change dramatically with the Napoleonic wars. For nearly two decades, the United States found itself practically cut off from its British supplies, and had to rely on its own ingenuity to make all the products, it needed; from textiles to Agricultural tools, from weapons to transportation equipment. Looking at things in retrospect, the development of a country always appears to be a logical and orderly process. In fact, history is composed, in large part, of accidents and unforseeable discontinuities and the development of American technology was immeasurably less simple and straightforward than this picture would suggest. The important thing is not so much the details of the American technological development as some of the conclusions which can be drawn from it.

First is the fact that free trade, especially in manufactured goods, is not conducive to the development of industry and technology in a developing nation. Second is that a society which for some reason or another is suddenly forced to rely on its own resources can often do so. Third is the crucial importance of demand, or rather of a need for the products and the technologies which were formerly imported. Fourth is that the development of new industries is not necessarily incompatible with the absence of craftsmen and a structural shortage of skilled labour. In fact the production processes of American industry were designed specifically to overcome this drawback. Another lesson from the American experience is that contrary to what happened in most European countries, a high proportion of the inventors and entrepreneurs came from the rural communities. Oliver Evans, the inventor of the automatic milling machine, was brought up in a Delaware farm. Eli Whitney, who was to play a crucial role in the development of the textile industry, and later the machine industry, grew up in his father's farm in Connecticut. Cyrus McCormick, whose name became the major trade-mark in agricultural machinery, was also a farmer's son, and Henry Ford himself came from a Michigan farm. These few examples are given here to suggest that development is not necessarily an exclusively urban phenomenon and that inventiveness and entrepreneurship in the rural sector are extremely important. This point must be emphasised since more than seventy per cent of our population still lives in rural communities. No society can be considered as truly developed unless it has a healthy agriculture, and the social and economic level of the agricultural sector is generally a good indicator of a country's overall level of development.

Appropriate technology may well be the only solution to the development, or more modestly, the survival of the rural communities. But its development and diffusion raises a number of political and social problems. One of these is the allocation of resources. Even though appropriate technology is comparatively inexpensive, if one measures its cost in terms of investment per workplace, its large scale diffusion requires a large sum of money which might otherwise be used for big projects based on modern technology. Since investment decisions in the developing countries today are taken for the most part by public authorities and not by private entrepreneurs, the development and growth of industries based on appropriate technology depends very much upon political options taken at the highest level. Appropriate technology will turn development into an autonomous process of innovation and growth from below. Socially and ideologically, this approach is very different from the idea of "growth from above" which until now has largely dominated the theory and practice of development. But growth from below may well be more effective in getting as wide a number of people as possible to take an effective part in the development process.

Within the last fifteen or twenty years, higher education has been one of the fastest growing sectors of the economy in the developing countries as can clearly be seen from the number of new universities which sprang up and the dramatic increase in the student population. One of the main motivations behind this explosive growth was to transform the developing nations into modern societies by building up a massive technological and educational basis. The somewhat optimistic ideology which legitimised the creation of hundreds of new universities has today lost much of its veneer and given way to a more sober assessment of what higher education can effectively achieve vis-a-vis national development. Whatever the failings of the universities, and here the disappointment is the inevitable counterpart of exaggerated expectations, it is still the most effective means for providing young people with the basic skills and training necessary in a modern industrialised society. These universities have a basic commitment to modern technology which are institutionalised in their curricula, their entrance requrement, their communication system and their quality control procedures. This commitment stands in complete opposition to the guiding philosophy of the intermediate or appropriate technology movement. University education is expensive, and for the developing countries prohibitively expensive; for example one year of higher education for one student costs more than the total yearly income of a hundred farmers. It is concerned with sophisticated modern technology, and it is to a large extent an importation of a foreign culture. Can any Nigerian university play a useful role in the field of appropriate technology for which it was never designed, and from which it is so far away culturally and politically?

