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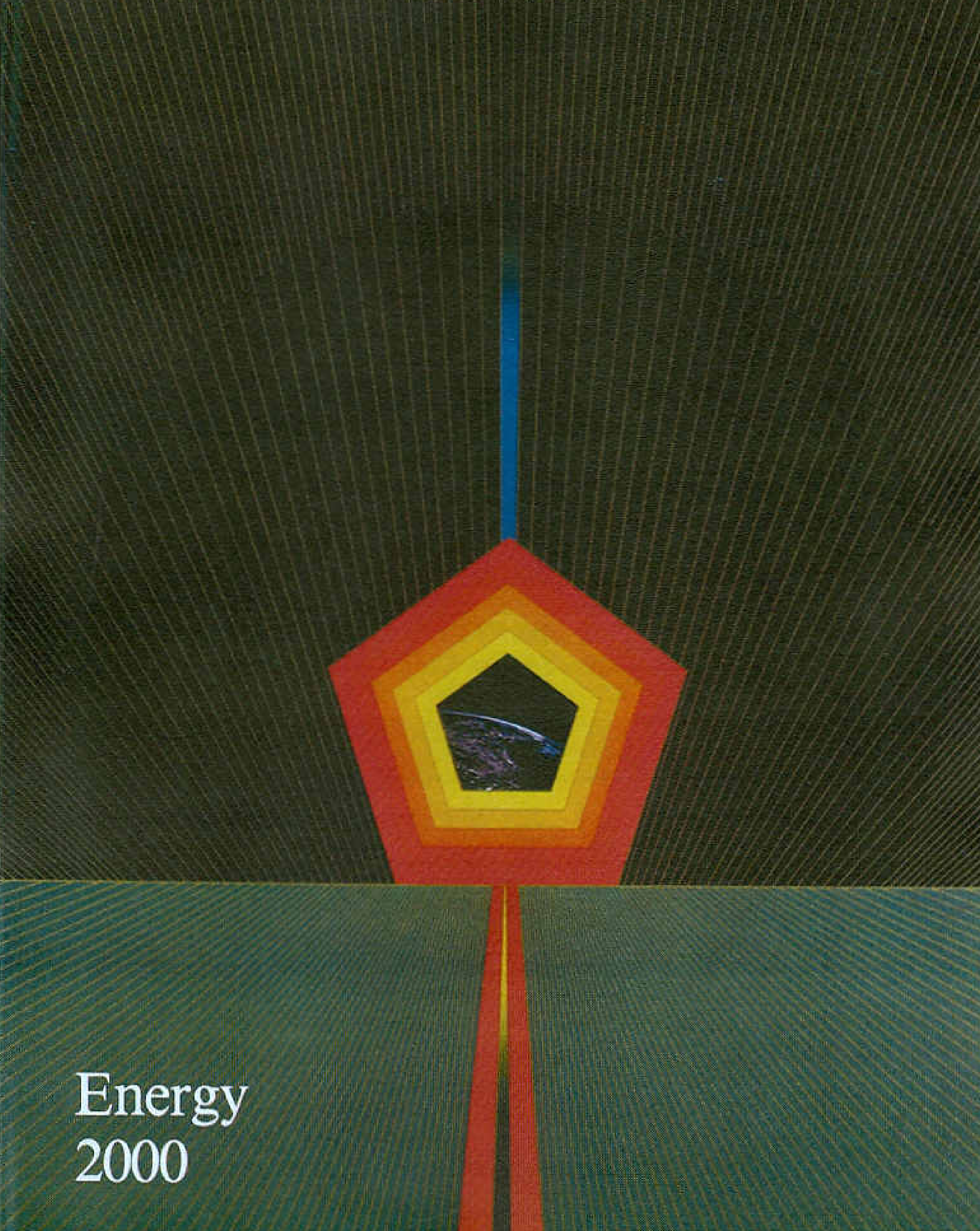

Energy 2000

TREASURES
OF
WORLD ART
164
India

Lotus-ruffed sun worshipper

An endless source of fascination for mankind, the sun has inspired a wealth of traditions, cults, philosophies and works of art. This circular motif representing a lotus flower in full bloom is dedicated to the golden orb, on whose energy all life depends. The figure framed by the ruff-like lotus is doubtless a sun worshipper. The bas-relief, now preserved in the Indian Museum at Calcutta, is from the lintel of a door of the great stupa of Bharhut (India) which dates from the second century BC.

The Unesco Courier

A window open on the world

JULY 1981 34th YEAR

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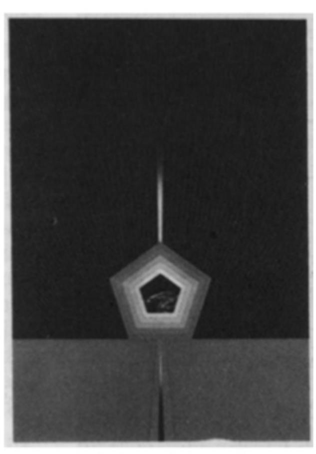

Cover design Nagai Kazumasa
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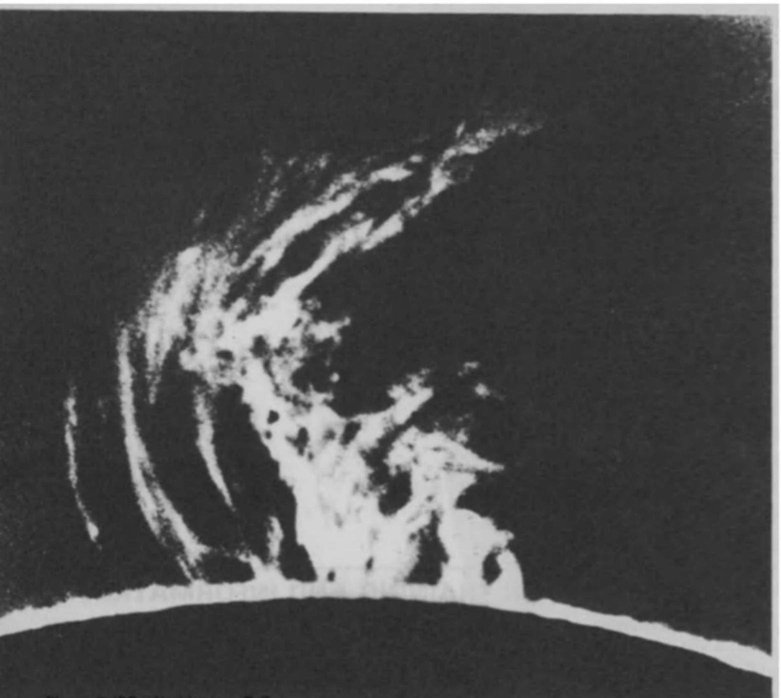
Cover

This issue of the *Unesco Courier* is devoted to world energy problems and the need to engineer a smooth transition to a new "mix" of energy sources which will reduce dependence on dwindling fossil fuels. This is not only a challenge for modern technology, it is a challenge for international co-operation and solidarity since the energy crisis, which affects all nations, is imposing a disproportionately heavy burden on developing countries struggling to pay for their development in a world of steeply rising energy prices. Unesco is closely concerned with world energy problems and is taking part in a United Nations Conference on New and Renewable Energy Sources which is being held in Nairobi (Kenya) between 10 and 21 August 1981.

Meeting the



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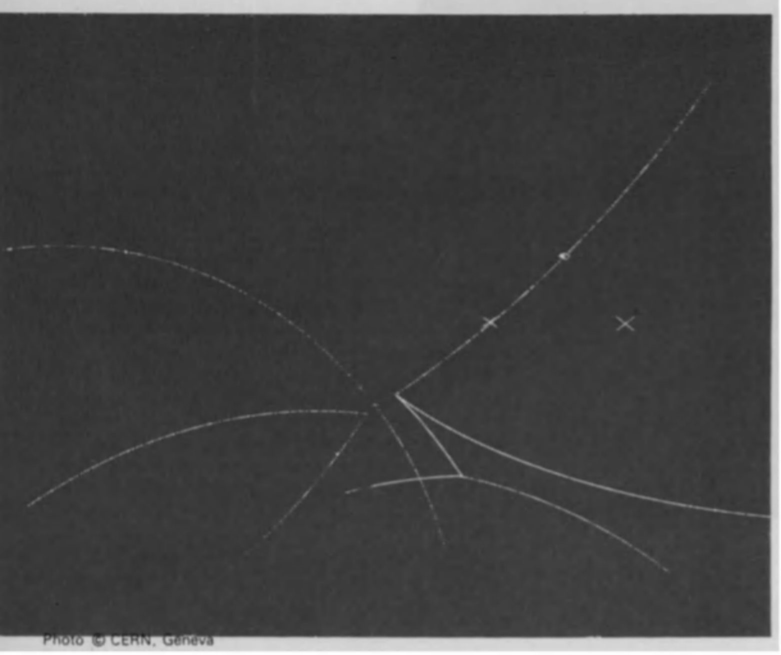


Photo © CERN, Geneva

ENERGY has always been a factor of fundamental importance in the life of human societies. All activity entails the expenditure of energy and hence, from the draught animal to nuclear fission, the history of energy merges with the history of mankind, in whose pattern it is in many respects one of the guiding threads. The production of energy down the ages has followed the development of scientific thought, and the forms of energy available and the manner of their use have often had a direct influence on the nature of society. In other words energy must be considered, in a historical perspective, in the light of culture in its broadest sense.

Thus in the nineteenth century the massive use of coal, coupled with the invention of the steam engine and progress in chemistry and steel manufacturing, made possible the first industrial revolution which transformed the essentially agrarian societies of Europe and then America. Likewise, the discovery of electricity and its host of uses, whether for lighting, mechanization, or communication, have made a deep impact on the lives of men and women of every continent and have fostered the creation and growth of the world's great cities. In the twentieth century the exploitation at an increasingly rapid rate of the other fossil fuels, oil and natural gas, has, along with the development of hydro-electric power and nuclear energy, enabled the industrialized societies to pursue the momentous changes which have given birth to the modern world, with its hopes and contradictions.

If energy problems are today so acute at the international level as to justify the holding of a United Nations Conference on New and Renewable Energy Sources, this is because it no longer seems possible to satisfy the world's constantly mounting energy needs by continuing to exploit, exactly as before, too limited a range of energy resources. The international community is thus confronted with the challenge of making forthwith those structural changes—economic, social and technological—which are required by the transition to new energy sources.

In fact, as this issue of the *Unesco Courier* makes clear, given the circumstances of production and living conditions which currently prevail in a number of countries, no single energy source can continue to meet all energy needs over a very long period; nor are there new sources capable of taking over fully from those which now exist. Such is the outcome of a world situation which has been characterized for too long by the intensive exploitation, for economic reasons related, for instance, to underpayment for energy, of non-renewable sources such as oil over which there hangs the threat of eventual exhaustion. The study of alternative solutions should aim to increase energy production but it must also situate this endeavour within a wider context. It no longer seems possible to envisage the future without taking into consideration total world energy consumption, together with the need for changes in the energy economy as a whole, with all the consequences which will ensue for the environment and for society.

Such a project concerns all countries, whether industrialized or developing. It is true that the problems it raises will differ from one nation to another, but it is in the interest of them all that the transition should take place smoothly, as part of a concerted effort. Par-

energy challenge

by Amadou-Mahtar M'Bow
Director-General of Unesco

ticularly important is the tapping of new, less costly energy sources which can be exploited almost everywhere. For the developing countries the problem is of vital importance. The increasingly unequal situation in which they find themselves today means that their chances of mobilizing the necessary financial resources are slight. Consequently they must find new resources, but above all they must have access, notably through a better flow of information, to the knowledge and techniques whose mastery is indispensable to their progress. For this to come about, these countries need to join in world decision-making as full and rightful partners. The transition to diversified energy sources is in large measure linked to the setting up of new rules and new mechanisms designed to alleviate the tensions of the world economy and to bring into being a more equitable international economic order, in a spirit of solidarity and concertation.

Unesco is taking part in this process of international reflexion and action. Apart from the fact that the whole thrust of its activities is to encourage the emergence of this new order, it is particularly qualified to contribute to the strengthening of international scientific co-operation which is indispensable to the advancement of learning and the free circulation of knowledge. It can also help countries which are attempting to solve their energy problems to draw up national policies which take account of all the factors involved, whether they are related to science, technology, education, information, or to social and cultural life.

The free flow of scientific and technical information and the exchange of data acquired through experience in different social, economic and cultural situations can make a decisive contribution to speeding up the exploitation of new and renewable energy sources, notably in the developing countries. With this in mind, Unesco is currently engaged in creating an international information system on energy sources, the use of which necessitates not only data from many fields—the physical sciences, ecology, the life sciences, engineering, economics—but also access to documentation on production, planning and training at every level, from university teaching to the education of rural populations. This system will thus be of interest to a wide range of users, from research workers to planners, from engineers to educators, not to mention the wider public whose involvement is essential where energy-saving or the adoption of new techniques are concerned. The setting up of such an information network is, of course, indissociable from an intensification of research, teaching, training and popularization, all of which Unesco's programme seeks to promote.

Unesco is also concerned to put the problems of energy in a context in which all their complexity can be grasped, and has accordingly set out to identify the many non-technical factors (especially those of a social and cultural nature) which affect the exploitation of the different energy sources. Social attitudes, differing from country to country, can have far from negligible effects on the possibilities and rapidity of change.

The environmental problems resulting from an increased reliance on coal and nuclear energy should not be neglected, either. Here attention has tended to focus on certain short-term effects on public health or working conditions or on direct consequences for the physical environment, at the expense of the longer-term social, cultural and ecological consequences for which there are often very few data available and which, if they are to be tackled comprehensively, require more concerted international action.

Through these studies and activities relating to energy problems Unesco wishes to contribute on the one hand to each country's efforts to pursue its development along its own specific lines and on the other to the efforts being made by the international community in the late twentieth century to achieve a balanced and more equitable management of the planet's resources, considered as the heritage of all peoples and of generations present and to come.

But an analysis of energy problems cannot be isolated from a historical appraisal of the relations between the successive levels of energy use by mankind and the evolution of the scientific concepts which make the use of energy possible. Energy produced by human and animal muscle was, for long ages in the history of mankind, the most important form of energy, as it still is for many peoples today. It underlay the earliest development of agriculture and urban civilization. As a result of the rise of the physical sciences and their application to the interpretation of natural phenomena, the meaning of the word energy gradually became wider: to mechanical energy were added thermodynamic and electrodynamic energy, opening the way for a first leap in the scale of energy production, from the kilowatt to the megawatt, and providing impetus for the first industrial revolution. The next theoretical development, the quantum theory, corresponded to the crossing of a new threshold: the use of energy from nuclear fission. This discovery, associated with the development of computers, led in turn to the second industrial revolution, with energy now being measured not in megawatts but in gigawatts. Other thresholds will undoubtedly be crossed with the continuance of fundamental research into the structure of matter and the development of techniques for effectively eliminating and recycling radioactive wastes. Nuclear fusion is a promising field because it releases even greater quantities of energy than those produced hitherto, and the fuel required is extremely abundant.

These successive breakthroughs in knowledge, promptly turned to practical use by human ingenuity, are the fruit of individual genius—the genius of the great scientists of every age whose achievements are so many milestones in the history of scientific thought. But just as the quickening tempo of progress in the last few decades was made possible as a result of the slow accumulation of universal knowledge and its transmission across time and space, so scientific and technological innovation, though it may be first and foremost a matter of individual or collective creation, cannot, given the complexity of the world today, serve the welfare of all without close co-operation between all those communities and centres in which it comes into being and finds application. This intellectual co-operation is a cherished field of activity for Unesco. By encouraging it, by tightening the bonds between the world's scientists, Unesco, in the field of energy and elsewhere, is also preparing a future in which man will possess knowledge to release forces on a par with his immense needs and will be sufficiently wise to master those forces. ■

The transition to a new energy mix

A United Nations Conference on new and renewable energy sources

Drawing © Atlantic Richfield Co., Los Angeles

by Enrique V. Iglesias

ENERGY is a fundamental issue to all people. It permeates the fabric of human society, affecting daily life in every home as well as world politics, international economics and national development strategies. In recent years, energy has acquired significant importance due to what has been called, with some ambiguity, the world energy crisis. Three important elements characterize this crisis and situate the problem in its correct perspective.

ENRIQUE V. IGLESIAS, *of Uruguay, is Secretary-General of the United Nations Conference on New and Renewable Sources of Energy, which is being held in Nairobi from 10 to 21 August. Since 1972 he has been executive secretary of the United Nations Economic Commission for Latin America.*

First, at the beginning of the 1970s, it became apparent that fossil fuels, for so long the basis of the energy balance of the modern world, would in the not too distant future be depleted. For the first time, the rate of reserve discoveries and the rate of consumption growth became inverted, providing mankind with a realistic perspective based on scientific assessments that depletion could take place during the next generation.

The second element of this crisis comes from the fact that for the first time in history, an energy transition will be accompanied by higher economic cost. Until recently, people had been living through a period of cheap energy and depressed oil prices. From now on, energy will be available only at higher prices, setting a new challenge of unknown proportions.

Lastly, the energy crisis has affected humanity in a very uneven manner. The crisis, affecting both industrialized and developing nations, has had a very special impact on the developing countries. These countries will have to go through their process of economic development and modernization with much higher energy prices than those paid by the industrialized countries. This undoubtedly presents the international community with a problem of equity and solidarity which should stimulate international co-operation.

The United Nations, whose *raison d'être* concerns international co-operation in the search for solutions to common problems of humanity, is in a unique position to discuss and initiate activities in the energy field.

For this reason, in December 1978, the General Assembly invited all governments to a Conference to be held in Nairobi from 10 to 21 August 1981, whose main objective was to be the elaboration of measures for the concerted action needed to promote the development and utilization of new and renewable sources of energy, in order to meet over-all future energy requirements, in particular within the context of efforts aimed at accelerating the development of Third World nations. These measures will be spelled out in the Programme of Action, one of the basic documents of the Conference, which is currently the subject of continuing negotiation with all participating Governments and Agencies.

One fact of enormous political importance calls for emphasis. For the first time in human history, the impending world energy transition necessitates that the international community work and debate collectively on possible options. This paves the way for the Conference to initiate activities designed to lead towards a new world energy mix based on a pluralistic and diversified framework of available energy sources that can provide a horizon of peace and security. It would be useful to recall here five elements of this energy transition.

The first element is its inevitability. Oil consumption in the world energy mix will continue to play a significant role although of relatively decreasing significance through the end of the century. The demand for oil will be important in the industrialized world where it is expected that the increment in demand will be of the order of 50% and will be 4 to 5 times the present demand of the developing world which requires energy sources to accelerate its process of development and growth.