The students of today are the engineers, technologists, industrial entrepreneurs and political leaders of tomorrow, and the type of education thev are now getting will determine to a large extent the type of society that will exist twenty or thirty years hence. This time-lag or production cycle of the educational system suggest that if appropriate technology is to play an important role in the development process, the present generation of students need not only to be familiar with it, but also to have a certain sympathy for it. The shift in values and attitudes which this requires cannot be achieved in a simple and straightforward way. One approach is the Indian idea of integrating intermediate technology into the engineering curricula and eventually having degrees in this field. This poses a number of problems. Academic curricula in engineering are designed in such a way that it is difficult to add on a new course without either suppressing some existing courses which are essential, or lengthening by several semesters the total time spent for a degree. For the time being, it does not seem possible to design a full curriculum focusing exclusively on appropriate technology. Another approach is to accept intermediate technology as a legitimate subject for an engineering student's final year project. This is the approach in the Faculty of Technology at Ife. Designing a windmill, a palm-nut crusher, a cottage refregirator or a water distribution system which uses local resources and which can be manufactured by people with little technical education is just as challenging, difficult and instructive as the design of a diesel engine, a steel bridge or an electronic circuit.

Encouraging universities in the developing countries to develop intermediate technology requires a modification of the system of promotion in these universities. In most universities, the evaluation of the performance of a staff is based (in addition to other things) to a large extent on publications. This yardstick is perfectly legitimate since research, preferably of a high quality, is accepted as one of the main objectives of the University. This does little justice to the missions of a university, notably, its educational role and its contribution to economic and social development. Changes in these evaluation criteria should take place and there is no reason why in the universities of the developing countries, contributions to the development of intermediate technology might not be one of the main criteria for promotion. In fact, from a social point of view, such activities are probably much more useful and rewarding to the country. The various steps outlined above amount in effect to an institutionalisation of appropriate technology. That they could be useful is more than likely. However, even if these steps were carried out, there would still be many problems. One of the most important of which is that the Universities in the developing countries belong essentially to the urbanised segment of the society. Lecturers and students, even if they come originally from a rural community have for the most part lost contact with the farmers and craftsmen in the villages. If they are to help develop new technologies which are truly appropriate to the rural people, they need to have closer contacts with those whom these new technologies will serve. One purpose of such contact is to make staff and students realise what the real problems facing the rural community are and how difficult their daily life can be. It can also serve to give them greater respect and more understanding for their values, skills and technology. One should not forget that the technology developed by generations of farmers in the developing countries are in many respects very sophisticated and ingenious, primitive as they may appear, when compared to what has been achieved in the developed countries. This technological foundation is in the process of disintegration, and vast amount of knowledge accumulated over centuries are now being lost within a few years. Much of this knowledge could serve as the basis for developing new and more appropriate technology. The idea here is not, of course, to preserve the past at all costs and turn the rural communities into museums, but to get farmers and craftsmen to participate in the process of development of new technology with the help of the universities, and to encourage the universities to identify, evaluate and analyse the vast pool of dormant technology which are available in the informal sector.

One must accept the fact that the purpose of research on appropriate technology in the developing countries and notably in their universities, is not only to develop new technology or new products but also to build up the capability for technological innovation. Mistakes are inevitable and inefficiencies are likely but this is a normal phenomenon. Victor Martinez, one of the experts on low-cost technology once said 'before reading Shakespeare, one must know the alphabet, and learning how to master technology calls first for a mastery of the alphabet of technology'. There is a growing temptation for developing countries to rely solely on the appropriate technology developed in the industrialised countries rather than develop their own. In fact, there are good reasons to believe that the patterns of technological dependence which characterised the relations between the industrialised and developing countries are being replicated in the field of appropriate technology. It is a well known fact that more than ninety per cent of the world's potential in science and technology is located in less than twenty-five highly industrialised countries, and that the developing countries taken as a whole do not account for more than one per cent of the world's output in science, technology and industrial innovation. For the time being, it is difficult to determine if the same imbalance prevails in the field of research and development in appropriate technology. However, if one takes into account the rapidly growing research and development effort in appropriate technology undertaken in the industrialised countries, there are reasons to believe that the same patterns of dependence upon modern technology transfers from the developed countries could develop. Such transfer can make some contributions to development but the problem of technological self-determination will remain unsolved.

One political and social issue raised by the development of appropriate technology touches upon the limitations of economic and industrial planning. A large number of developing countries have a national plan and a large bureaucracy to implement it. Apart from ideological choices and political fashions, one of the motivations for planning is that market forces, both national and international are not conducive to real development. While the motivations for planning in the developing countries are perfectly legitimate, the results are often disastrous and disappointing. For one thing, national economic or industrial planning, is from an administrative point of view, a "high technology" activity which requires not only an efficient information system, but also a high degree of administrative competence. This means that there must be available a number of highly qualified people and what might be called an administrative tradition. In many developing countries none of these requirements is fulfilled.

Planning inevitably gives the idea that it is possible to control and direct all of a country's economic and industrial activities. It may be relatively easy to decide upon the construction of a steel mill, a big dam or an electrical distribution system, but these represent only a small fraction of the economic and industrial activities in a country. What makes an economy work are the hundreds and thousands of farmers, craftsmen, tradesmen, repairmen and industrial workers who provide their fellowmen, often on a very small scale, with the vast range of products and services they need. To the economic planners, the way in which the activities of these people are organised may seem irrational and in-efficient, and there is an inevitable temptation to re-organise them in a more coherent way. For instance, by replacing the thousands of small transport companies by a large transport co-operative, by setting up price control mechanism for basic products like bread, rice, sugar or flour or by bringing all the small tradesmen to form a large marketing organisation without taking into consideration the managerial capability and the infrastructural facilities available in the country. What usually ensues from such reorganisation efforts is, at best, another type of inefficiency, and at worst complete chaos. Even in the most underdeveloped society, the economic system is probably too complex and diverse to be organised in a rational way. What appropriate technology has to offer here is not a means of controlling and operating the economic system in a coherent way, but rather a series of technical tools to reduce the inefficiencies in specific areas. A very simple example can illustrate this point. In most developing countries, the small scale farmer sells part of his products in the open market. Since all the farmers are doing the same thing at the same time, prices collapse and there is little or no incentive for the farmer to produce more than he needs. To the economic planner, one solution to this problem might be to impose some minimum price for agricultural products. To the intermediate technology specialist, the solution lies elsewhere, namely, in developing a number of simple storage methods which will allow the farmer to stock his surpluses for a few weeks or a few months, and thereby obtain a better price for his products.

The design of a national policy for appropriate technology is still very much in its infancy, and there are no real models to serve as reference points. A number of countries, both developed and developing, have performed some very interesting experiments and the activities of the various appropriate technology groups have shown some of the main problems of innovation, and pointed to the direction in which a policy for appropriate technology might go. These experiences are probably not sufficient to provide a clear-cut answer to the question of what can be done in practice to foster the development and diffusion of appropriate technology. A certain number of general principles are nevertheless beginning to emerge. The first is the need to recognise that a national policy on appropriate technology must try to enhance the vast stock of appropriate technology developed by small local firms, individual craftsmen and inventors, educational institutions, charitable organisations, and institutional entrepreneurs. Along with this pool of technology, which belongs for the most part to the informal sector, there is also a vast amount of technology from the developed countries which in many cases is equally appropriate, and which could be used in a much more effective way. The appropriate technology groups represent, in a sense, the tip of the technological iceberg, and one of the aims of a national policy is to explore and exploit that part of the iceberg which lies below the surface.

A second general principle is that centralisation as well as coordination from above is not the most effective approach to innovation in appropriate technology. What is needed is not a monopoly of the inventive process by government but a much greater degree of initiative throughout the economic and political system or, to put it somewhat differently, a form of technological federalism, with initiatives and innovations coming from all levels. This diversity necessarily implies a certain amount of disorder, duplication and apparent inefficiency. But innovation like biological processes is inherently wasteful, and order grows out of disorder. What this means in practical terms is that a policy for appropriate technology should involve as wide a number of institutions and people as possible. One of the basic aims of a national science and technology policy should be to encourage, or at worst tolerate, this federalism rather than to suppress it for the sake of coordination and rationalisation. The research system is much too complex and delicate to be organised in an orderly way, and a large part of its internal dynamism stems from duplication, competition and disorder.

The third general principle is that a policy for appropriate technology, whether it is initiated by government, private industry or any other organisation, cannot and should not focus exclusively on the development of new types of hardware. Hardware is undoubtedly very important but so are new forms of organisation, more efficient uses of existing resources, and faster transfer of knowledge between sectors.

One of the fascinating phenomena in the social history of technology is the association of certain ethnic, religious or social groups with particular types of technology. The case of the Benin bronze, the Abuja pottery, the leather work in Northern Nigeria are good examples. Most of these technological traditions are disappearing rapidly, although they have in some cases been successfully revived. Along with the technology, what also disappears is its underlying culture, its values, its system of learning and such important things as pride in one's work and social consideration. One of the aims of a national policy for appropriate technology should be to identify these local traditions and attempts to use them as a basis for the development of new but somewhat related technology. The idea here is not to return to the past and rebuild an industry with little future, but to help those who have generations of experience behind them make the transition and adapt in an innovative way, to the neew needs of the community. The craft of the silversmith can be immensely important in making or reparing small machines; the art of the potter can be useful in building up a water distribution system or an irrigation network; and a traditional gun-maker can learn how to make more complex metal working equipment. What is often overlooked is that these technological traditions carry with them a certain psychological image, which from a marketing point of view, can be extremely important. This image of a product or a technology often survives long after the technology has disappeared.