All this will occur regardless of conservation or investment policies. At some moment in the next century, oil will be even less significant in the world energy consumption pattern, making imperative a new energy mix. This is the inevitable challenge facing the industrialized and developing countries collectively.

The second characteristic is that the transition is viable. It is not possible to say today that the world lacks energy resources. That is not the problem. The problem is the potential scarcity of certain types of fuels, mainly the liquid fuels. Experts have told us on several occasions that energy resources do exist, and point out that the real problem is one of investment in technological resources and in production. There will, they say, no longer be a single alternative energy source as in the past, but instead a mixture of such sources.

A third aspect of this energy transition is that it will be much more complex than energy transitions in the past—a complexity due mainly to the fact that humanity has maintained, over many decades, artificially low and depressed fossil fuels prices and that the current adjustment has been produced by a process which has complex implications. Over the short term, the problems of balance of payments, imbalances in the energy bill and imported inflation will affect particularly the developing countries which have not even been able to make adjustments by expanding their exports but which are increasing their indebtedness.

More important than this, however, the transition will mean that higher and higher proportions of the sums available for investment will have to be devoted to energy. This means that there will be fierce competition between investment for energy and other economic and social investment. Some developing countries might even be obliged virtually to stop investing in energy, which would constitute a very serious threat to their future development.

The fourth characteristic of the energy transition is that it implies varying degrees of urgency. It appears that the world is facing an energy transition which will manifest itself in a different manner for the modern sector of the world economy than for the traditional sector. To the modern sector, the energy transition presents a strong technological challenge to make available a diversity of energy sources. Yet if we follow historical optimism and humanity's achievements over recent decades in the energy field, there will be no room for pessimism: the world, particularly the modern sector, will always find ways to effect an adequate energy transition. On the other hand, a very different situation obtains for the traditional sector basically located in the developing countries. The rural areas of many of these countries are still operating on fuelwood and charcoal and have not yet made the first energy transition.

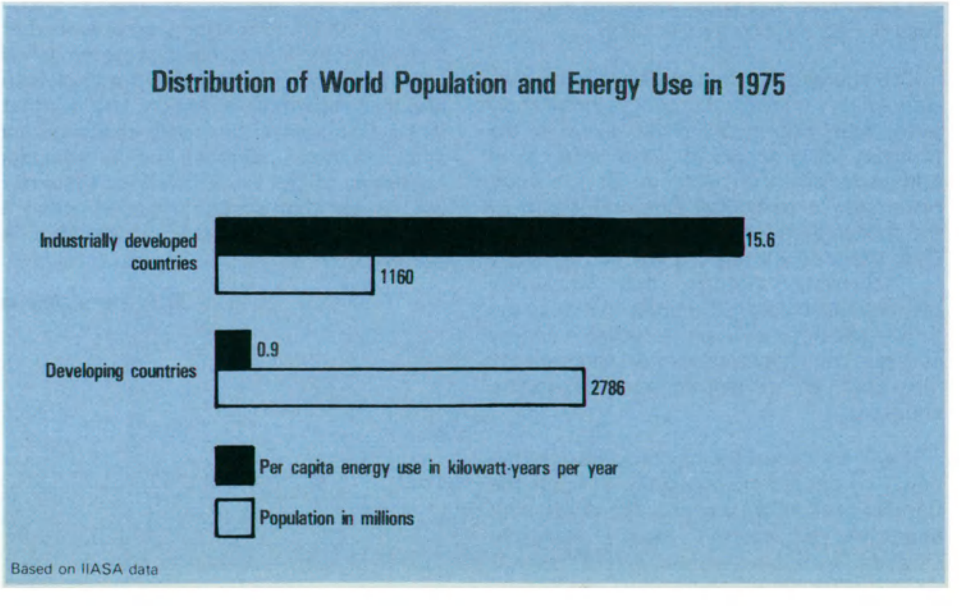
Lastly, I believe that the fifth aspect of the energy transition involves efficiency in the use of energy as a fundamental element of this transition. This has been noted very clearly by the industrialized countries which in recent years have made very commendable efforts to conserve energy. However, there is still a lot to do to improve the efficiency of primary energy use. When experts tell us that only 15 per cent of the primary energy reaches its end use and that 70 to 80 per cent is lost along the way, this obviously leaves much room for improvement. This is true not only for the industrialized countries but also the developing countries.

The Conference therefore has as its primary objective to examine the options available for an energy transition involving these five characteristics. Another aim of equal importance is to examine the energy transition in the context of the requirements of developing countries. Here is where the need to consider a development strategy provides the energy transition with a new dimension.

In this context new and renewable sources of energy can play a substantial role. However, increased access for developing countries to energy supplies *of all types* is fundamental to the process of accelerating their development and is consistent with the goal of a more equitable distribution of economic opportunities among nations.

One fact is now certain; the prevailing development patterns can no longer be sustained in either the developed or the developing countries on the basis of the existing energy systems. Recent studies have shown that, while there is generally a strong positive correlation between the level of development of a country and its energy use, it is possible to design development strategies that would require less energy than in the past. New energy systems have to be developed for all countries based on greater diversification and self-sufficiency and on a significant increase in the efficient use of energy sources. This may be easier in the developing countries for whom options are more varied, unhampered as they are by long-established industrial infrastructures.

It is both a sovereign right of as well as a unique challenge to each country to find an answer to this question within the framework of their development strategies and energy policies. It is a challenge to the responsibility and solidarity of the international community to find a way to help developing countries obtain the basic energy inputs they need to accelerate their economic and social development.



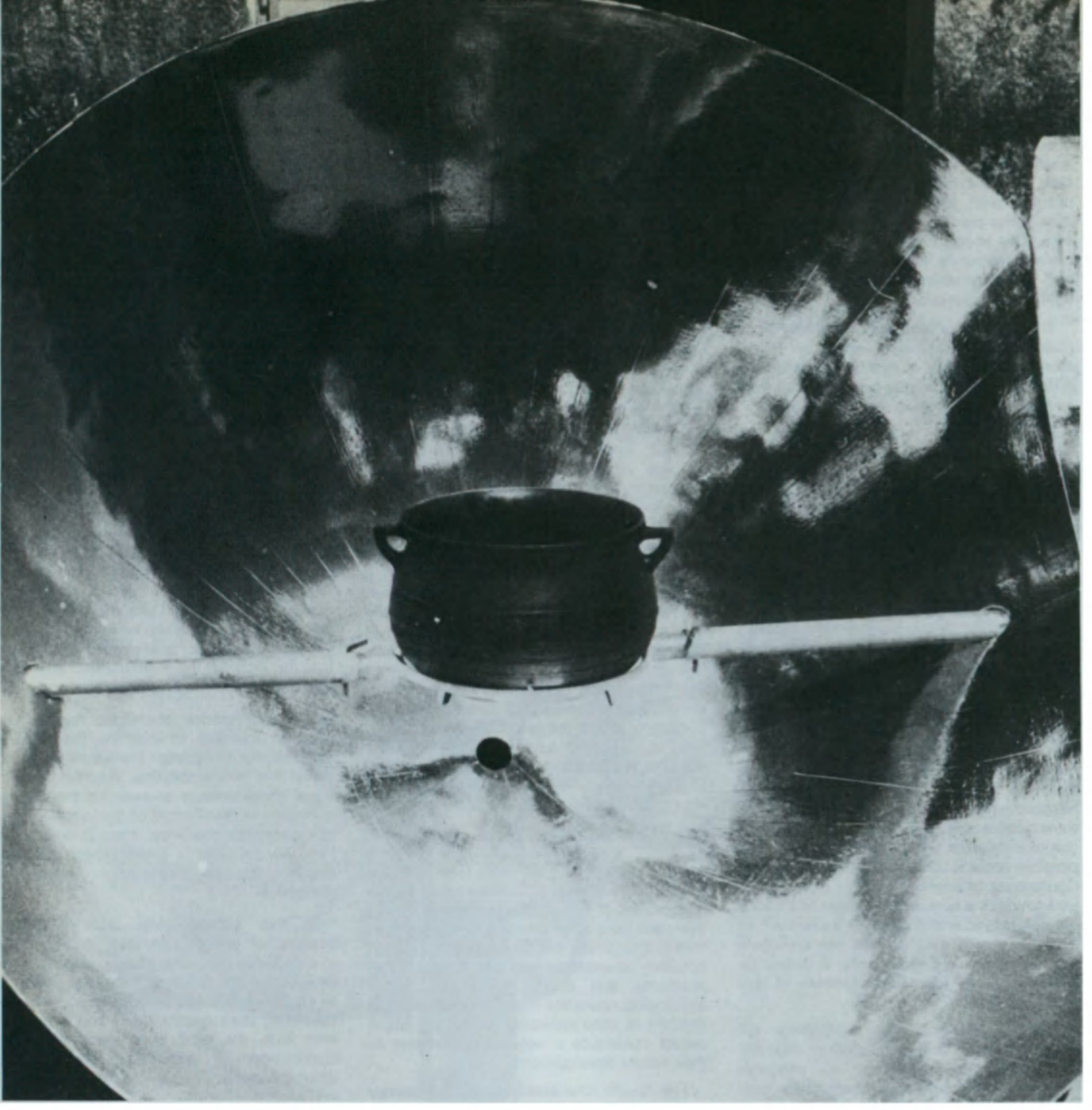


Photo © C. Naigeon, Paris

How then can we create awareness of the need to prepare and promote this energy transition in developing countries in a way which will be innovative and at the same time ensure the energy required for development? I believe that the first consideration needed is to emphasize that countries cannot consider an energy strategy in isolation. Energy is most definitely a central component of any nation's general development strategy.

The other important consideration is that when energy strategies in the developing world become part of an overall development policy, they can be used to promote economic and social development. Great imagination is required to formulate strategies for the energy transition that will become not merely simple passive inputs into the development process, but an engine of growth based on the use of natural resources, of labour, and of local technologies.

The common global interest to increase the energy available should be based on a diversified and sustainable mix which can ensure for humanity a stream of renewable resources for the future. This effort complements a development strategy that will make an active and dynamic contribution to the economic and social development process during the energy transition.

The energy transition will have to be considered at two levels of urgency. In the short term, high priority must be given to the problem of energy for the rural poor and especially the depletion of fuelwood resources—a particularly important part of the challenge faced in developing countries. Over the medium term, it will be necessary to accelerate strongly and vigorously technological research in order to reduce the time it takes for new and renewable energy sources to penetrate into the energy mix both of developed and developing countries.

It will be necessary to stimulate international co-operation, especially through the transfer of financial resources to developing countries, to support energy research, technology transfer and investment and to do away with bottlenecks in our attempts to increase and diversify the energy supply, particularly in developing countries.

Finally, the Nairobi Conference should serve to promote a strong co-operative effort within the United Nations system which will have major responsibility for implementing the Programme of Action. I believe that, if this Conference can really challenge and stimulate the co-operative and co-ordinating capacities of the United Nations system, it will render that system more effective in responding to the needs of its Member States.

■ **Enrique V. Iglesias**

Profiles of change

All paths to a viable world energy system lead through a gate marked 'global co-operation'

by Wolfgang Sassin

INCREASING interdependence between nations inevitably gives rise to new problems which if they are not tackled and mastered in good time may become chronic and form a focus for international tensions.

When things reach that stage nations are tempted simply to try to adapt as best they can to the situation on hand, with each country using available resources to strengthen its own position. The will to work together for a long-term solution is lost and this creates at the very least an additional obstacle to world as well as national development.

The energy problem that became apparent in the early 1970s seems to be evolving along these lines. It arises from the rapid changeover from national energy supply systems to a global system based on highly localized oil reserves.

The swift rise in world energy consumption that took place at the same time has been a decisive factor (see diagram this page).

When the first oil crisis developed, one small area, the Gulf, was meeting 20 per cent of the world's energy needs. The major part of the output of the Member States of the Organization of Petroleum Exporting Countries (OPEC) went to the industrialized countries of Western Europe and to the United States and Japan.

Today, nearly eight years after the first oil embargo of 1973 when OPEC took control of the oil price-fixing mechanism, three facts are clear: (1) throughout the world, oil consumption has peaked at about its 1973/74 level; (2) so far no alternative energy source has been able to take over the role played by oil up to 1973 as a cheap production factor promoting economic growth; and (3) the world economy is going through a phase of reduced growth and is facing severe structural crises and increasing difficulties with regard to the international division of labour.

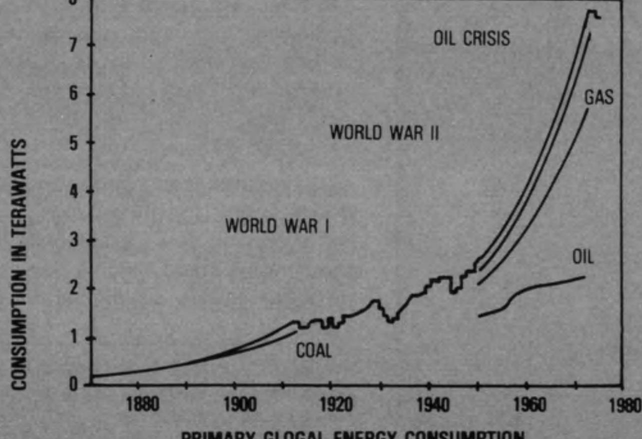
In recent years efforts have been intensified to find national solutions to the energy problem. Some industrialized countries, faced with the prospect of drastically reduced economic growth and obliged by rising prices to adopt fuel-saving measures, seem to have fairly good hopes of limiting their dependence on an uncertain supply system. Other countries, especially in the Third World, are relying on increased exploration of their still unprospected territories and on stepping-up technological development in order to tap resources unavailable up to now for technical or economic reasons. This is especially true of biomass, hydropower and solar energy, through which the rural populations of the developing countries are attempting to meet their energy needs using traditional and at present not very efficient technologies.

Whether these unco-ordinated efforts can ever solve the energy problem is an open question. In any event, for a long time to come, many countries will still have to rely on energy imported from abroad. That is one of the weak points of national energy policies, though by no means the most significant. Energy has been and remains a decisive factor in industrial development. Even if it were possible to devise means of ensuring a fair free market distribution, scarce supplies and high prices are bound to put a constraint on development and, in a world based on the international division of labour, this would be economically damaging to all countries. There is plenty of evidence of this. Local and national efforts in the energy sector must therefore be assessed in a global and long-term context.

History shows that the changeover from one source of energy to another takes many decades. The switch from wood to coal, and then from coal to oil and gas took more than half a century. The changes to these new energy forms took place in favourable circumstances—rapid economic growth and decreasing production costs of the new forms of energy.

In the future it will be more difficult in many respects to maintain sufficient energy supplies. In the first place, the world popula- ▶

The deep concern about energy today relates to the fact that the resources of oil and gas, our most modern and most important energy forms, are limited. Figure below summarizes the history of consumption of primary energy over the past 100 years. Total consumption has grown at an average rate of 5 % per year, except at times of world-wide crises: World War I, the recession of the 1930s, World War II, and now the oil crisis. It is worth noting that this high growth rate was supported by coal around 1900, whereas for the last two decades it has been based on oil and gas, which presently account for 73 % of the primary energy consumption of the world.



PRIMARY GLOGAL ENERGY CONSUMPTION

Graph © IIASA, Laxenburg, Austria

WOLFGANG SASSIN, *of the Federal Republic of Germany, recently became deputy leader of the energy systems programme of the International Institute for Applied Systems Analysis (IIASA) at Laxenburg (Austria). A physicist by training, he has been a member of the programme since 1975.*

IIASA is a non-governmental, multidisciplinary, international research institution founded in 1972 by the academies of science and equivalent scientific organizations of 12 nations. Its goal is to bring together scientists from around the world to work on problems of common interest, particularly those resulting from scientific and technological development. The Institute now has 17 national member organizations in: Austria, Bulgaria, Canada, Czechoslovakia, Finland, France, the German Democratic Republic, the Federal Republic of Germany, Hungary, Italy, Japan, the Netherlands, Poland, Sweden, the U.K., U.S.A., and U.S.S.R.

tion is growing at an unprecedented rate: some 400 million people have been born and added to the global population total since the first oil crisis and their material needs will soon make themselves felt. Even if there is a considerable reduction in the average number of births per family, the world population will almost double in the next fifty years.

Projections show that the demographic growth will be much greater in Third World countries than elsewhere because of the large proportion of young people and children reaching or approaching reproductive age. In the next two decades, the integration of these new generations into their country's economy is going to spark off an explosion in demand for goods and services.

The character of energy

When people talk about energy, it is not always clear what kinds of energy they are talking about, and this adds to the problem. Therefore, in order to understand the physical energy system, it is important to distinguish between energy at various stages of conversion and use.

Primary energy is the energy recovered from nature—water flowing over a dam, coal freshly mined, oil, natural gas, natural uranium. Only rarely can primary energy be used to supply *final energy*—energy used to supply the consumer with energy services. One of the few forms of primary energy that can be used as final energy is natural gas, which is why it is a fuel of preference whenever it is available.

For the most part, primary energy is converted into *secondary energy*. This is defined as an energy form that can be used over a broad spectrum of applications. Electricity and gasoline are the major examples. Less convenient (which is why they are declining in their market shares) forms of secondary energy include charcoal, sorted and graded coal, and cut and split fuelwood. In order to apply energy without making undue demands on the consumer, it must be converted into a form that may be readily transported, distributed and used in a variety of devices. The trend has been toward grids, for obvious reasons—specifically toward electricity, gas, and district heating grids. For convenience of storage, portability, and transportability, the trend has also been to liquid fuels, of which gasoline and diesel oil are the best examples.

Primary energy is converted into secondary energy in several different ways. For example, central power plants produce electricity and, sometimes, district heat. Refineries convert petroleum to more convenient liquid fuels—gasoline, jet fuel, diesel oil, and naphtha. Sometimes the conversion plant is the end point of a system, as with nuclear fission energy (for which chemical conversion, isotopic enrichment, and fuel fabrication all precede the power plant); sometimes, as with a hydroelectric or a wind generator, it is a simple machine. But regardless, there are *conversion losses* in going from primary to secondary energy and *transmission losses* in getting that energy to the consumer. It is wrong to think of these losses as waste. They represent a trade-off of efficiencies: the use of energy to transform and transmit energy permits the end user to apply it efficiently for his purposes.