Many of the traditional technology which have survived in developing countries today are well known outside their area of origin, and the reputation, or image, which some of them still have is a major asset which could be exploited in a much more effective way. Yet it is surprising to see that virtually no systematic attempts have been made to draw up inventories of these existing stock of traditional technology. Without such inventories it is difficult to know what exist, let alone what could be improved and developed. Drawing up such inventories is one of many tasks which a national policy for appropriate technology should tackle.

Modern science and technology are closely associated with universities which supply the system with the highly qualified manpower it needs and perform the greatest part of the country's fundamental research. In the same way that the university is the cornerstone of modern science and technology, the primary and especially the secondary school is a basic element in intermediate technology. One of the functions, unfortunately rarely fulfilled, of the primary and secondary schools, should be to give children a certain feeling for technology in general, and for the appropriate technology to be made useful in everyday life in particular. Secondary Schools and indeed Teacher Training Colleges should be one of the main centres of attention of a national policy for appropriate technology.

One of the most widespread assumptions about the science and technology system is that innovators are highly educated people and that most innovations come from large research laboratories. As a result, national technology policies are almost unanimous in stressing the need for training more university graduates, and until quite recently, in emphasising the vital importance of greater expenditure on research.

Industrial history however clearly shows that a large number of important innovations are made by individuals with little if any university education. What this suggests for national policy vis-a-vis appropriate technology is that the promotion of invention and innovation should focus on this vast pool of uneducated entrepreneurs and innovators which exist in our society, but which is either being neglected or repressed as a result of the unduly optimistic belief in the virtues of higher education. It should be stressed that an appropriate technology policy suggested above is not a substitute for modern science policy, but rather a complement. The idea here is to have two parallel policies, and not to replace one by the other. The dualistic policy suggested here is but a reflection of the social and technological dualism which characterises the economic system in the majority of the developing countries.

A national policy for appropriate technology cannot be carried out exclusively by the government. It should be a collective effort involving as wide a number of institutions as possible. Both public and private sector and local authorities have as important a role to play as the Federal Government, because appropriate technology, contrary to large scale modern technology, is probably one of the areas in which a country can assert its sovereignty in the most effective and positive way. One of the biggest problems which many developing countries have to face is that of preserving a certain balance between the centrifugal forces of diversity and the centripetal forces of modernity, and any national policy for appropriate technology must take this into account. The dualistic policy suggested above, implies that not only do we need a policy for appropriate technology but also a policy to control the transfer and diffusion of modern technology.

If there were no problems about importing foreign technology, there would be no need for any major concern with policy for technology transfer. Throughout the developing countries, there is a growing concern that the process of importing foreign technology generates significant problems for the recipient countries, and operates in a way that does not maximise the net benefits for those societies. At the same time, the precise nature and size of these present and future problems and opportunities are often far from clear.

The process of transferring technological know-how from one culture to another, and specifically from an industrialised nation to a less developed country, is as yet little understood, as equally are the obstacles to transfer and the best means of overcoming them. When technological know-how are transferred from one country to another, assimilative and reproductive propensities, cultural prides, social motivations and creativity of the people of the recipient country play basic roles. When one talks about technology transfer it does not mean the mere passing on of some technical information but the actual transplantation from one environment to another of applied scientific methodologies and their operating data. Hence technology transfer can conveniently be looked at as comparable to organic transplantation work as carried out in agricultural operations or in animal and human bodies by surgeons.

The organic nature of technology transfer does not imply that the new environment (the recipient country) should be exactly the same as that of the donor. Potatoes, pears and pineapples grow in different soils while animal and human organs can be transplanted into different bodies. Technology can also prosper in dissimilar environments, often showing improved results in the process. Thus, many of the technology of ancient Asia produced more effective results in Europe after their transfer via Arabs, Persians and the Greeks. A similar example is the spectacular growth and intensity of European technology in the United States of America. The successful transfer of technology is essentially a question of organic growth. This means therefore that the problem of technology transfer is, in the ultimate analysis, a predominantly human problem. All those areas of human personality, tangible and intangible, which contribute towards creativity and achievement are inextricably linked with the problem of technology transfer.

Apart from the question of transferring technology to a new soil, and making it grow to its full stature, it is essential that these technologies should be able to reproduce themselves as well as cross-fertilize the dormant areas of growth in the new environment, producing new technologies in the process. The long-term growth of any technology, therefore, implies that it must not only be productive during its life span, but also reproductive before it is obsolete. This is an equally vital aspect of the organic nature of transfer of technology for which requisite infrastructure, organizational and institutional bases have to be provided.

Within a given society, technical change involves a process of invention, innovation and diffusion of the new technology or technique by imitation and acceptance. But an accepted technology transferred to another society involves commercial risks, a need for adaptation, and meets resistance to change, so that the transfer becomes more of an innovative than an imitative process. To the recipient society, it is new technology, no matter the level of acceptance and its age in the disseminating society. In general, technology transfer and diffusion is a cultural, social and political process, and not just the imitation of manufacturing processes. Clearly, given the inherent difficulties, technology transfer and diffusion cannot be a spontaneous process as we tend to regard it in Nigeria, but require institutionalized channels of action.

Considering the fundamental role of nationalism, and socio-economic factors in technology transfer and diffusion it would be instructive to study historical developments in some of the Asiatic countries which fostered their respective progress. Among all Asiatic countries, Japan stands out conspicuously, as the one which has been most successful in retaining her self confidence and national pride without any serious foreign subversion. Her success in being able to retain her national culture, patriotic fervour and self-confidence are, in fact, important contributory factors to her success in economic development.

The fact that her success in absorbing Western technology, frequently improving the quality and cost performance in the process of adaptation is a logical development of her past history and culture, is often forgotten. Failure to appreciate this is tantamount to failure to understand the fundamental nature and effect of Japanese history on its present development. Attempts will therefore be made to highlight a few basic issues.

The original Japanese state of Yamoto gave its sovereign three articles as symbols of power—the mirror, the jewel and the sword—and these still continue to be the subconscious elements of Japanese national mentality. The mirror symbolizes the ability of the Japanese mind to reflect and reproduce an observation with precision and exactitude, the jewel symbolizes love of lustre, cleanliness and beauty, and the sword, ability to defend the national integrity under adverse circumstances. The Japanese exhibited remarkable propensities for absorbing modern ideas and "Japanizing" them through a process of adaptation characterised by precision, skill, aesthetic abilities, and above all. by self-discipline and patriotism of the highest order.

The details of Japanese success in transferring American and European technology, particularly during the last two decades, and improving these further through ruthless scrutiny of engineering design, cost, quality and further research, are too well known to need elaboration here. In spite of massive vulgarities which the tourists can see in Japan today, it would be wrong to assume any real disintegration of the foundations of her national culture or sense of values. The greatest lesson which Japan provides to developing countries, like Nigeria, is that effective industrialization could take place without the cultural and social values being displaced and that industrialization is even more effective under such conditions. In Japan, the pattern of industrial management and human relations, apart from fostering intimate cooperation through joint consultation, has essentially been an extension of traditional Japanese paternalism and the family system, to an industrial organization, with all its ethical values, responses, and responsibilities. Implicit in such a pattern of paternalism is the ethical obligation of sharing the profits with the workers; this is of fundamental importance to developing countries. The phenomenon of technological development is an integral part of national life, its culture, value premises, social structure and economic organisation. Technologica growth and industrialization cannot be viewed in isolation from these fundamental issues.

Technological improvements in production are not necessarily dependent on capital intensification. A lot can be achieved by improving and re-arranging working methods such as improving tools, introducing instrumentation or better process control, improving skills–often with very little cost. Such significant areas of improvement are frequently lost sight of, particularly in the developing countries where, unfortunately, the mental attitude of the present leadership is often conditioned by a deep-rooted inferiority complex, and a passive uncritical acceptance of Western ways. Most of the technological deficiencies in the developing countries are not due to lack of expensive equipment (there are thousands of these in Nigeria), but to the lack of the right mental attitude, which seeks constant improvements by questioning, self-criticism, and by tenacious perseverance. These attributes are generated by the proud emotions of a cultured nation. In the absence of proper social and economic motivation workers can hardly be blamed for not being too enthusiastic in matters relating to technological development In the absence of self confidence and pride in native capabilities, the management is prone to recline and seek guidance from abroad. In the process of economic development, foreign aid or expertise can hardly be effective substitutes for more fundamental psychological and socio-economic elements in a people.