These final steps are the conversion of secondary energy into *final energy*—the energy in a motor, a stove, a computer, or a light bulb—and of final energy into *useful energy*—the energy actually stored in a product or used for a service. It is important to realize that in providing the service—say, a well-lit room—energy is not merely a stored entity, but even more an input for the efficient use of other resources, of labour, of capital, and especially of skill.

Source : *Energy in a Finite World*, 1981
International Institute for Applied Systems Analysis, Laxenburg, Austria

Establishing the necessary infrastructures is a highly energy-intensive process, so that, even given technically improved systems with higher energy efficiency and reduced per capita economic growth rates, the energy supply would have to be increased substantially in the coming decades.

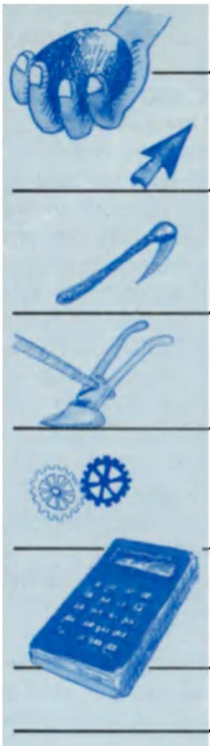
This prospect shows that it was a mistake to let the world's energy supply potential reach near-stagnation, even though as a consequence certain countries—especially the rich industrialized nations—are now adopting energy conservation measures. This stagnation has several causes. The traditional oil-producing countries, pointing to the finite nature of their reserves, have been restricting their output; in other countries production capacities have fallen; coal production has not expanded substantially in spite of the increased oil and gas prices of 1973/74; and, finally, many developing countries are experiencing a crisis in the non-commercial energy sector, with large areas facing a severe firewood shortage.

Against this background the International Institute for Applied Systems Analysis (IIASA) in Laxenburg (Austria) has carried out a comprehensive study of the possibilities of developing the various energy sources on a global scale and eventually balancing supply and demand (1). The idea was to view these problems in a world perspective instead of approaching them merely at the national level. In this context the sum total of imports needed by individual countries in order to balance their energy budgets had to be matched by corresponding export surpluses available in other countries. Such a method of course excludes consideration of all but the basic factors determining the "global" system. It also involves very broad assumptions about the behaviour of the various countries within this "closed global economic system".

The grouping of the world's over 160 countries into seven major regions was an essential step. The industrialized nations form three groups classified according to their economic system and the abundance of their energy reserves: the market economy countries of North America; the planned economies of the Soviet Union and Eastern Europe; and the Organization for Economic Co-operation and Development (OECD) countries minus North America—i.e. Western Europe, Japan, Australia and New Zealand. The developing countries are divided into four regions : Latin America; the oil-rich countries of the Middle East and North Africa; an area encompassing black Africa and South-East Asia; and, finally, the planned economy countries of Eastern Asia.

Taking into account the various stages of development, the IIASA experts evaluated the economic and social trends in each of these regions and on this basis calculated probable energy requirements. They also

(1) Energy in a Finite World *(Vol. I:* Paths to a Sustainable Future; *Vol. 2:* A Global Systems Analysis*) report by the Energy Systems Programme Group of IIASA, Programme Leader: Wolf Häfele. Ballinger Publishing Company, Cambridge, Massachusetts, 1981.*



Individual consumption expressed in thousands of kilocalories per day	Food	Domestic and services (1)	Industry and agriculture	Transport	Total
Primitive man	2				2
Hunter	3	2			5
Primitive farmer	4	4	4		12
Developed farmer	6	12	7	1	26
"Industrial" man	7	32	24	14	77
"Technological" man	10	66	91	63	230

(1) The services sector includes office work, trade, teaching, etc.

Drawings Jacques Vincent. Unesco Courier

calculated each region's potential in fossil fuel resources and reserves, as well as the timing and rate for the introduction of new and renewable energy sources. These projections are based on assumptions regarding the positive outcome of future prospecting, research and development projects. By adding together the figures for all countries and regions, the global potential in ultimately recoverable resources can be obtained, thus making it possible to quantify the results of the vigorous efforts required in the coming decades. In the present state of technology and at the present level of energy production costs, only about one third of the estimated ultimately recoverable fossil resources is accessible.

Rough calculations already show that some of the seven regions will not be able to meet their energy needs entirely from their own sources, for their traditional non-renewable energy reserves—oil, natural gas and economically extractable coal—are too small, and new or renewable sources, such as oil shales, tar sands and nuclear and solar energy in all their forms, cannot be developed fast enough.

All this substantiates the assumption of the IIASA study, of an open and production-cost-oriented access to the world's energy supplies. Apart from certain limitations with regard to traditional oil deposits, all seven world regions share the globe's energy sources and have access to the new extraction and conversion technologies.

Despite this optimistic assumption about universal co-operation in solving the energy problem, closer studies indicate that insufficient power supplies will remain a constraint on world economic development for the next fifty years.

The total energy demand is so great that questions of preference do not arise: all sources have to be developed.

On the consumer side, too, energy must be used more rationally. The unusual and disturbing discrepancy between the predictably great efforts required to produce energy and the limited prospects for economic growth has led the authors of the IIASA study to develop a "low-growth" scenario alongside the initial "high-growth" one. In the "high-growth" scenario previously accepted economic targets have been reduced, especially in the developing countries, while in the "low-growth" model, which postulates a reduction in economic growth, world energy demand is substantially decreased.

PRESENT AND ESTIMATED FUTURE WORLD USE OF NEW AND RENEWABLE SOURCES OF ENERGY

Source	Present use in billion (10^9) kWh	Utilization in the year 2000 in billion (10^9) kWh
Solar	2-3	2,000-5,000
Geothermal	55	1,000-5,000
Wind	2	1,000-5,000
Tidal	0.4	30-60
Wave	0	10
Thermal gradient of the sea	0	1,000
Biomass	550-700	2,000-5,000
Fuelwood	10,000-12,000	15,000-20,000
Charcoal	1,000	2,000-5,000
Peat	20	1,000
Draught animals	30 (in India)	1,000
Oil shale	15	500
Tar sands	130	1,000
Hydropower	1,500	3,000

Source : United Nations *Development Forum*, 1981

No study, however complete, can predict the future. But carried out with care it can indicate what kind of political and social decisions lie before us. The choice will depend to a large extent on the value system prevailing at the time, but it will also be influenced by the availability of relevant data on the true situation and on the possible consequences of having adopted certain measures and rejected others. In this sense, IIASA's "high" and "low-growth" scenarios describe future trends that are basically feasible. Both give an idea of the upper limits of the global economic development process. These limits are determined by the earth's energy resources as provided by nature and by the efficiency of present energy production and conservation technologies. Two key conclusions emerge from these scenarios:

(1) In both scenarios the construction of a global energy supply system calls for vigorous efforts, but these do not appear unrealistic given the projected volume of economic activity in the regions under consideration. In any case, the relative investment burden on the economy is roughly the same in each scenario. In other words, provided the proper preliminary measures are carried out in good time, it is technically possible to make available a sufficient amount of energy to sustain high economic growth rates. Low growth rates do not help to overcome energy crises.

(2) If sufficient co-operation for the development of supply capacities is not forthcoming, overall costs will exceed the sum projected in the IIASA scenarios. Efforts made by individual countries to husband their own viable energy resources and develop those that are still unexploited, as well as to maintain a safety margin for the future, may be understandable at national level, but they tend to aggravate the problem at world level. They compel other countries to make an early changeover to alternative energies that are both scarce and more expensive.

In practice, political, social and organizational difficulties always give rise to pragmatic energy strategies of this kind. And this can lead to a vicious circle: the hasty introduction of insufficiently developed alternative energy sources in any part of the world will strengthen the arguments of those advocating national and local solutions.

Then again, energy that proves too costly is another pitfall to be avoided, for it could easily foster economic stagnation. The development of alternative sources requires more capital and manpower than the traditional oil and gas production technologies. Thus the transition to new and more expensive forms of energy would be an additional burden on an already stagnating economy.

Solving the world energy problem is becoming more and more a race against time. To win it will take more than scientific and technical feats. In the first place efficient use must be made of available resources, of the possibilities of advanced technology and of the considerable investments necessary to tap potential energy sources. This requires close economic and political co-operation between energy-producing and energy-consuming countries. Individual nations must also realize that ensuring a stable energy supply requires much more effort than would appear from short-term local analyses. But even when these conditions are fulfilled, the reward—stability—does not in itself produce any immediately consumable benefits. Rather the rise in costs resulting from the increased volume of investments needed to ensure a stable energy supply must be seen as a share in the global economic development burden.

But here political will, though necessary, is not enough: suitable technical and institutional preparations to distribute that burden are also essential. At the international level the IIASA studies identify three critical areas sharing the following characteristics: a rapidly growing gap between the rising energy demand and the means of satisfying it; a very marked dearth of information about the factors likely to inhibit or encourage the discovery of new technical solutions; and a lack of vigour in developing such technical solutions.

These three areas of strategic importance for the stabilization of the global energy system are:

(1) The development of appropriate technological processes and procedures which in the next twenty to thirty years will lead to the development of a synthetic liquid hydrocarbon industry operating on a worldwide basis. Given the role synthetic fuels will be called upon to play in the world energy budget, future production programmes will have to outstrip by far the output of all the nuclear energy programmes of the last thirty years.

(2) Provision of energy to the rapidly growing urban areas of the developing countries. High energy consumption densities call for highly efficient conversion and distribution systems, and the power required to operate these cannot usually be supplied by renewable sources in nearby areas. Like industrialized countries lacking in energy reserves, these urban developing areas are dependent on the existence of an operational international energy system.

(3) The interaction between the tapping of the renewable energy potential in the developing countries' rural areas and the ecological and climatic systems. In relation to yield, the exploitation of renewable sources such as biomass, hydropower, wind power and energy from the oceans has in many cases a greater effect on natural systems than the tapping of fossil fuel resources. In order to ensure responsible land use in many of the world's habitable areas, studies must be made of the consequences of extensive farming, changing hydrological conditions and the use of "natural" renewable energy sources, as well as their ecological and climatic effects. There is an urgent need, therefore, for a global ecological assessment of the world's as yet unspoiled natural regions with a view to controlling future damage to the environment.

Resolute international efforts to deal with these problem areas—and the list is by no means complete—would help to bring about a sharper awareness that the energy problem represents a common challenge for all the countries of the world. Such awareness is essential for the political compromises that will have to be made if we are to achieve constructive action instead of being content with simply managing ever-dwindling resources.

Wolfgang Sassin

Two supply scenarios, global primary energy, 1975-2030
(In Terawatt-years per year)

PRIMARY SOURCE (1)	BASE YEAR 1975	HIGH SCENARIO 2000	HIGH SCENARIO 2030	LOW SCENARIO 2000	LOW SCENARIO 2030
OIL	3.62	5.89	6.83	4.75	5.02
GAS	1.51	3.11	5.97	2.53	3.47
COAL	2.26	4.95	11.98	3.93	6.45
LIGHT WATER REACTOR	0.12	1.70	3.21	1.27	1.89
FAST BREEDER REACTOR	0.00	0.04	4.88	0.02	3.28
HYDROELECTRICITY	0.50	0.83	1.46	0.83	1.46
SOLAR	0.00	0.10	0.49	0.09	0.30
OTHER	0.21	0.22	0.81	0.17	0.52
TOTAL (2)	8.21	16.84	35.65	13.59	22.39

1. Primary fuels production or primary fuels as inputs to conversion or refining processes.
2. Column totals may not add up exactly owing to rounding off of figures.

Table W. Sassin

Photo © Wetmore - S.P.L. - Cosmos, Paris

IMPLICATIONS OF A SUSTAINABLE ENERGY SYSTEM

Does the world possess the productive and institutional capabilities, the capital and material resources, and the discipline to achieve a sustainable energy system? What does it mean to mobilize building programmes on such a scale around the world or to build the productive plants to turn out the dozens of billions of tons of concrete and steel to build these grandiose new plants? It would take time and material inputs—especially capital. There would also be institutional barriers of all kinds at all levels to overcome. Above all, it would demand generally much greater productivity worldwide, and this would mean increased levels of interregional trading of all kinds—of labour, of skills, of technologies, of knowledge, of energy, of products, of food and so forth.

To give an idea of what this means in terms of capital investment, even the energy demand projections of the IIASA "low scenario" would require between 1975 and 2030 an increase in the world's capital stock by a factor of approximately 20 to 30.

This is why it is so important that the eight billion or so people living in 2030 be rich, not poor, and much richer than today. That they be rich does not mean that they discover some new treasure of physical resources that has previously been completely overlooked; it means that they learn how to use the limited resources available more efficiently, more ingeniously, more productively. The process is continuous, and it is cumulative.

The higher our productivity—that is, the more wisely we invest our current resources of energy, labour, capital, and know-how—the closer we will come to transforming the possibility of a sustainable energy system into a reality. To succeed would be to cross a distinct threshold—to decouple the world's energy supply from the problem of resource supplies. It is a threshold perhaps as great as that passed by our distant ancestors when they launched the era of domestic farming. To cross it is the modern challenge—and it is not beyond our capabilities.

Source : *Energy in a Finite World*, 1981, IIASA, Laxenburg

The developing world demands a place in the sun

by Abdou Moumouni Dioffo

THE developing countries of Africa, Asia and Latin America are privileged for the most part as regards renewable energy resources—the sun, the wind, the heat gradient of the tropical seas and the photosynthetic process in tropical forests. This is an important asset and, in years to come, it could lead to the development of a global energy policy in which the interdependence of these countries will guarantee their independence.

But harnessing solar energy in areas where it is readily accessible calls for a choice between different technological options, and the countries concerned must examine very carefully what the direct and indirect repercussions are likely to be on important areas of their national life such as the economy, population distribution, land use planning, and the choice of a model of industrial development which, in the long run, could change the course of their social and cultural development.

Whether the applications of solar energy are thermal, mechanical or electrical, the selection of plant and equipment most likely to promote economic, social and cultural progress has first and foremost obvious economic implications. According to whether equipment is imported or produced wholly or partly on the spot the national economy has to face problems such as currency shortages and economic dependence on the exporting country or inability to meet investment costs and uncertainty as to the viability of the equipment under local conditions.

The demographic implications are generally less apparent. But where rural solar equipment—for pumping water, grinding flour and providing light and power for domestic and community use—is centralized, the population will tend to concentrate round these points. And here lies a danger for the country in question; exercising what is supposed to be a purely technological choice, it could very well end up as a centralized society on the lines of the industrialized nations, with all the accompanying social and cultural consequences.

Similarly the adoption of a technology based on very powerful solar plants—from 100 kilowatts to several megawatts—is bound to lead to concentrations of another kind, where all the main economic and industrial activities are grouped round places equipped with energy-producing installations. The type of society that will emerge is likely to be a replica of the "consumer society", with moral values entirely alien to the national culture. This represents a real threat

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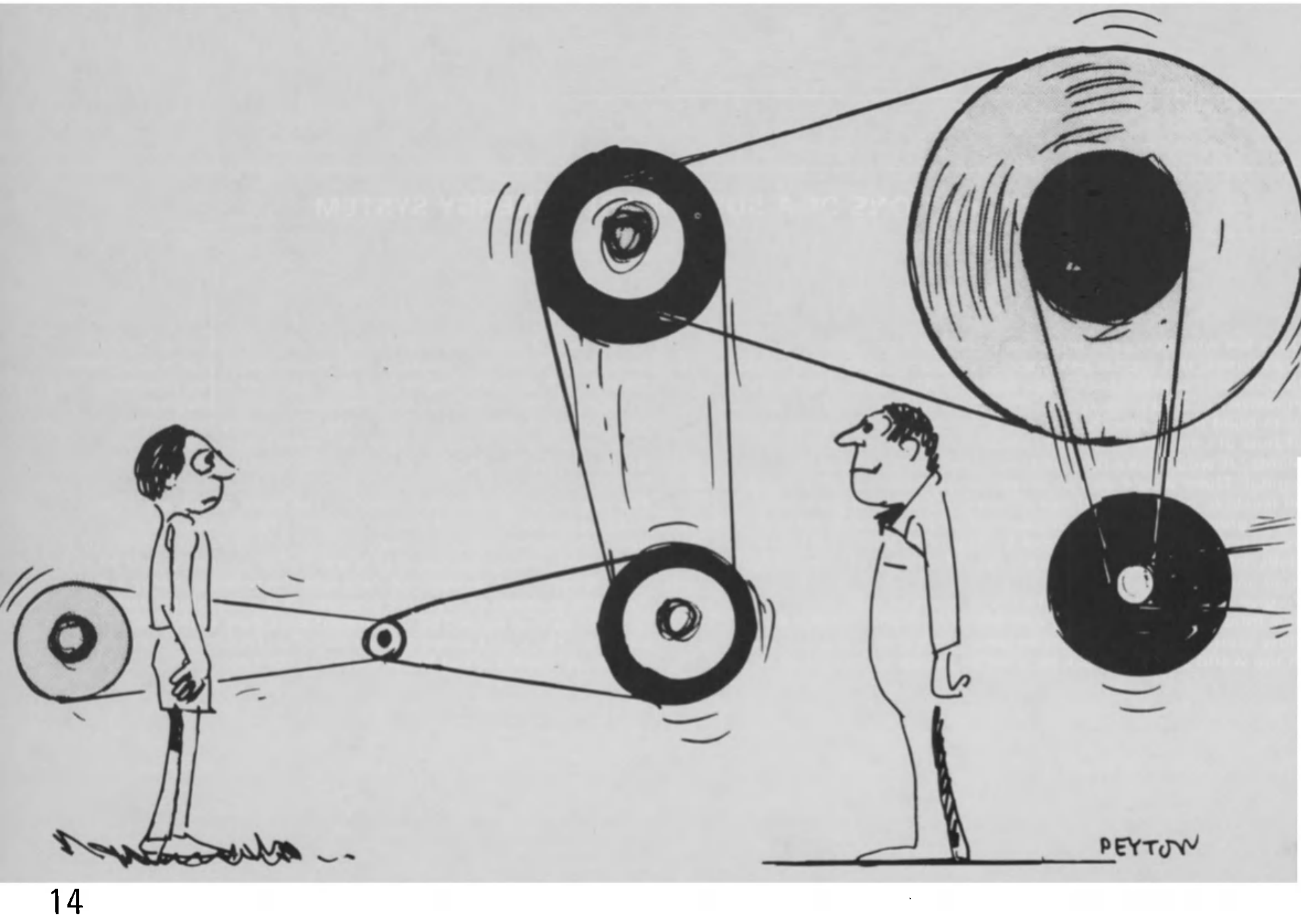
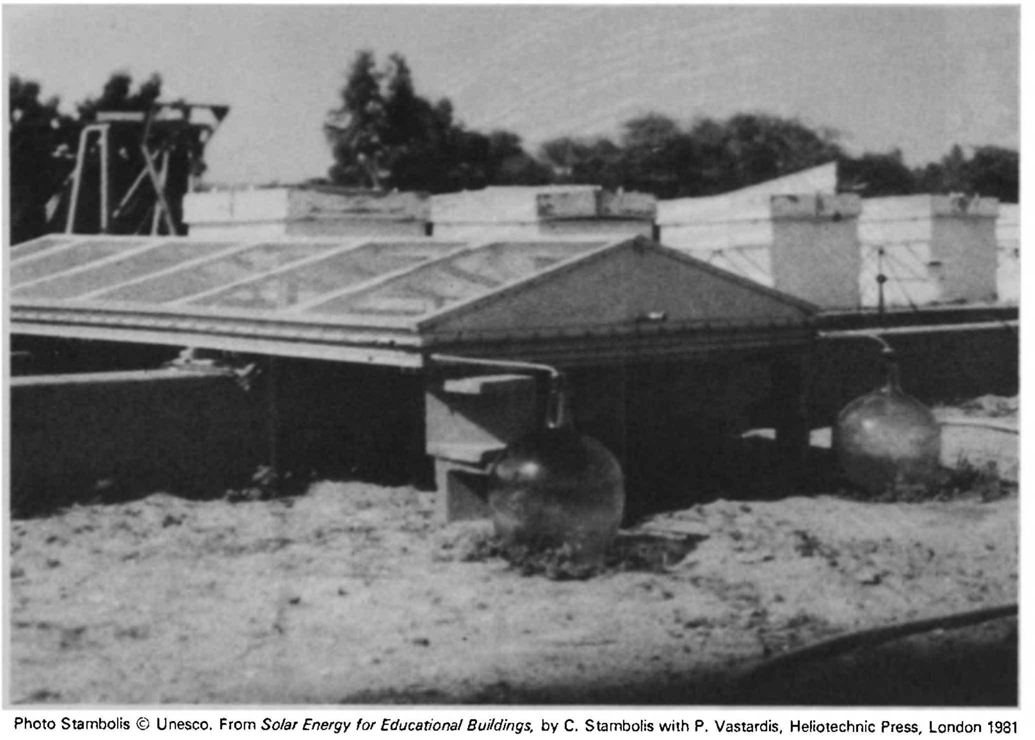


Drawing © Peyton, London



A portable solar still developed and manufactured by the Office of Solar Energy (ONERSOL) in Niamey, Niger. Small solar stills providing less than 200,000 litres of water per day have an important role to play in parts of west Africa, such as the coastal region of Mauritania and northern districts of Mali and Niger, where the water supply is brackish. For larger installations, however, there seems little prospect at present of solar desalinization installations becoming competitive with those using conventional fuels.

Photo Stambolis © Unesco. From *Solar Energy for Educational Buildings*, by C. Stambolis with P. Vastardis, Heliotechnic Press, London 1981

to the cultural identity of the peoples of the developing countries.

Finally, as regards land use planning, a whole complex of factors has to be taken into account so as to ensure the balanced development of all sectors of the economy (agriculture, stock-breeding, agro-food industries and production of building materials), as well as the wise use of natural resources to safeguard the environment (including measures to limit or eliminate overgrazing, deterioration of arable land and destruction of the plant cover), and a rational distribution of industry.

So, more than the type of technical process or even the size of plants, the model of technological development must be taken into account when establishing a national strategy that will give solar energy a place among accessible energy sources. The stakes are enormous, since the technological option selected can either perpetuate the developing country's dependence on imported science and technology or promote the development of a national capability. The provision of solar plants on a turnkey basis and the so-called "transfer of technology", as this type of transaction is grandly termed, are a delusion. This must be clearly understood if decisions are to be based on the country's real development priorities and not on commercial considerations divorced from the people's true interests.

The countries of Africa, Asia and Latin America enjoy extremely promising natural conditions for tapping the sun's power, but because scientific and technological research has lagged behind they sometimes lack the know-how needed to develop solar equipment. The industrialized countries, on the other hand, are at a disadvantage with regard to climatic conditions but possess the industrial bases essential to such development. Genuine co-operation between the two groups of countries both in scientific and technological research and in industrial production is therefore a prerequisite for the efficient utilization of solar energy to benefit millions of people in the rural areas of the Third World.

In the developing world the level and main trends of solar energy research vary considerably from one country to another. Though a great deal of interest has been generated in this field, the activity of research institutions often stagnates, because human and financial resources are in short supply, and researchers work in isolation. In such cases it is easy for foreign firms and organizations offering technical assistance or bilateral co-operation to effect what amounts to a "take-over" of national institutions. The only effective solution lies in increased scientific and technical co-operation between developing countries of the same region or even different regions. Then, and then only, can the question of co-operation between developing and industrialized nations be approached on a sound basis taking into account the interests of all concerned.

It was not until the "oil crisis" that large-scale solar research programmes were launched by a number of industrialized countries. At present most of these programmes have only very limited targets (the provision of auxiliary power for domestic and industrial heating and supplementary electricity supplies). But their true purpose in the long term is to develop alternative energy sources that could be substituted for the world's rapidly dwindling oil supplies and, in the short term, to exploit the huge market of the developing countries to develop solar equipment in highly lucrative conditions. To all intents and purposes this would mean that research and industrial production would be virtually financed, if not subsidized, by the developing countries themselves.

A radical change of approach is therefore needed to establish genuine co-operation in this field between the two groups of countries. Given the present oil crisis, the role of solar energy in the long term and its short- and medium-term possibilities in many developing countries, it is in the interests of both parties to come to grips with the situation.

Industrial co-operation between developed and developing countries in the production of solar installations also raises many complex problems. The international division of labour at present reduces the developing nations to the role of mere producers of mineral and agricultural raw materials, creating an uneven pattern of exchange which perpetuates the economic dependence of the Third World on the industrialized world. The latter today virtually monopolizes the various industries basic to solar energy production, including the metallurgy of iron and ferrous metals and that of aluminium, copper and other nonferrous metals; glass and transparent plastics; and heat insulation processes that use minerals or organic substances. Yet the raw materials used in all these processes come mainly from the developing countries. In most cases they are partially processed before being exported. This is the case with aluminium oxide from Guinea and Ghana which is processed on the spot or in Cameroon; copper from Zaire and Zambia; and the petroleum products of Nigeria, Algeria and the Middle East.

To reinforce the developing countries' self-sufficiency, industries manufacturing finished and semi-finished products could be established in the raw material-producing countries, provided such measures were supported by industrial co-operation on a world scale. This would be in everybody's interests in the long run. In the present energy crisis the under-exploited hydroelectric potential of Africa, Asia and Latin America seems to offer an ideal source of power for processing from start to finish the many minerals found in these areas. ▶

A basis would thus be provided for the establishment of light industries producing components for solar plants—electronic parts, precision engineering, metal and mechanical equipment, etc—and economic development at national level would be guaranteed by the interdependence of the various industries.

This approach would lead to a new international division of labour beneficial to the entire world economy and, by bringing about a marked lowering of production and transport costs as well as retail prices, it would speed the introduction of solar energy, since under this system plants would be constructed from start to finish in the places where they are to be used. In relation to the new world energy consumption pattern the foreseeable consequences are such that there should be no difficulty in gaining unanimous acceptance for this set of measures.

■ **Abdou Moumouni Dioffo**

Photo Stambolis © Unesco. From *Solar Energy for Educational Buildings*, by C. Stambolis with P. Vastardis, Heliotechnic Press, London 1981

Photo Andanson © Sygma, Paris

Above, photovoltaic panel in the courtyard of a school in Niger powers the school's educational television set. Right, the Maine-Montparnasse skyscraper in the heart of Paris.

World energy file

"Thunderbolt", by Roy Lichtenstein.

by Zoran Zarić

THE 4,500 million people on the earth currently use about 10,000,000,000,000 watts of energy. This is equivalent to 2.2 kilowatts per head. A single bar electric fire is usually rated at 1 kilowatt (kW).

To understand the energy problem, it is important to distinguish between power and energy. Technically, power is the rate at which work is done or energy used. A 1 kW electric fire has a power rating of 1 kW; it uses energy at the rate of 1 kilowatt-hour (kWh) per hour—24 kWh per day, or $24 \times 365 = 8,760$ kWh per year. Thus the average rate of energy use over the whole globe is 19,272 kWh per year per head, which is the same as 2.2 kW continuous.

When talking of global energy use, figures in watts or even kilowatts tend to get very large. Scientists use a system of shorthand to make the numbers seem smaller:
1 kilowatt (kW) = 1,000 or 10^3 watts
1 megawatt (MW) = 1,000,000 or 10^6 watts
1 gigawatt (GW) = 1,000,000,000 or 10^9 watts
1 terawatt (TW) = 1,000,000,000,000 or 10^{12} watts.

Total energy consumption of the whole world is now 10 terawatts (TW).

The same prefixes can be used in front of units other than watts. Thus 1 gigatonne (GT) is 1,000,000,000 tonnes. While electrical energy is usually expressed in terms of the watt, some fossil fuels such as coal and oil are more conveniently measured in tonnes. The energy contained in one tonne of hard coal is 8,139 kWh; the energy in one tonne of oil is 11,964 kWh.

However, although the average per capita energy consumption is 2.2 kW, energy is not used uniformly throughout the globe. Consumption in North America is about 10 kW per head. Consumption in the other industrialized countries varies between 2 and 7 kW. The rest of the world, comprising three-quarters of mankind, consumes less than 2 kW, on average about 450 watts. Nearly 400 million people live on less than 100 watts. Energy consumption, in other words, follows the global economic order rather closely.

The most reliable forecasts all seem to suggest that by the year 2000 there will be 6,700 million people, consuming an average of 3.06 kW per capita. This gives a total energy consumption of 20.5 TW, slightly more than double that of today. Fifty years later, by 2050, there will be 10,500 million people, consuming an average of 5.28 kW. This gives a total consumption of 55.4 TW, some five and a half times as much as today.

The "World Energy File" on the following pages is an attempt to indicate briefly where this energy may come from. ▶

ZORAN ZARIĆ, *Yugoslav specialist in thermodynamics, is a member of the Serbian Academy of Science and Arts and president of the Yugoslav Association for Solar Energy. He has been for many years Secretary-General of the International Centre for Heat and Mass Transfer, which co-operates closely with Unesco in the energy field. This article is based on the manuscript of a book by Zoran Zarić, provisionally entitled* Energy for the Future, *to be published by Unesco in 1982.*

Fossil fuels

Photo Louie Psihoyos © National Geographic Society, Washington, D.C.

THE fossil fuels consist of decayed plant matter. Their energy is contained in chemical bonds, derived originally from the sun's energy which was fixed by plants millions of years ago through photosynthesis. Fossil fuels consist mainly of carbon, in combination with other elements. It is estimated that there are something like 10^{16} (10,000 million million) tonnes of fossil carbon underneath the earth's rocks. Unfortunately, not all of it can be easily or economically recovered. There are four main sources of fossil fuel.

Coal is found most commonly north of the equator, and in particular north of the 30° N latitude line. Some 88 per cent of the known reserves are found in the Soviet Union, the USA and China. There are also extensive deposits in central Europe.

So far the world has used up about 130 gigatonnes of coal. The known recoverable reserves of coal amount to 600 GT (about four times as much as has been already used). But future estimates are optimistic. There may be as much as 10,000 GT of coal on the earth, of which it is thought we can expect to recover 2,500 GT.

We are currently using about 2.6 GT of coal a year, worldwide. In 1980 global energy consumption, from all fuels, was the equivalent of about 10 GT of coal equivalent—so coal is now providing about 26 per cent of our global energy needs. Fifty years ago it provided nearly all our energy, and it may soon have to provide much more of our energy than it does now. Research is now being done into how to turn coal into forms of natural gas and oil, and into how to use it more efficiently.

Oil is undoubtedly the most useful fossil fuel, mainly because it is so easily transportable. More than half of the proven reserves are found in the Middle East, and the world has so far consumed about one-third of what is known to exist and to be recoverable. In some countries, such as the United States, as much oil has already been consumed as is known to be left.

Currently we are using about 3 GT of oil a year. Proved reserves amount to some 88.4 GT but as much as 300 GT may be ultimately recoverable. At the moment we are discovering new reserves at the rate of about 5 GT a year, which is faster than we are consuming the product. However, it is thought that maximum oil production will occur about 1990, and that thereafter world production (and therefore consumption) will decrease.

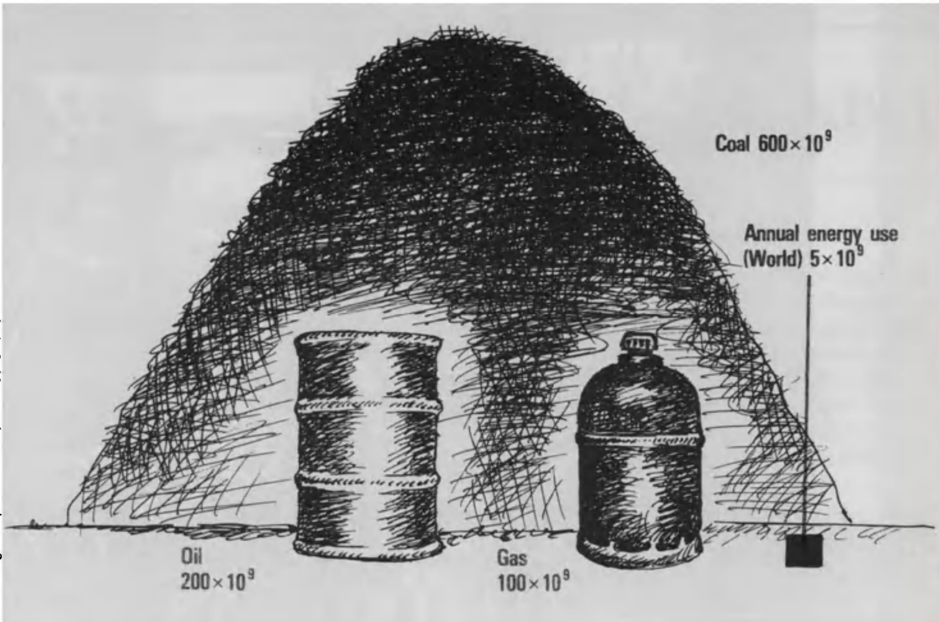
Natural gas is likely to have a longer future than oil. About 40 per cent of the known reserves are in the member States of the Organization of Petroleum Exporting Countries (OPEC) and 30 per cent in the Soviet Union. In fact, the USA and the USSR together consume 70 per cent of world natural gas supply.

So far we have consumed about 40 per cent of the known reserves. In energy terms, the proved reserves are about two-thirds those of oil. But estimated recoverable resources are probably as large as those of oil. As we currently use 2.5 times more oil than natural gas (again, in energy terms), natural gas is going to last a good deal longer than oil. World production is expected to peak in the year 2010, by which time we will be using three times as much natural gas a year as we are now.

Oil shales and tar sands are the last source of fossil fuels. The shales are found 70 per cent in North America and 25 per cent in Latin America; the tar sands are found mostly in Canada, with other deposits in South America, Siberia and Nigeria. Reserves are quite extensive—roughly comparable to those of natural gas—but the problem is how to recover the fuel.

Both deposits must be heat-treated to release their fuel, and the fuel must be upgraded to rid it of impurities. The result is an expensive fuel. For example, for each barrel of oil extracted from oil shale, 1.7 tonnes of rock must be separated and then disposed of.

It is expected that fossil fuel use will peak in the year 2010 by which time we will be using twice as much fossil fuel as we do now.



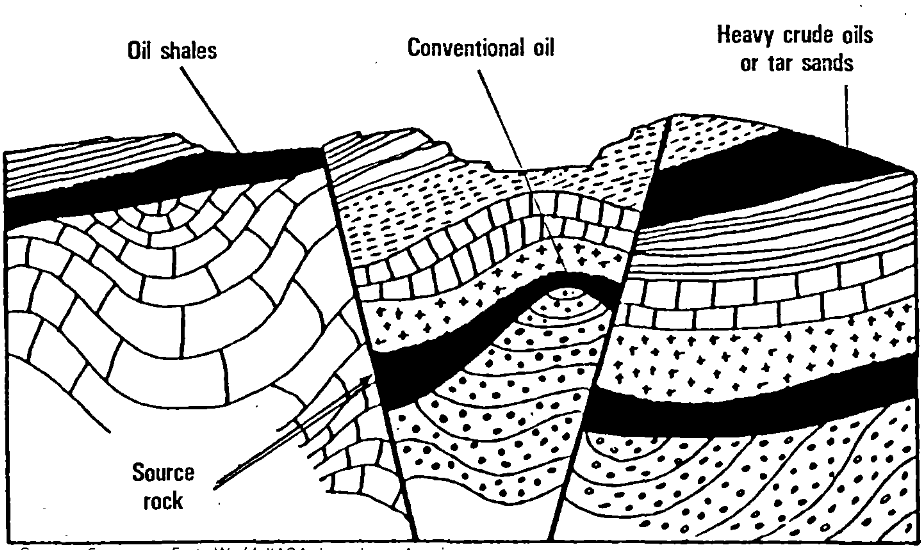
Proven resources total 900×10^9 (or 900 billion) tonnes of coal equivalent

Coal is not a new or renewable source of energy but reserves of coal are huge in absolute terms and dwarf those of oil, gas and the unconventional hydrocarbons—oil shales and tar sands. In a conventional oil field, the crude oil is trapped between grains of sand in a stratum capped by other rock which is impermeable. Drilling a hole through the latter produces a gusher as the weight of strata above pushes out the fluid below. However the oil may not be fluid but highly viscous; alternatively it may be trapped among such fine particles that it cannot flow. The former is called a tar sand, the latter is an oil shale, but both terms are imprecise.

A glance at the known reserves, however, is sufficient to stimulate invention. The amount of heavy oil in the single tar sand deposit along the Orinoco in Venezuela may exceed that of conventional oil in the entire Middle East. Some oil-importing developing countries have fields with one to five billion barrels. They include Colombia, the Ivory Coast, Madagascar and Turkey. The tar sands of Canada (mostly Alberta) have reserves of 800 billion barrels but are still dwarfed by those of Venezuela estimated at over 2,000 billion barrels.