It should further be mentioned that massive investment on foreign technology tend to become weakening and self-defeating in the long run, unless they are counter-balanced by adequate amount of indigenous research and development efforts. Such R & D efforts, particularly during the initial stages need not be original work. Efforts to modify foreign designs and specifications to conform to the dictates of value engineering, efforts towards material substitutions, manufacturing spare parts, providing common components from indigenous resources, fabricating simple parts of a plant; all these go a long way towards creating a progressive technological climate. Foreign firms who invest in developing countries via subsidiaries or affiliated companies should be made to conduct research on local materials and components.

For a successful transfer of technology, it is essential to have within the country, reasonable facilities for carrying out design, plant and production engineering work for technical establishments, as well as undertaking problem solving and consultancy work for them on an ad hoc basis. Most of the equipment manufactured in Western countries require modification to meet the demands of local variables, for which design work has to be undertaken. Design work is involved in the installation of a particular layout, for fabricating the utility system for manufacturing portions of a processing plant, product and process modifications. In fact, without local design facilities, transfer of technology would lose much of its purpose and meaning. Similarly, maintenance, repairs and plant engineering work in general, have fundamental bearings on the successful transfer of technology. Apart from the direct utility values of such services, they create an impact on the progressive technological climate. We, in this country, have to formulate a series of research and development programmes which are related to specific socio-economic goals, and which are integrated financially and institutionally into an overall strategy.

Considering the principles outlined earlier on appropriate technology and the control of the importation of modern technology, four main lines of action are suggested for the formulation and implementation of a technology policy for the country. These are: (i) increasing the demand for local technology (ii) increasing the capacity for the absorption of technology (iii) regulating the importation of technology and (iv) developing the production of technology. These four main lines of action should take place simultaneously.

The main objectives of these lines of action are:

(i) to channel the demand for technology which is now oriented towards external sources to local sources;

(ii) to provide the country with the necessary capacity to understand better the principles of any imported technology; to master its application and to modify such technology to suit local conditions;

(iii) to secure maximum possible advantages from technology and

(iv) to increase the country's bargaining power in buying technology and

(v) to increase the country's capacity for generating technology in priority areas.

The disaggregation of technological package is a very fundamental policy instrument which can be used for all these lines of action. This disaggregation of technological package consists of two stages. First, a separation of the technology into each of its modules or components and second, a technical disaggregation in which each module is examined from an engineering point of view, differentiating between the "medullar" and "peripheral" aspects. The "medullar" component is that which is specific and inherent in the process and which distinguishes it from other processes. The "peripheral" component is generally common to different processes and is relatively more freely available than the "medullar" component. It should be noted however that the definitions of "medullar" and "peripheral" given above are only valid for a particular process, and that, that which is "medullar" in one process can turn out to be "peripheral" in another. Disaggregation of technological package strengthens the bargaining power of technology buyers and helps to regulate the importation of technology which can be produced locally, thus generating a demand for technological activities. It permits technology buyers to have a greater understanding of the characteristics of imported technology and hence facilitates its absorption.

The technology policy discussed above is a "basic need oriented" policy, which implies the participation of the people in making the decisions which affect them through organisations of their own choice. It is important to recc nise that the concept of basic needs is a country specific and dynamic ncept. This concept should be placed within the context of the country's over-all economic and social development. In no circumstances should it be taken to mean merely the minimum necessary for subsistence. It should be placed within a context of national independence, the dignity of individual and people and their freedom to chart their destiny without hindrance.

There has been much agitation in recent years about our need for more engineers and technicians in order to promote technological innovation and close what had been called the "technological gap" between the developing and developed countries. Yet the pattern of technological education in higher institutions in this country has remained unchanged. Technology faculties in our Universities are competing with other faculties for the dwindling financial resources. In order to increase our capacity for generating technology, we must put more emphasis on technological education both at the professional and sub-professional levels. If Nigeria is to rise to any height and gain respect among the comity of nations it must, as a matter of urgency, establish at least three Technological Universities Three of the existing Universities should serve as the nuclei for these Technological Universities. The conversion of three of the existing Universities should be gradual but there should be a declared intention early enough so that proper orientation and the machinery for internal reorganisation would be established in the Universities so ear-marked.