Oil shale reserves are even larger. The developed market economy countries together have 2,247 billion barrels with the lion's share (2,100 billion) in the United States. Among the developing countries which import oil but also have oil shales are Argentina, Thailand, and Morocco with 300 million to one billion barrels each while Brazil has 800 billion barrels. The Soviet Union and Zaire also have substantial deposits. Current producers include China which gets nine per cent of its oil from the shales of Manchuria and Kwangsi (45 to 70 million tonnes of shale annual production). The Soviet Union processes 35 million tonnes from which 12 million tonnes of oil is extracted.

Source: United Nations *Development Forum*



Source : *Energy in a Finite World*, IIASA, Laxenburg, Austria

Bridging the gap in training and information

by James F. McDivitt

Why has technological progress in exploiting renewable, non-polluting energy sources not been followed up by their rapid and widespread application and use? There is no one answer to this complex problem, but there is general recognition that many of the obstacles are not technical in nature. Among the major non-technical constraints which emerge from detailed international studies carried out by Unesco are lack of specialized information and public information, and lack of trained personnel for installation and repair.

In spite of the explosion of interest in new energy sources, a Unesco study on education and training in this field reveals that no systematic approach has yet been developed to meet the urgent need for skilled manpower. The survey, which covered some 300 institutions in 86 countries, indicates that while much more needs to be done to train research scientists, engineers and technicians in all aspects of new energy technology, it is just as necessary to provide courses for policy-makers who must take decisions on energy matters.

In many cases lack of information is the block to more effective training and to greater public awareness of the possibilities of alternative energy sources. Even in countries where modern information systems are available it is today virtually impossible to keep up with new developments in this field because the volume of publications is so immense and the information sources are so scattered. This is another area in which major programmes must be developed and here too Unesco is playing a leading role.

In 1980 Unesco carried out a study on the need for and the feasibility of an international information system on new and renewable energy sources. The study revealed universal awareness "of the dangers of unsound investments based on unreliable information. All [users] wish to avoid the over-enthusiasm expressed in certain circles for some energy alternatives whose results and performance might later prove disappointing. All users are conscious of the fact that their choice of an alternative energy could be influenced by direct or indirect pressures exercised by those in charge of the marketing of relevant materials and processes."

Following this study, Unesco's General Conference in 1980 approved a programme for the development of such an information network, to be based wherever possible on existing systems and services. The programme is now going forward and a number of pilot projects are at the advanced planning stage. ■

JAMES F. MCDIVITT, *Canadian geologist, is director of Unesco's Division of Technological Research and Higher Education.*

Unifying the fundamental forms of energy

by Abdus Salam

Nobel Prizewinner for Physics, 1979

UNTIL about two decades ago, physicists believed that there were four fundamental forms of energy: the gravitational force; the electric force (including magnetism); the strong nuclear force, which is responsible for the powerful attraction among protons and neutrons, the particles that compose nuclear material; and the weak force which plays a vital role in changing one kind of subatomic particle into another.

Now it is commonplace that all these forms of energy can be made to interconvert—the gravitational into the electric, for example (hydroelectricity is a manifestation of this), or the strong nuclear into electromagnetic (as when the nuclear energy in the sun's interior converts into the electromagnetic energy of the heat of the sun's rays).

Twenty years ago, my colleagues and I suggested that there were indications that the weak nuclear form of energy was basically simply identical with the electromagnetic. This was not just a matter of interconversion of one form of energy into another. Our results went deeper. In our view, there should be no basic distinction between electricity and nuclear forces. We said that they were simply identical. We suggested that under suitable conditions in the laboratory this identity, normally hidden, could be made manifest.

The first indication of the theory's correctness came in 1973, when the European Nuclear Research Laboratory in Geneva (CERN) found experimental evidence of neutral currents which are an essential part of the predictions of the theory. The clinching evidence was provided in 1978 by the Stanford Linear Accelerator in the United States which, in an epic experiment, confirmed its second aspect—its heart as it were—the unification of the electromagnetic force with the weak nuclear to one part in four thousand as predicted. An experiment at Novosibirsk by a group led by Professor Barkov further confirmed this.

The next task is to test if the third form of energy (the strong nuclear) is also part of this unity. Together with some colleagues, we have drawn up a theoretical formulation and suggested experiments to test the idea. These experiments have begun in the United States of America, in Europe and in India. If the results are positive, in about three years we shall have demonstrated that all nuclear force—not just the weak nuclear—is identical with the electric force which binds an atom together.

There will then remain the final goal of uniting the gravitational force with the newly recognized electro-nuclear force. The epitome of this will be to find that the force which makes an apple fall or which keeps the moon in orbit, the force of gravity, is an aspect of the same unity of which the electric force or the nuclear forces are part. ■

As announced at a meeting of the European Physical Society held on 14 July, in Lisbon, the preliminary results of an experiment carried out recently at a depth of some 2,000 metres at the Kolar gold mines in India supports Dr. Abdus Salam's theory and seems to have shown that three of the four fundamental forces indeed form a single electro-nuclear force. —Editor

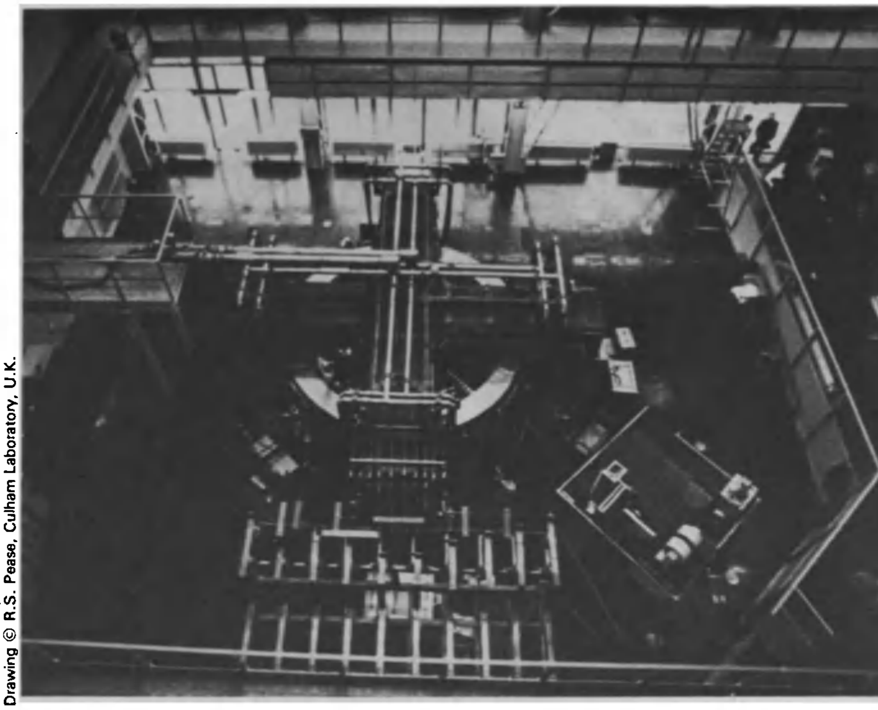


Photo © APN, Moscow
Drawing © R.S. Pease, Culham Laboratory, U.K.

Research into the production of energy by nuclear fusion is carried out in the Soviet thermonuclear "Tokamak 10" installation, above. To obtain a fusion reaction the reacting mixture, or plasma, must be heated to about 100 million degrees centigrade. The problem is how to insulate the plasma from the walls of the container. In the tokamak apparatus this is achieved by holding the plasma in a magnetic field. The plasma is contained in a doughnut-shaped vessel, right, around which coils are wound to create a strong magnetic field which stabilizes the plasma. An electric current flowing through the plasma itself heats the plasma and produces another magnetic field that holds it away from the container wall.

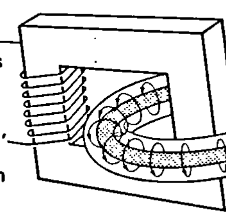


Photo © Scrobogna, International Centre for Theoretical Physics, Trieste

When young scientists from developing countries return home to pass on their knowledge after advanced studies abroad, they are likely to shoulder a heavy teaching load which restricts their opportunities to do original research. They may feel cut off from the latest developments in their field. Almost 20 years ago, the International Centre for Theoretical Physics, at Trieste, was created to offer such men and women a way out of this intellectual isolation. The Centre, which is financed by Italy, the International Atomic Energy Agency and Unesco, is a place where they can update their knowledge, think, work, and above all enjoy the stimulus of contact with other scientists. It was founded on the initiative of Professor Abdus Salam who had himself known the frustrations of isolation in the early 1950s when, after work in high energy physics at Cambridge and Princeton, he returned home to Pakistan to teach. He was his country's only theoretical physicist at that time. "Isolation in my field", he wrote later, "as in most fields of intellectual work, is death". Today Prof. Salam directs the Centre, which each year welcomes some 1,500 physicists for visits and seminars. Above, Prof. Paul Dirac, who won the Nobel Prize for physics in 1933, delivers a lecture in the Centre's amphitheatre.

Nuclear power

NUCLEAR energy is produced when mass is converted into energy. There are two possible ways of doing this. In nuclear fission, energy is produced when a nucleus is bombarded by neutrons and splits into two. In nuclear fusion—so far only seen on earth as the thermonuclear explosion of a hydrogen bomb—two light nuclei are forced together to form a heavier nucleus which contains less energy. In the process energy is released.

Thermal reactors

The first chain reaction was produced in a squash court in Chicago in 1942. Since then more than 200 nuclear thermal reactors have been built, with a total output of about 120,000 megawatts. This is about 6 per cent of the world's electricity production. More than one third of these reactors are in the United States and they produce 12 per cent of that country's electricity.

By 1985 there are expected to be 414 reactors in operation—196 in Europe, 170 in North America, 43 in Asia, and 5 in Latin America. Together they will produce 307,000 megawatts.

By the end of the century nuclear power production may have risen by a factor of three. This will require about 500,000 tonnes of nuclear fuel a year, and some 4 million tonnes of uranium will have been used since nuclear energy began. This is roughly equal to the total amount of known uranium reserves which are economically exploitable. Without either breeder reactors which produce more fissile material than they consume, or fusion reactors, nuclear energy would then come to a dead-end.

Breeder reactors

A breeder reactor, which will double the amount of fissile material in 6 to 10 years, increases fuel usage by about 60 times. Hence, with the breeder, the uranium available could be made to last very much longer. Furthermore, it is technically possible to use not uranium but thorium as the main fuel. There is much more thorium than uranium available in the world, and this could extend the life of the fission reactor for a very long time.

Breeder reactors are still being developed. Several are now being experimentally operated but none is producing commercial electricity. The first operational reactors are expected during the 1980s but large-scale breeder reactors will not be producing electricity before 1990. Technically, breeder reactors are difficult to operate: they require a large inventory of fissile material, normally plutonium obtained from the spent fuel of a thermal reactor running on uranium. As this is the material used in the manufacture of nuclear weapons, there is concern about the prospect of having to produce and store large quantities of plutonium. By 1985 about 100 tonnes a year of fissile plutonium will be needed. This will rise to some 500 tonnes by the year 2000.

Breeder reactors have a much greater power density than thermal reactors, and they have to be cooled by liquid metals such as sodium and potassium. Liquid sodium is a highly dangerous material; it catches fire on exposure to air and explodes in contact with water.

Fusion reactors

Fusion reactors are likely to work by fusing together deuterium and tritium, producing an isotope of helium (an inert gas) and a great deal of energy. Deuterium can be obtained in unlimited quantities from sea water; tritium is obtained by irradiating lithium—which is abundant—with neutrons in the fusion reactor itself. Thus there is no fuel problem with the fusion reactor. Further, the product is stable and not fissile, so the process is potentially cleaner than any fission reactor could ever be.

However, to obtain a fusion reaction means heating a very high concentration of deuterium and tritium to about 100 million degrees and containing the fuels long enough for fusion to occur before they cool or melt and vaporize their surroundings. This has been done in the hydrogen bomb, but never in the laboratory. However, research into nuclear fusion has been greatly increased since about 1975, and is now running at about $1,000 million a year. It is expected that the scientific feasibility of nuclear fusion will be established in the 1980s. Technical feasibility may not be achieved before 1995 and full-scale demonstration of fusion power plants may have to wait until the decade 2005-2015.

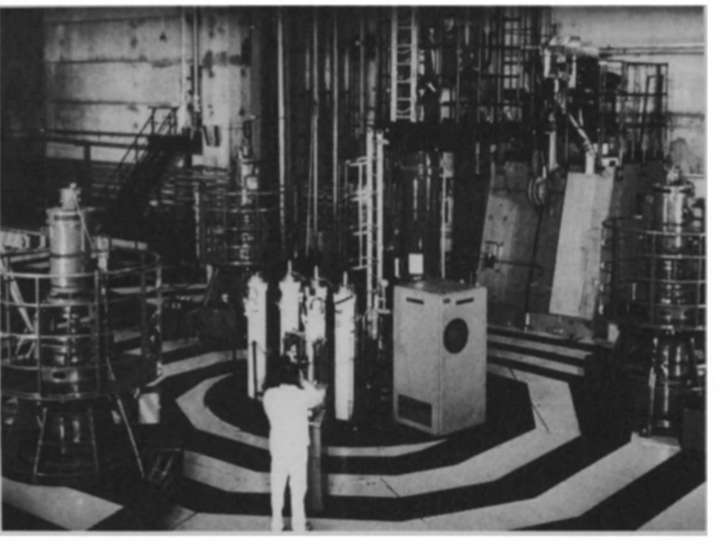


Photo Brigand-Morceau © SODEL, photothèque EDF, Paris

There are grounds for concern about the safety of all nuclear reactors. None is ever perfectly sealed, with the result that each reactor adds slightly to the level of background radiation in the atmosphere. There is a natural level of background radiation which we have now increased by about one third as a result of such things as nuclear fall-out from weapons tests, medical use of X-rays and even watching television. A colour television may impart a dose of radiation of as much as 2 millirems an hour to the viewer. By comparison, a nuclear reactor increases the dose to the population living nearby by only 5 millirems a year—which is about 2 or 3 per cent of background radiation. So concern about radiation levels from nuclear reactors is unfounded.

However, there is always the possibility of an accident which might release large doses of radiation into the surrounding area. The records, however, are reassuring. In the United Kingdom nuclear industry between 1962 and 1975 there were four deaths at work among the staff (none directly caused by nuclear activity). In the same period, 66 members of the staff were killed in road accidents.

Similarly, there is now a one in 4,000 chance of being killed in a road accident every year. The chance of a major nuclear accident is calculated at one in 5,000 million per year. A major nuclear accident is more than 1,000 times less likely than a major earthquake or the failure of a large dam.

However, the problem of disposal of spent radioactive materials has not yet been satisfactorily solved. Every 1,000 megawatt reactor produces about 9 cubic metres of highly radioactive material a year. It must be stored for tens of thousands of years before it becomes harmless. Deep burial in sealed containers is the expected solution but the associated hazards are not yet fully resolved.

The safety problems of breeder reactors are likely to be the most severe—partly because of the greater amount of fuel that is used, partly because the fuel is potential nuclear weapons material (and is also the most toxic material known), and partly because the liquid metal coolants are themselves highly dangerous. None of these problems appears to be technically insoluble but they are much more serious than those of the thermal reactor. Above, Experimental Breeder Reactor II at Argonne National Laboratory's Idaho site.

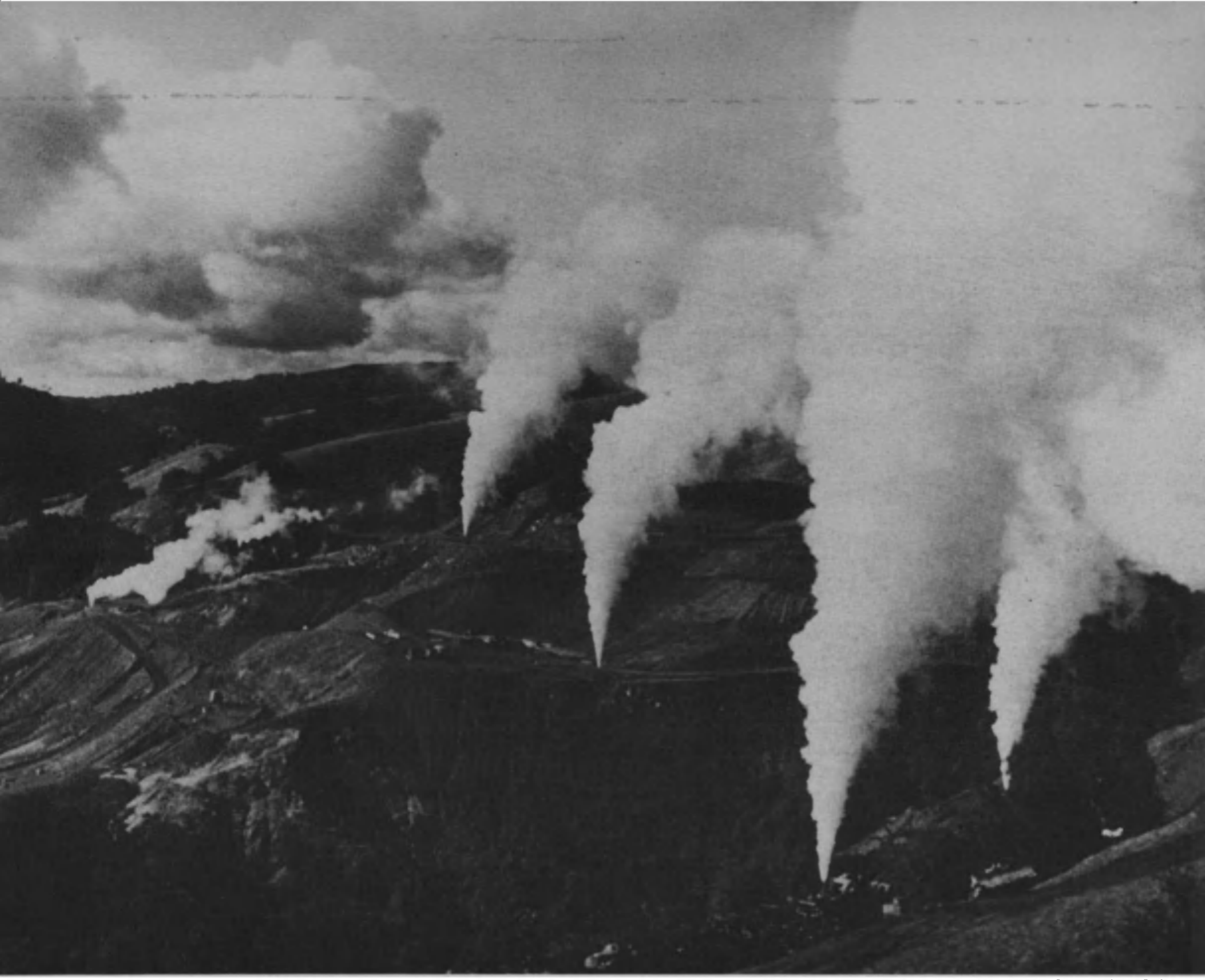


Photo © A. Ten Dam, Paris

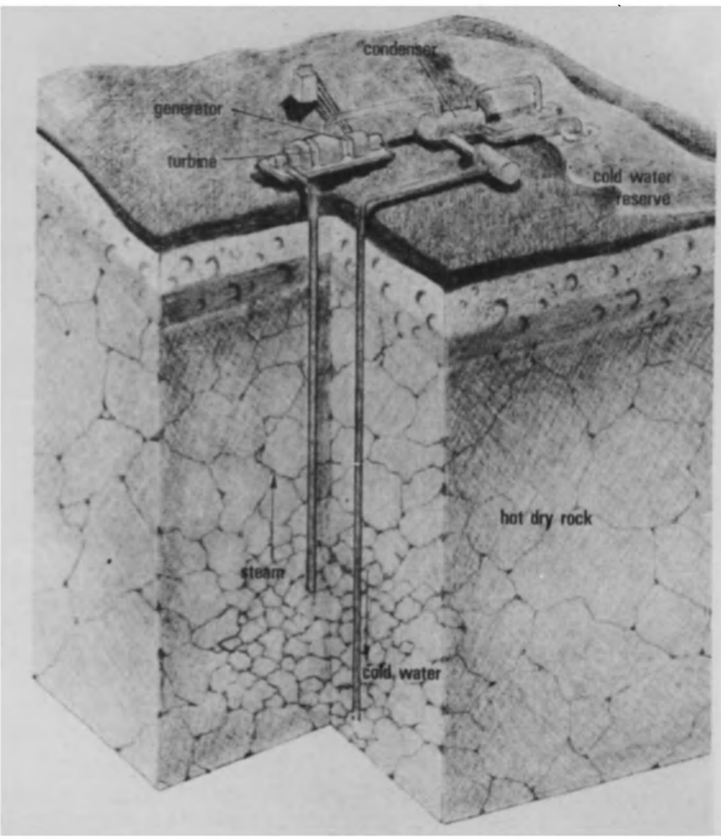
Geothermal energy comes from nature's own nuclear reactor. It arises from the radioactive decay of an isotope of potassium and other elements which are spread about in the earth's crust.

For every kilometre down this generalized heating raises the temperature 30 °C. In some areas geological activity accentuates this effect and temperatures may rise by 80 °C per kilometre. Where sandstone and other porous rocks allow groundwater to circulate, heat is transferred to the water which may come to the surface naturally at springs or geysers, or may be obtained by drilling. However, since the weight of the rocks makes the crust impermeable deeper than four kilometres, geothermal steam is rarely hotter than 300 °C, limiting efficiency. The water and steam are often corrosive and are difficult to use in conventional turbines. New designs may overcome this difficulty.

When geothermal energy provides merely hot water it is used for space heating and agriculture, or to pre-heat water in conventional steam-generating power plants. Italy pioneered geothermal exploitation for its electrified rail system. New Zealand, Iceland, France and Japan apply geothermal energy to space heating. The African Rift and Pacific Basin rim are other favoured areas.

There are great hopes for hydro-fracturing hot dry rocks which are far more widely distributed than porous rock geothermal fields. Water is pumped down one hole, through the fractured rock and back up another hole. The main problem is how long before the hot rocks cool (they take a very long time to heat up again). Current geothermal electricity costs are competitive with nuclear and oil-powered stations. Above, a geyser field in California. Right, diagram shows how geothermal steam is obtained.

Source : United Nations *Development Forum*, 1981



Drawing © P. Charpiot, Paris

Geothermal energy

EACH square metre of the earth's surface continuously radiates about 0.06 watts —not enough to be felt by a human being but enough, over the whole earth, to lose the planet some 2.8×10^{14} kWh every year. At this rate the earth would cool down to the temperature of space in only 200 million years. The fact that the earth is already 4,500 million years old means that energy is being supplied from within the earth. That energy comes from heating from the radioactive decay of certain isotopes in rocks in the earth's crust. Thus geothermal energy is really another form of nuclear energy.

The heat of the earth has been exploited for hundreds of years—even by the Romans who used geothermally heated water for bathing. Today there are about 20 geothermal power plants in operation, ranging from a few megawatts to 500 MW each. Together they produce some 1.5 GW.

Geothermal energy can only be used where it is available fairly close to the Earth's surface. This tends to be in regions where there are volcanoes or frequent earthquake activity. Some of the countries in which geothermal energy is now being used include the USA, the USSR, New Zealand, Japan, El Salvador, Mexico, the Philippines, Iceland, Italy, France and Hungary.

The last two countries use only warm water for space heating. Most of the others use either dry steam or very high temperature water under pressure as an energy source for powering turbines to produce electricity. These are the easiest forms of geothermal energy to exploit. However, a great deal of energy is contained within hot rocks in the crust. If cold water could be pumped down to them, energy could be recovered as steam or very hot pressurized water. This technique is still being researched. If successful, it would increase geothermal energy sources enormously.

There is still enormous scope for geothermal energy production, particularly in the unknown area of heat recovery from hot rocks, and in the use of the truly enormous reserves of underground warm water which could be used for space heating and the raising of crops in greenhouses. Geothermal energy also has the advantage of rather few environmental disadvantages. It is, however, technically a finite resource because the energy contained in the crust gradually disappears as it is used up. On average one well will produce about 5 MW and has a lifetime of 10 or 20 years.

New and renewable sources of energy: costs and constraints

by Boris M. Berkovsky

THE social and economic constraints that hamper wide-scale use of non-conventional energy sources are not always clearly understood.

Renewable energy sources are highly capital-intensive, mainly because of the cost of the equipment involved. Analysis of rough estimates of the cost of electric power generation on the basis of renewable energy sources shows that only big hydroelectric power stations, under favourable construction and operating conditions, can compete with the large-capacity power stations using coal or nuclear fuel. The unique hydroelectric generators installed at Sayano Shushensk, Ust'-Ilim, Nourek (see photo page 26) and a number of other sites were an essential factor in the doubling of electric power production in the 1970s as compared to the 1960s, and in Syria the El Soura hydroelectric power station, built with the assistance of the Soviet Union, provides over 70 per cent of the electric power produced in the country.

In a certain, very limited, number of places geothermal power stations of medium capacity may be commercially viable suppliers of electric power. Other renewable sources of energy are less economical than thermal and nuclear power stations linked together into a common power generation/consumption system. This is because they are dispersed, they lack continuity and therefore necessitate the provision of alternative back-up systems, and they involve a certain risk factor since they all require the use of technologies and processes that are not fully proven.

The proposed new large-scale technologies, such as those for the use of solar energy in outer space or of the temperature gradient of the tropical seas, turn out, when analysed in depth, to be much more costly than initial estimates suggested. Calculations show that to produce the power required to light the homes in an average town of 10,000 inhabitants by one of these methods would need between 10,000 and 40,000 man-hours annually as compared to 200 to 500 man-hours for a conventional power plant burning hydrocarbons.

High consumption of materials is another constraint hampering the use of solar and other new and renewable sources of energy. For example, to ensure the "reaping" of solar energy by special collectors at the rate of 1 Q per year (in 1975 world energy consumption was 0.25 Q) the collectors would have to cover a surface of 130,000 square kilometres, an area roughly the size of Greece or Czechoslovakia.

This would involve enormous amounts of material. The manufacture of the simplest solar energy collector (they are made of blackened sheet metal, usually aluminium, with tubing inside for the circulation of liquid) requires 10 kilograms of aluminium per square metre. Thus 10,000 tons of aluminium would be required per square kilometre. It would also involve taking out of normal use vast areas of land.

The alienation of considerable areas of land and sea surface is also a prerequisite for large-scale energy production through direct conversion of solar energy and the use of the thermal energy of the oceans. Scientists have calculated, for example, that to produce energy to the value of 1 Q per year using the thermal energy of the seas and oceans, the devices needed to capture and transform this energy would cover practically all the tropical and subtropical seas, to the detriment of maritime operations and fisheries. In addition, the one degree centigrade drop in the surface temperature of the tropical seas that this exploitation might entail could cause a drop in the mean annual temperature in the tropics and greatly influence the climate on a global scale.

The main constraints impeding development of new and renewable sources of energy are thus: high initial costs, high consumption of materials, the alienation of large land and sea surfaces, lack of sufficient trained personnel, absence of a specialized information infrastructure, and legal and administrative difficulties. The status of non-conventional energy sources is rarely defined in legislative documents with sufficient clarity and precision and as a result conflicts of interest arise which may take a very long time to resolve.

All the constraints enumerated above are inherent in the development of non-conventional energy sources and constitute a major obstacle to their large-scale introduction. The problem calls for an integrated approach at the governmental level, the elaboration and implementation of long-term plans and programmes and extensive international co-operation in the promotion of which Unesco will play an essential role. ■

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Photo © JAMSTEC/International Energy Agency

Tide

ABOUT 3 terawatts of power are locked up in the world's tides. Only in a few places of the world, however, is it economic to recover the energy; those are places where the tidal range is very high as in some parts of the English Channel, the Irish Sea, and along the North American and Australian coasts and on some parts of the White Sea and the Barents Sea. There are in fact some 24 potential tidal power sites in the world, so this can hardly be described as a global resource.

For technical reasons, tidal power plants only operate at 25 per cent of their rated capacity—so maximum global potential is only 20 GW out of the total possible of 80 GW. Only one large tidal power station has been built—at La Rance, in France, where capacity is 240 MW and about 60 MW is produced, fairly economically. Studies are in hand for another huge site in France of 12,000 MW and for a 3,800 MW site on the coast of North America at the Bay of Fundy.

Wave

Another 3 terawatts of power are stored in ocean waves. The average wave in the North Sea contains an energy of 40 kW for each metre of its length for 30 per cent of the time and about 10 kW per metre for 70 per cent of the time. Estimates vary widely as to how much wave power could be extracted. One estimate puts it at 100 GW global. Another suggests 120 GW for the UK alone. For the moment, however, the matter is academic as there are no wave power plants operating. Several experimental prototypes have been built and are being tested. The UK and Japan are in the forefront of this type of research.

Invented by Japanese engineer Yoshio Masuda, navigation marker buoys powered by wave energy have been in use in Japan since 1965. The motion of the waves is used alternately to suck and pump air through a low-pressure air turbine which drives an electric generator. The small electric current thus produced is sufficient to power the lamps of the marker buoy. An attempt is being made to use the same principle to generate power on a larger scale using an experimental sea-going ship-like buoy, the Kaimei (above) designed by the Japan Marine Science and Technology Centre. Cockerell rafts (below) operate on a different principle. Named for their inventor Sir Christopher Cockerell (best known as the inventor of the hovercraft), Cockerell rafts are articulated platforms which convert into energy the undulatory motion of waves. The models under test as shown in our photo are one-hundredth of the size that would be needed for Atlantic conditions.

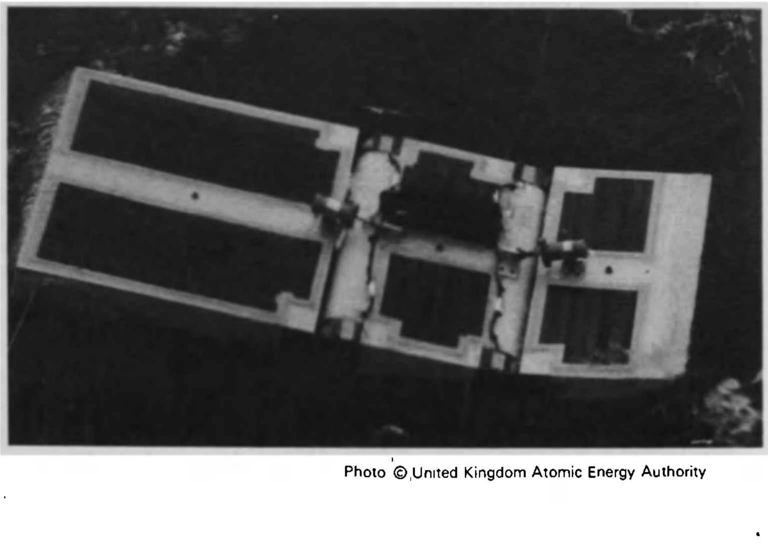


Photo © United Kingdom Atomic Energy Authority

Wind

The winds blowing over the earth contain some 2,700 terawatts, and windmills have been used for thousands of years to capture a tiny fraction of this energy. There is now renewed interest in wind energy but there are two main problems. The first is that the wind blows irregularly and so the energy captured must be stored in some way, which greatly increases its cost. Secondly, the energy in the wind is very dilute. It actually requires a five times greater land area to capture wind energy than it does to capture the equivalent amount of solar energy with solar collectors—although admittedly most of the land on which windmills were erected could also be used for agriculture.

Wind energy is useful on a small scale for local needs but to make a significant contribution machines of between 100 kW and several MW will have to be developed. Several are now being tested, the largest being in North Carolina.

Of the 2,700 TW of power in the winds, only a quarter is available in the first 100 metres above the surface. Taking into account only the land areas and inevitable inefficiencies, a maximum of 40 TW would be available if wind machines were built all over all the continents. However, even ten per cent of this is 4 TW which is greater than the hydropower potential.

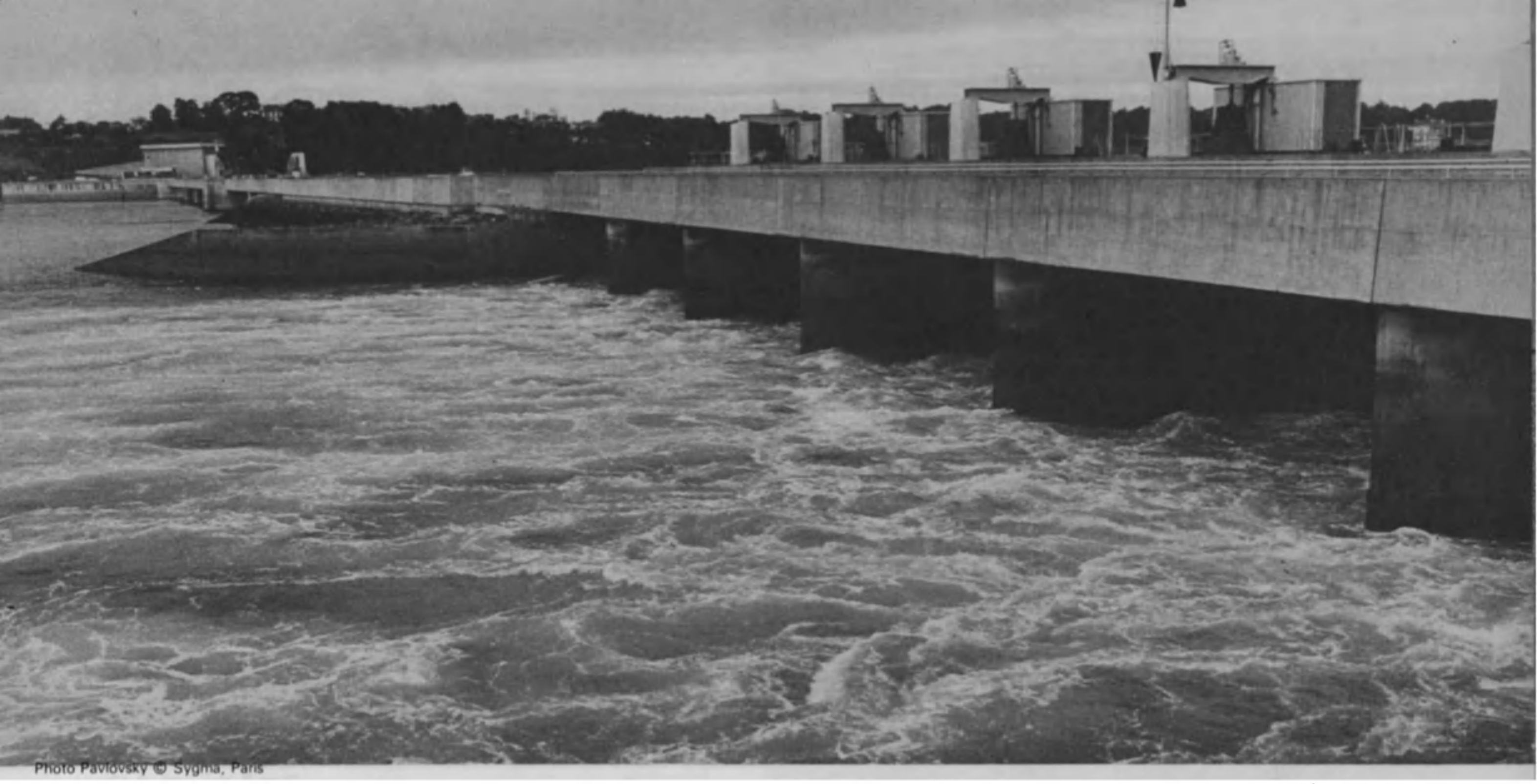


Photo Pavlovsky © Sygma, Paris

Above, the tidal power station at La Rance, France. Right, a new wind turbine generator on Block Island, State of Rhode Island, U.S.A. Its blades measure some 38 metres from tip to tip and in a 30-kilometre-an-hour wind it can generate the electricity used in 50 average American homes. Below, a wind-operated water pump in the Gezirah district of Sudan.

Photo Eric Schwab, Unesco

Photo © NASA, Washington, D.C.