The problem of harnessing science and technology to national development is basically one of education. Our existing educational system is fundamentally informative, commonly passive and autocratic and it has created an environment which hinders the development of science and technology. Instead of developing creative and inquisitive minds which are pre-requisite to technological innovation, it has fostered undisciplined thinking. individual and collective irresponsibility and the pursuit of material and superficial intellectual values. All these constitute open warfare on technological development. An educational system which fosters the teaching of science at a very early age of the child is capable of providing a critical and reflective attitude in the child. True scientific education will provide the child with a mental discipline that will guide him in seeking and respecting the truth and in acquiring a receptive attitude. What one advocates here is an educational system which develops in the child inventive creativity and therefore originality and objectivity thus permitting him to analyse rationally the world around him, adequately weigh his reactions and establish cause and effect relationship that would help him to face everyday problems. This does not imply that every child should be trained to be scientist, but that he should be capable of applying scientific method in all its scope to the problems of modern living. This type of educational system will develop more objective individuals capable of formulating hypotheses and proving them, being critical of themselves and of the society in which they live, willing to accept changes and approach with a reflective and creative mentality within the frame work of social justice. I am convinced that the defect in our present educational system is one of the major causes of our scientific and technological underdevelopment.

University of Ife and a National Technological Tradition

It is necessary to focus attention on the technological milieu which we have tried to foster over the last decade or so at the University of Ife and the department of chemical engineering in particular. Realising the importance of technological education to national development and in particular the pressing need for chemical engineers, the University of Ife took the pioneering step in 1969 of establishing the first Department of Chemical Engineering in black Africa. The main objective of the chemical engineering programme at Ife is to give the students a sound command of basic chemical engineering principles, versatility of mind, insight and perspective concerning natural phenomena, and the habit of continued learning. From these attributes comes the best assurance against professional obsolescence especially in today's world of rapid technological change. The programme aims at developing in the students a versatility of mind and an ability to learn a new so that, as professionals, they will work at the frontiers of their field and bring forth new technologies, the very nature of which may be essentially unknown during the period of their formal education.

The degree curriculum and research objectives are such as to provide instructions and training required for:

(i) the evaluation of natural resources useful as raw materials;
(ii) adapting available technology to local conditions; and
(iii) developing techniques to process local materials hitherto not developed.

Bearing in mind the above objectives, the research work in the department can be divided into two broad areas:

(i) Development of Appropriate Technology; and
(ii) Adaptation of available technology to local conditions.

The work on the "Design of a Solar Pump" falls under category one while the "Preparation of Furfural from Agricultural wastes" and "Extraction of Bitumen from Nigerian Tar Sand" fall under category two.

The Solar Pump could be used to pump water from boreholes or with some modifications for irrigation. The principle involved is as follows. High pressure steam at about 5 atmospheres is allowed to expand through an orifice (in the form of an ejector) at a high velocity. This creates a vacuum or a sunction which is used to lift water from a well into a storage tank. The high pressure steam is generated using solar energy. The ejector pump designed has a capacity of 30 litres per minute and a static head of 20 feet. Effort is now being focussed on the design of the solar collector.

The production of furfural from some agricultural wastes such as saw-dust, corn cob, and bagasses is part of a comprehensive programme in the department, of finding uses for locally available agricultural residues. Furfural is one of the most important members of the family of heterocyclic compounds known as Furan. One of the large scale uses of furfural involves the production of adiponitrile, an intermediate in the production of nylon.

Theoretically, furfural could be produced from a great many agricultural residues but in practice, economic considerations limit the choice of raw materials to a comparatively few agricultural wastes. Typical raw materials, available in Nigeria, which may be used for furfural production are: corncobs, cotton seed hull bran, rice hulls, groundnut hulls, sawdust, bagasse and corn stalks. Since the yield of furfural is about 11 to 20% the remainder being largely cellulose, lignin and ash, the choice of raw materials is therefore dependent upon availability, delivered price, conversion cost and the value of the by-products produced. The choice of raw materials is also influenced by other parameters like potential furfural content, moisture content and bulk density. The potential furfural content of bagasses and saw-dust is low compared to that of cotton seed hull bran or corn cobs, but due to their high bulk density, a greater weight of each could be charged and hence more furfural produced per batch. Hence the production of furfural from two agricultural residues, saw-dust and bagasse was studied.