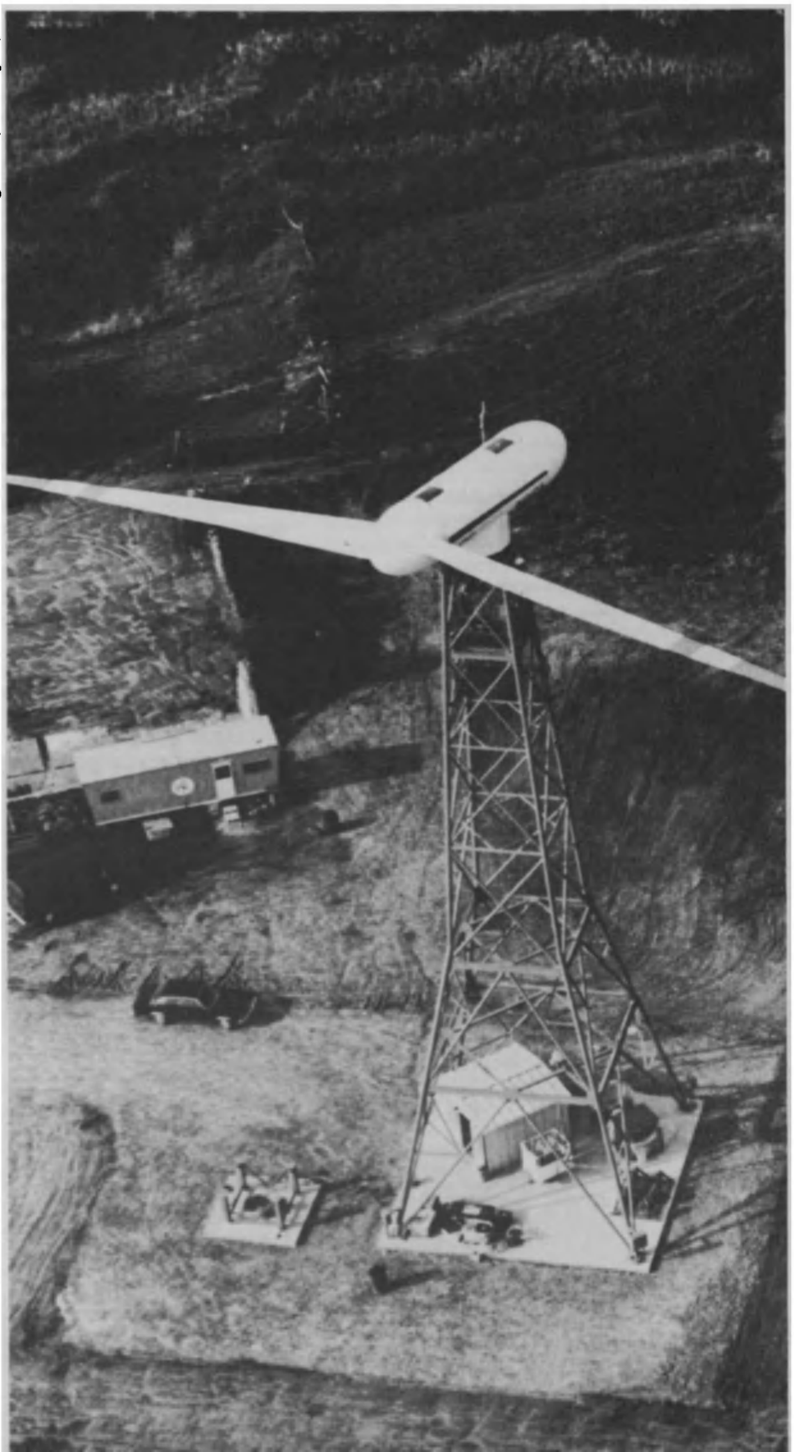


Photo P. Malinovsky © APN, Moscow

Hydroelectric power is generated by water flowing through turbines. The quantity of electricity generated varies according to the mass and speed of the water passing over the turbines.

Capital costs are high but operating and maintenance costs are lower, and the production of hydroelectric power plants, which may have a lifetime of up to 100 years, can be regarded as inflation-proof. In recent years there has been heavy emphasis on economies of scale. The world has 2.2 million megawatts potential power of which only 18 per cent has been exploited. Norway, Canada, Sweden, Brazil and Sri Lanka get over three-quarters of their total power from hydro.

Environmental and social problems with some of the larger schemes have dulled hydro's bright image. Good agricultural land is often flooded, farmers are displaced, disease may spread and climate may be changed. Interest has recently revived in small-scale hydro for developing countries. Projects can be implemented in places without an electricity grid and electricity demand structure. They can form a focal point for industrialization in rural areas. The manufacturer can involve local materials and skills and encourage the population to stay. China has already built over 90,000 small hydro stations, and even in rich countries like France and Sweden, exploitation of thousands of sites is under way. Combined units in developing countries can provide mechanical output for milling during the day and electric power for lighting and cooking by night. Technological advance and standardization is expected to bring down present costs by 20 to 30 per cent. Above, the hydroelectric power plant at Ust'-Ilim, in eastern Siberia. Right, a small hydroelectric power station in Yongan county, east China. Below, the Kariba Dam across the Zambezi River on the border between Zambia and Zimbabwe which provides 8 million kilowatt-hours of electricity annually.

Source : United Nations *Development Forum,* 1981

Photo Li Kaiyuan © New China Pictures, Pekin

Photo Paolo Koch © Rapho, Paris

Hydropower

THERE are a million million million (10^{18}) tonnes of water on the earth. Only 1/2000th part of this, however takes part in the annual water cycle, being evaporated and then precipitated again as rain or snow. Even this tiny part is equivalent to 500,000 cubic kilometres (km^3) of water. In fact every year, 430,000 km^3 are evaporated from the oceans and 70,000 km^3 from the continents. When this water is precipitated 390,000 km^3 falls on the sea, and 110,000 km^3 on land. So every year 40,000 km^3 of water runs off from the land and into the sea. As the average height of the continents is 800 metres, it is easy to work out that the total potential hydropower of the globe is 10 TW (roughly total global energy consumption).

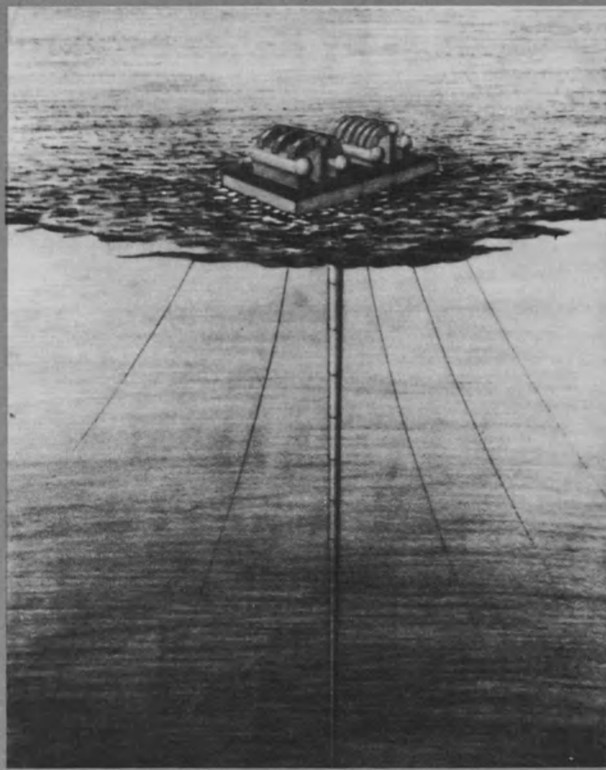
However, only a fraction—perhaps 15 per cent—of this can be economically recovered. This leaves a total potential of 1.5 TW. In 1975 total annual hydropower production was about 11 per cent of this. Thus there is still some way to go—particularly in countries in Africa and Asia where the potential is largest but the least used.

Fifty years ago some 40 per cent of world electricity came from hydropower. Today that figure has dropped to 23 per cent—but that is still much higher than the fraction supplied by nuclear power. In some countries in Latin America as much as 80 per cent of electricity demand is satisfied via hydropower.

Today there are more than 70 plants in operation of more than 1,000 MW. Some have a capacity of 10,000 MW. And there are millions of a few kilowatts. Hydropower is useful in that it runs off a renewable resource, is extremely efficient as it produces electricity direct from a form of mechanical energy not heat, and can be produced in plants of almost any size.

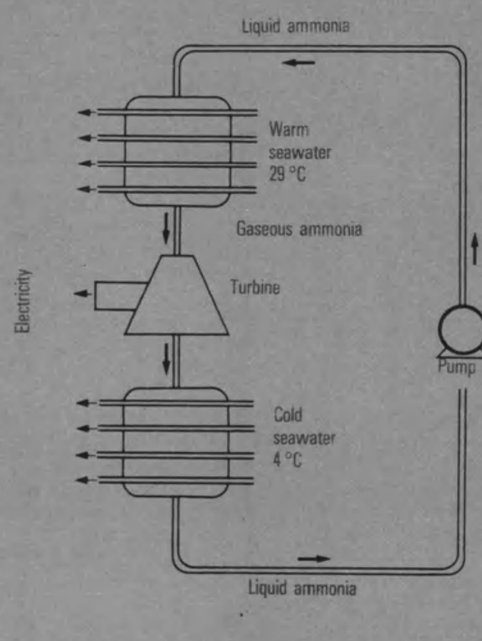
Ocean thermal energy

Between 5 and 8 terawatts of power are locked up in ocean currents. Attempts to recover some of this with ocean current turbines still look somewhat futuristic. However, the temperature difference between cold water a few hundred metres down and warm water near the ocean surface does offer an enormous potential energy source, estimated at 20,000 to 40,000 TW, of which some 4 TW might be recoverable in practice. The system of using this energy, which depends on operating a turbine from the small temperature differences which exist, is very inefficient. Nevertheless small power plants called OTECs (Ocean Thermal Energy Conversion) are now being tested and a 100 MW prototype is being planned for some time after 1985. OTEC power plants would either transmit their power to shore or use it at sea to recover minerals and other resources.



Drawing © CNEXO, Paris

The oceans of the world absorb nearly 70 per cent of the solar energy that reaches the earth. Ocean Thermal Energy Conversion (OTEC) is a way of tapping this huge energy store by exploiting the temperature difference between the sun-warmed surface water and the cold waters of the ocean depths to drive turbine generators which produce electricity. Two types of OTEC systems—the "closed cycle" and the "open cycle" systems—are now being experimented with. Diagram below illustrates the working of a "closed cycle" OTEC. Ammonia, which has a low boiling point, is pumped round a closed circuit. First it is heated by the warm ocean water (top of diagram) so that it turns into vapour. The vapour passes through a turbine where it expands, driving a generator. Emerging cooler and at a lower pressure it flows to a cold-water heat exchanger where it cools further to become liquid again and the cycle recommences. In an "open cycle" OTEC, seawater is used as the operating fluid, its boiling point being reduced by passing it through a vacuum chamber maintained at 3.5 per cent of normal atmospheric pressure. Above, artist's impression of a floating "open cycle" ocean thermal power station now under study by the French Centre National pour l'Exploitation des Océans (CNEXO).



Drawing © R.A. Meyer, OTEC, Chicago

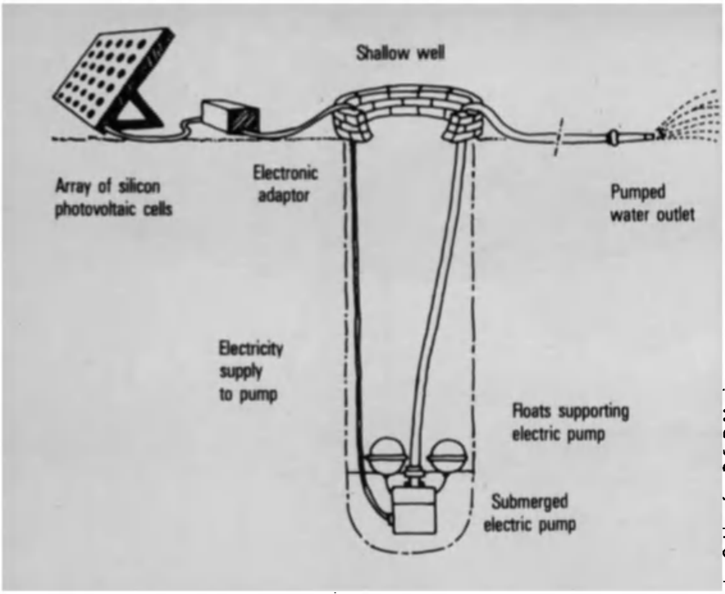


Diagram from United Nations *Development Forum,* 1981

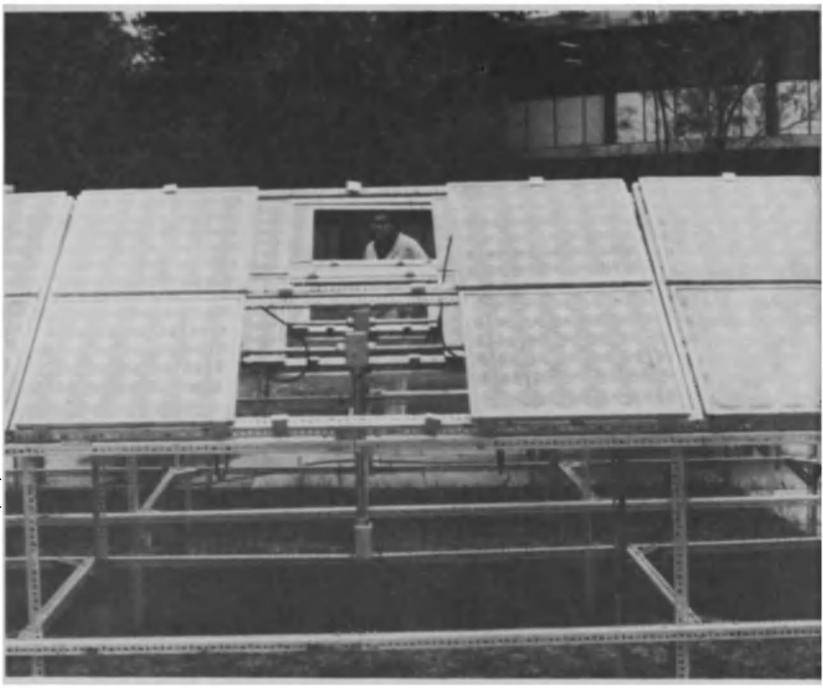


Photo © Christian Schlaepfer, R & D Mexico

Discussion of solar energy tends to concentrate primarily on questions of technology and cost, but, if solar energy is to be widely and successfully introduced, a determined effort will have to be made to educate the public to understand and accept this new energy source. Below, at a school at Tiverton, in England, which has solar installations for space-heating and domestic hot water as well as heat recovery units and rainwater recycling powered by a wind pump, the services are exposed internally and colour-coded so that the workings of the system can be traced around the school. The children monitor the system to see how much energy is being used. Above, diagram shows the working of a simple, photovoltaic water pump. Above right, a Mexican research worker checks solar photovoltaic panels designed for use in rural communities. Right, a thermal solar power station in Senegal.

Photo © Unesco Features

Photo © Devon County Council Photographic Unit, U.K.

Everybody takes the sun for granted. Constantly and without fail, it rises in the morning and sets in the evening. Considering mankind's residence on earth, the sun is an object that will last for ever, radiating the energy that makes life possible on earth.
The sun is a peculiar hydrodynamic object, 1,390,000 kilometres in diameter, which was formed from a cloud of gas composed mainly of hydrogen. Its core is extremely hot with temperatures high enough to allow the fusion of hydrogen to helium. This fusion at the solar core releases energy in the form of high-frequency electro-magnetic radiation, which is transferred slowly out to the surface through a succession of radiative processes. The radiation that finally reaches the earth comes from a narrow surface region, rather opaque to visible light, called the photosphere. The energy output of the sun requires the burning or conversion of mass into energy at the rate of 4.2×10^6 tons per second. Considering that the total mass of the sun is 22×10^{26} tons, one can easily calculate that the sun will continue radiating energy for another 2,000,000 million years! Electromagnetic radiation emitted by the sun's photosphere region travels through space at the speed of light (300,000 kilometres per second) in the form of diverging rays. The earth, which is at a distance of 150 million kilometres, intercepts approximately only two-billionths of the sun's radiant output. The amount of solar energy reaching the earth's surface in any one year is over fifty times greater than the present estimates for all the energy available from the proven fossil fuel reserves, and 35,000 times greater than present annual world energy consumption.

Source: *Solar Energy for Educational Buildings,* by C. Stambolis with Peter Vastardis, Heliotechnic Press, London, 1981, a Unesco/UNICEF sponsored study

Solar energy

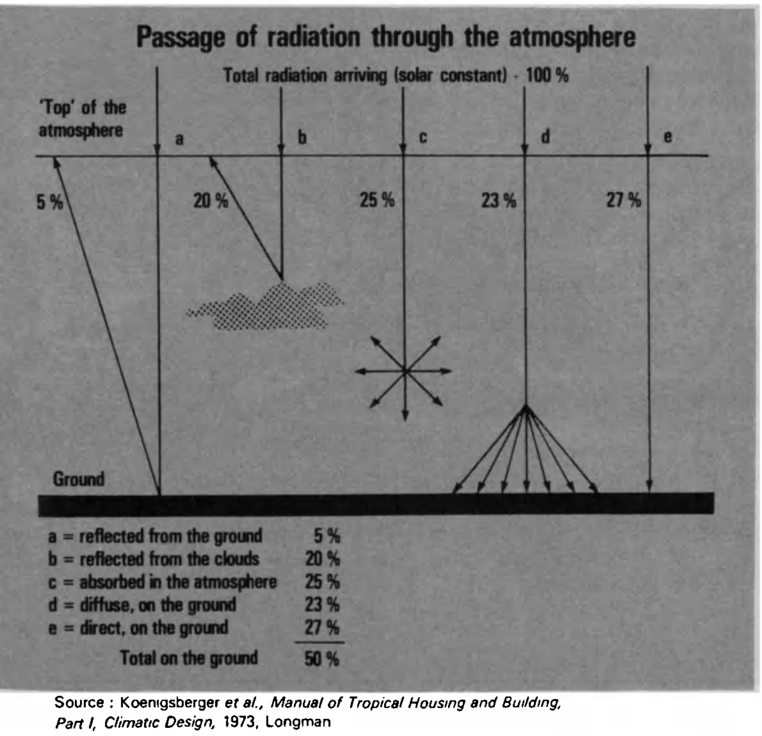
THE average amount of solar energy hitting the earth's atmosphere is enormous—about 1.353 kilowatts per square metre, or 178,000 terawatts. The amount reaching the earth's surface is much less; and the fraction of that which could be recovered less still. The global potential, then, is best counted as the solar energy falling on land which is neither occupied nor farmed. The yearly average value for that is some 10,000 TW—roughly 1,000 times current global energy consumption.

The maximum value which solar insolation reaches is about 1 kW per square metre—and that only for an hour or two at mid-day during high summer. In most areas of the world the average insolation is of the order of 200 W per square metre. Africa and Asia appear to be the best continents for the collection of solar energy.

Although very diffuse, solar energy is highly useful in that it can be used cheaply for a variety of jobs. Domestic hot water heating is the best known, and in Israel one family in five has a solar collector on its roof. Solar energy can also be used for crop drying, air conditioning, space heating, water pumping, desalination and the generation of both very high temperatures and electricity. The highest temperature so far achieved is about 4,000° on the Kelvin temperature scale in a solar furnace in the Pyrenees, where mirrors reflect solar energy over a large area onto a furnace.