All known work on the production of furfural are in the form of patents. This is an indication of the importance of this work to industrial development. The maximum yield obtained so far is 12% by weight for bagasse and 10% by weight for saw-dust at 90°C, one atmosphere and a particle size of 0.338mm. This compares favourably with what has been reported in some patents. Application of the "moving boundary model" to the digestion showed that the saw-dust and bagasses particles behaved as if they were spheres during digestion. More work is planned for high pressures and temperatures in order to optimize the process. Since the outlook for a chemical industry based on agricultural residue, whose availability is virtually unlimited and which is renewed annually by nature, appears encouraging, the future industrial production of furfural and other derivatives from agricultural wastes, appeared sufficiently hopeful to justify increasing expenditure on research in this field.

The growing energy shortage facing many countries of the world today makes it imperative to focus attention on new and potential reserves of energy. Conventional crude petroleum has been the most regular source of petroleum fuels. It is also the major raw material feedstocks for petrochemical and polymer industries. The continued depletion of the crude petroleum reserves, aggravated by increased demand for oil motivated by political crisis, has led to the current energy crisis which poses a threat to the refining and petrochemical industries. These industries are the cornerstone of major products like resins, fibres plastics pharmaceutics and chemicals like nitrogeneous fertilizers whose roles in modern technology and the standard of life of man are very obvious. The Nigerian Third National Development Plan is very definite in recommending the productions of these hydrocarbon based products.

A potential alternative hydrocarbon energy source is Bituminous Tar Sand. Tar sands are naturally occurring sand deposits impregnated with varying amount of heavy viscuous and sulphur containing petroleum substance. This material can be upgraded, after the sulphur and traces of metals have been removed to yield "synthetic" crude petroleum. Nigeria has lots of Tar Sand. This has been established from investigations carried out by us at the University of Ife.

The area of occurrence of tar sands deposits is in the Ijebu-Ode/Okitipupa area. Bituminous seepages occupy a belt of about 110 Kilometers long lying between latitudes 3^{o} 55′E and 5^{o} 00″ E with an average width of 6 kilometers. The thickness of deposits ranges from 0.5 to 13 metres with an average of about 6 metres. The tar sands reserve has been conservatively estimated to be more than 31 billion tonnes.

It is generally accepted that for the mining of any tar sands deposit to be economically viable, the minimum bituminous content should be about 10% by weight. The large Canadian Athabasca tar sands deposits in Alberta which is currently receiving a tremendous amount of exploitation has an average bituminous content of about 12%. It is thus very encouraging that our preliminary investigations have indicated that the Nigerian tar sands deposits have an average bituminous content of about 20% by weight. This means that the tar sands deposits constitute a potential reserve of over 78 billion barels of this bituminous material.

The Canadian petrochemical tar sand based industry presently achieves a conversion rate of 75% in the manufacture of synthetic crude oil from the bituminous material. If this same conversion is applied, it means that Nigeria has a potential source of about 59 billion barrels of synthetic crude oil existing in the tar sands deposits. This is equivalent to about 80 years of natural crude petroleum for Nigeria at the current production rate of about 2 million barrels per day. Consequently, prompt and concerted effort to exploit these tar sands deposits could add to the much desired flexibility of Nigeria's future petrochemical industry.

Much of the work done in other countries, especially Canada, on the processing of tar sands are very highly proprietary. Thus, the need arises for a complete and original work to ascertain the feasibility of using the tar sands in our petrochemical industry.

It must be noted that the heavy bituminous material from the tar sands contains about 5% by weight of sulphur. This constitutes a potential source of sulphur for the sulphuric acid and super phosphate production plants.

In conclusion, I would like to emphasize some aspects of this lecture which require immediate attention. In order to improve our indigenous innovative capabilities and link science and technology to production, urgent consideration must be given to the following:

(i) formulation of a Technology Policy taking into consideration the social and technological dualism which characterises our economic system;

(ii) conversion of three of the existing Universities into Technological Universities;

(iii) development of a science-based educational system which develops creative and inquisitive minds;

(iv) establishment of a Ministry of Science and Technology. (The National Science and Technology Development Agency should form the nucleus of such a Ministry and because of the importance of this Ministry, the responsibility for running it should be vested in the President of the country;

(v) Establishment of a Technology Package Board. The Board will be responsible for approving and disaggregating any imported technology with a view to controlling the importation of technology and increasing the demand for local technology.

I wish to end this lecture where I began, that is with chemical engineering as a profession. I believe that chemical engineering contalls all the challenging elements for satisfying man's fullness of being. The chemical engineer who has found himself in the universal quest for meaning in life can project that self effectively through the unlimited potential of this profession. The level of the development of this profession is an index of the technological development of any nation because chemical engineering is the VOICE of technology.