The generation of electricity from sunlight appears the most promising line of attack. One method is to arrange for mirrors to reflect solar energy onto a boiler in which steam is raised to drive a turbine. Many small-scale attempts are now being made to produce solar farms which will provide electrical power in this way in the kilowatt range. In addition, there are now a dozen or so attempts to provide large-scale solar energy power stations in the megawatt range, using a basically similar technique. A 10 MW solar power station would need some 2,000 reflectors, each of 25 m² surface area.

The alternative is to use photovoltaic cells which convert solar energy directly into electricity, typically with an efficiency of some 10-15 per cent. Small power units in the range 250-1,000 kW have already been set up, but are expensive due to the high cost of the cells, which can be as much as $10 per watt installed. With mass production and more research, however, it is hoped to reduce this cost to below $0.5 per watt, at which point the electrification of isolated villages with photovoltaic units would become feasible.



Source : Koenigsberger *et al.*, *Manual of Tropical Housing and Building, Part I, Climatic Design*, 1973, Longman

Solar power for the Sahel: A Unesco feasibility study

A dramatic reduction in the cost of photovoltaic cells (solar cells which convert sunlight directly into electricity) by 1985, comparable to that which occurred in the price of transistors during the 1960s, is forecast in a Feasibility Study carried out recently by Unesco for the Regional Solar Centre to be established in Bamako, Mali.

The decision to set up the Regional Centre was taken in October 1978 at a meeting of the Heads of State of the six countries that make up the West African Economic Community (CEAO)—Ivory Coast, Mali, Mauritania, Niger, Senegal and Upper Volta. It illustrates the determination of the countries of the Sahel to solve their energy problems and move towards greater technological independence.

The purpose of the Unesco Study was to provide guidelines for the organization, financing and work plan of the Regional Centre which was conceived of as a large pilot unit for solar training and research and the production of solar equipment. The Study includes an in-depth analysis of the energy situation and needs of the six CEAO countries covering conventional as well as new and renewable sources of energy. Particular consideration was given to solar and wind energy.

Of all the renewable energies hydroelectricity is the cheapest, and, wherever consumption is high and the distances involved justify the installation of transformers and power lines, this solution is to be preferred to local energy production.

Where energy consumption is low and distances are too great to justify the cost of installing power lines, local solar or wind installations offer the best solution. The Unesco Study shows that small diesel-operated power stations of up to 100 kW are more costly to run than solar or wind installations.

Calculations made for the Unesco Study on the basis of costs as at May 1979 show that, for pumping water for irrigation in arid areas, for up to 30 kW of installed capacity, solar pumps are cheaper per cubic metre of water pumped than diesel-operated pumps. Since then the cost of oil has almost doubled whilst the cost of photovoltaic cells has dropped rapidly and the solar pump solution is now probably cheaper per cubic metre of water pumped for up to as much as 50 kW of installed capacity. Under average conditions an installation of this size could handle the irrigation needs of between 50 and 100 hectares of land.

But energy cost is not the only criterion of choice. Other factors have to be taken into account such as the reliability and life of the equipment selected, the qualified personnel needed to produce, operate and maintain it, the ease with which it is possible to increase or decrease operating capacity, the possibility of producing all or part of the equipment in the user country. On all these counts photovoltaic solar installations have a clear advantage over alternative systems such as diesel, solar thermodynamic or wind installations.

Photovoltaic solar installations require virtually no maintenance, spare parts or supervision by qualified personnel. They work unattended and need only a simple monthly check. Their capacity can easily be enlarged by the addition of further cell panels. Furthermore, they can already be partially produced in developing countries using imported solar cells and it is anticipated that in the near future even these will be produced in the user countries.

A big effort is now being made in a number of industrialized countries to perfect new and simpler techniques for the production of photovoltaic cells. It is forecast that the price of a solar cell module will drop from 13 dollars (the price in February 1970) to about 50 cents by 1985 and to 15 cents in 1988. A drop in price of this scale will make photovoltaic solar energy an even more attractive proposition for developing countries.

Although the Unesco Feasibility Study was based on the situation in the six countries of the West African Economic Community, its general conclusions are valid for all developing countries in the world sun belt. It is hoped that the basic technical orientations and priorities proposed in the Unesco Study will be adopted and that wide application of its findings will represent a considerable step forward towards the achievement of a viable new energy strategy. ■

Energy alternatives and development strategies

EVER since the world woke up to the harsh realities of the energy crisis discussion has tended to concentrate on the technical and financial constraints that will have to be overcome if a solution is to be found. But the introduction of new energy sources involves much more than technology and finance and many non-technical obstacles stand in the way of a smooth transition to a viable new energy mix.

It was to examine these problems that twenty-five specialists from around the world attended an International Workshop on Non-Technical Obstacles to the Use of New Energies in Developing Countries, sponsored by Unesco and nine organizations working in the energy field and held at the Rockefeller Foundation Study and Conference Centre, at Bellagio, Lake Como, Italy, from 25 to 29 May 1981.

One of the major topics discussed by the participants was the problem of the social and cultural impact of the introduction of new sources of energy in developing countries and the lead time needed to prepare the necessary social and institutional changes and to make them acceptable to the societies involved.

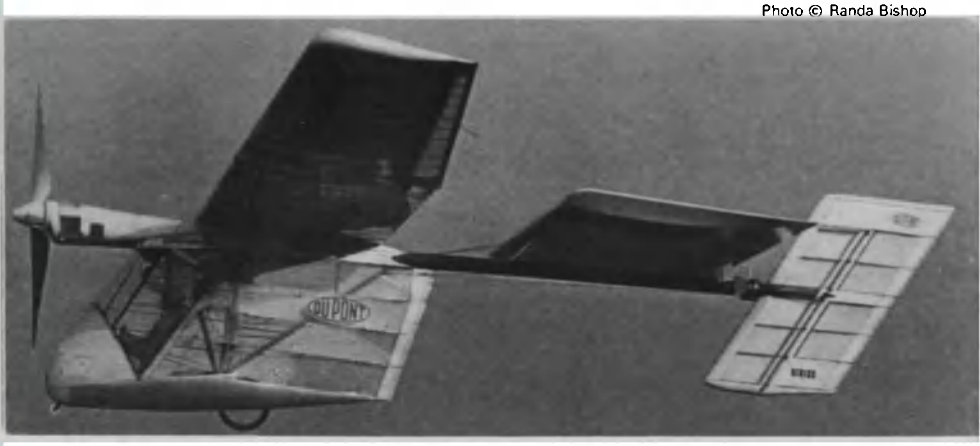
In their concluding statement the specialists noted that the impact of change in the energy mix on all societies and cultures involving the introduction of new energy sources was not fully understood. In less developed countries many social and cultural constraints were intimately linked to the problems of poverty. The delicate balance of survival strategies made risk-taking on new technologies difficult, a factor which needed greater emphasis in planning and implementation procedures. Special care would have to be taken in development programmes (afforestation, stove design, alternative cooking fuels such as biogas) to avoid misunderstandings and possible negative rather than positive impact.

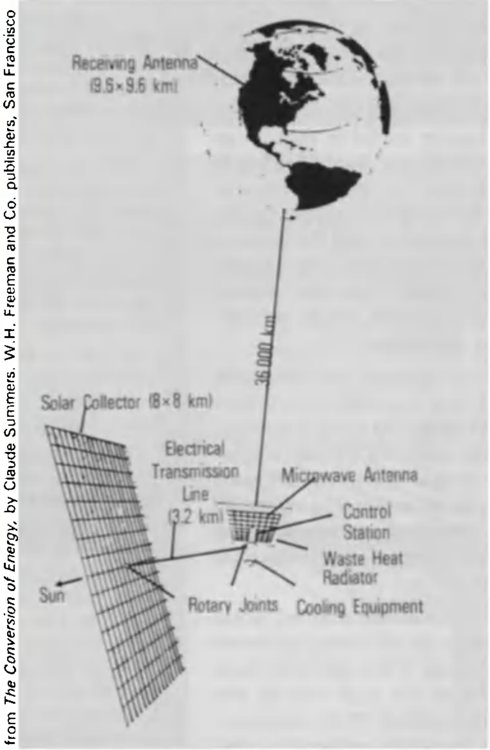
It was important to distinguish between the different groups within a society so that technologies and institutional arrangements could be selected and adapted to the needs of the people who would use them (men, women, urban, rural, poor, landlords). The institutional framework for the application of new sources of energy in developing countries often tended to favour the urban and commercial sector, whereas the major needs might well be in the rural and traditional sector. Institutional support for new and renewable sources on a small-scale, decentralized basis might require special attention since it did not fit most existing patterns.

Cultural attitudes which favoured energy-intensive approaches (e.g. large automobiles or climate-controlled architecture) also impeded the adoption of new technologies. Alternative life styles which were less energy consuming were needed both in developed and developing countries.

Cultural and social values should not, however, be viewed only as constraints; they should also be built upon in the search for alternative development patterns that offered the possibility of breaking away from exclusive reliance on the dominant commercial fuels of today. ■

Photo © Randa Bishop





Drawing from *The Conversion of Energy*, by Claude Summers. W.H. Freeman and Co. publishers, San Francisco

Flights of fancy

The first solar-powered flight across the English Channel was made on 7 July by the *Solar Challenger*, above, a lightweight plastic aircraft piloted by Stephen Ptacek (whose name means "little bird" in Czech!). The 290-kilometre flight took 5 1/2 hours. The craft, designed and built in California, has over 16,000 solar cells which capture the sun's rays and convert them into electric power to operate a motor which turns the propeller.
Drawing, left, shows the audacious design concept for a solar satellite power station, which would orbit at a height of 36,000 km in space where solar energy is available virtually 24 hours a day. The solar collector would convert solar energy into electricity and feed it to a microwave antenna. The antenna would direct a microwave beam to a vast receiving antenna on earth where the microwave energy would be converted back to electricity.
Below, newspapers hot from the solar press were produced during an experiment in the Tuileries Gardens, Paris, as far back as 1882.

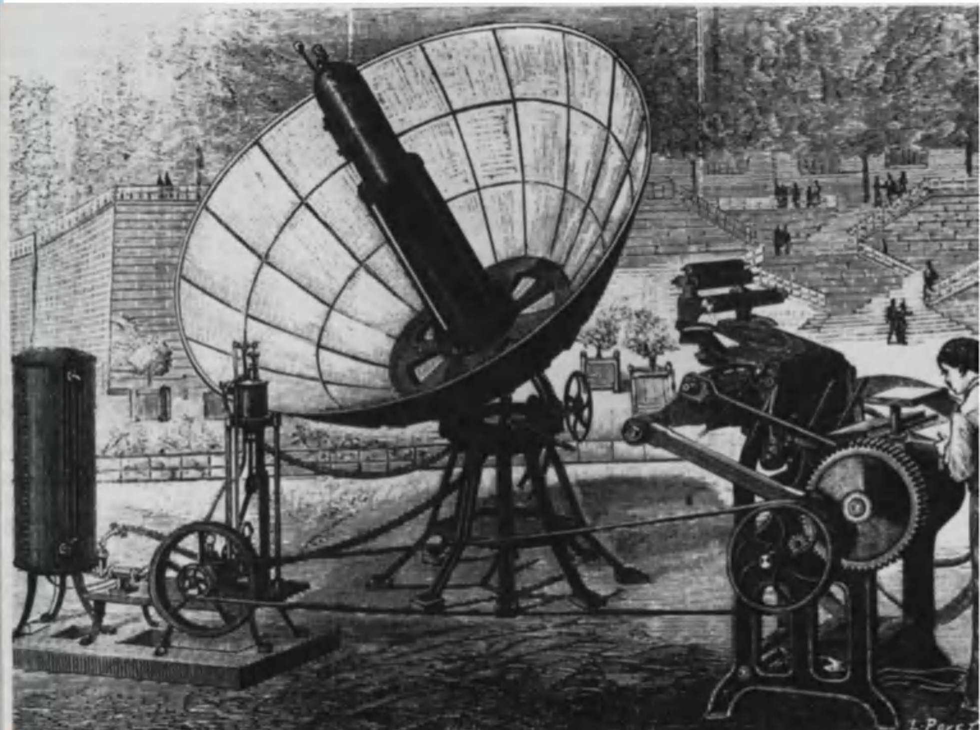
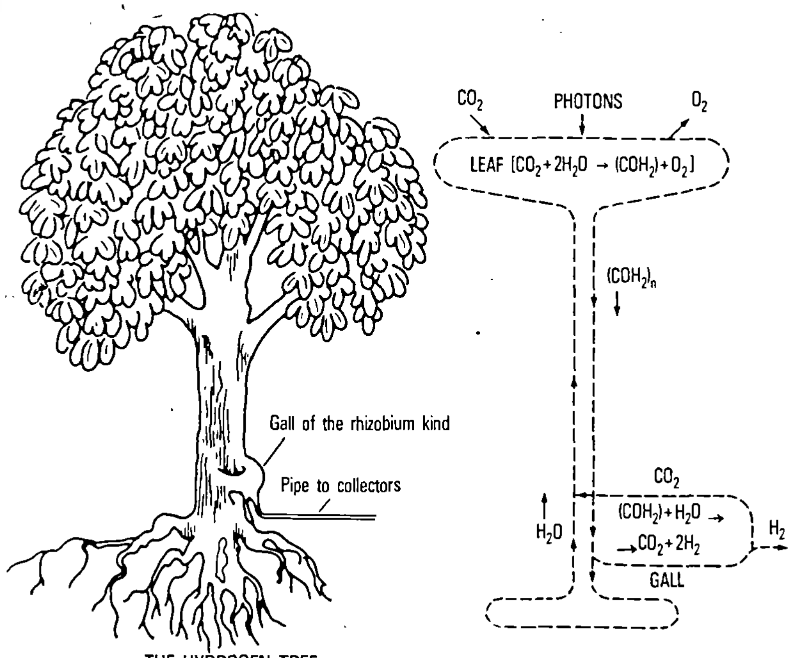


Photo © Musée des Techniques CNAM, Paris



THE HYDROGEN TREE

Drawing from *Energy in a Finite World*, IIASA, Laxenburg, Austria

A radical new approach to solar energy may come from biotechnology—a broad class of systems that have at their core photosynthetic and biological energy conversion processes.
Plants have long "known" how to use the energy of sunlight to split water, but they do not evolve hydrogen explicitly, since it is needed only for internal energetic processes within the plant itself as a means for reducing carbon dioxide. However, it may be possible to develop new biological structures that in fact evolve hydrogen. At IIASA, Cesare Marchetti considered the concept of hydrogen-producing trees. The concept is essentially one of replacing expensive solar collectors and solar cells with tree leaves. Swollen plant tissues, so-called galls, located at the tree trunk would be genetically programmed to use the solar energy captured in the leaves for generating hydrogen gas as a by-product of photosynthesis. The hydrogen gas would be collected within the galls and piped to a central storage system. The essential features of such a system already exist in nature. Many insects and bacteria induce the formation of galls in different types of plants. These various kinds of galls, which number in the tens of thousands, then provide the shelter or nutrients needed by the organism that caused them. In at least one case, that of Rhizobium bacteria in symbiosis with leguminous plants, substantial hydrogen is produced in the galls, though currently it simply escapes to the atmosphere. It has been estimated that in this way U.S. soybean plantations leak about 30 billion m^3 of hydrogen annually. Adapting this potential so that the plants can be easily integrated with some sort of collection system will depend on advances in the techniques of genetic engineering. Left, graphic presentation of the proposed hydrogen tree with a very schematic chemistry. The gall actuates a reverse of photosynthesis and makes hydrogen (or methane) available in an enclosed cavity that can be tapped by a collector pipe.

Solar fuels

SOLAR energy is used by plants via the mechanism of photosynthesis—carbon dioxide in the air and sunlight are in this way made to produce carbohydrates. All fossil fuels—coal, oil, natural gas and lignites—as well as timber, farm crops and even animal dung are therefore best regarded as solar fuels. More than 95 per cent of our current energy consumption comes from solar fuels.

About 90 per cent of the energy stored in plants on the earth's surface is in the form of trees. The total energy stored is about 635 terawatt-years, which is roughly the same as the amount of energy stored in our coal reserves. Unlike coal, however, this energy is renewed annually at a high rate. The earth's biomass yield on land is calculated to be some 28.65 TW—three times current global energy consumption—of which half is produced by forests. Microscopic plants in the oceans also fix solar energy, producing about 14.35 TW. These are rather conservative figures, and assume an efficiency of photosynthesis of 0.2 per cent on land and 0.02 per cent in the oceans. In fact, photosynthesis tends to be more efficient than this.

The best known use of solar fuels is burning wood for cooking and heating. Globally, about 1-2 TW are provided in this way, primarily in Africa and Asia where in some areas timber provides 80 per cent of energy requirements. But a consequence of this is that forests are being used more quickly than they grow.

The burning of dried dung fuel is also common, but removes important fertilizer from the land. A more efficient use of dung is to ferment it anaerobically in a digester to produce methane gas. Small digesters are now common in India and China, even though they are rather expensive to build. The dung from one cow should in theory provide enough methane gas to cook for one person.

A similar technique is to ferment biomass to produce alcohol which is a good liquid fuel. Brazil leads in this technology and aims eventually to substitute all petroleum with alcohol fermented from sugar cane and other specially grown crops. Even under good conditions, however, 1 km^2 of sugar cane is needed to provide sufficient fuel for 100 cars. Although many other countries are now investigating the possibilities of substituting petrol with alcohol—even industrialized countries—there will inevitably be competition for land with food producing activities.

■ **Zoran Zarić**

Photo © M. Pignata-Monti, Paris

More than one-third of the world's population depends on wood for cooking and heating. Eighty-six per cent of all the wood consumed annually in the developing countries is used for fuel, and of this total at least half is used for cooking. Nearly everywhere, reliance on charcoal as a source of fuel is increasing. In Tanzania, for example, the charcoal share of the wood fuel burned, which was 3 per cent in 1970, is expected to rise to 25 per cent by the year 2000. In principle this is discouraging, because in preparing the charcoal more than half the wood's energy is wastefully burned away. But charcoal makes wood energy easier and cheaper to transport, and the growing reliance on it is a result of the increasing distance from harvest site to the user. Also, charcoal is preferred because of its steady and concentrated heat, its smokeless burning, and because it can easily be extinguished when the fire is no longer needed. Charcoal can also substitute for fossil fuels, which in some places is an urgent need. Regardless of overall inefficiency, it seems clear that more meals will be cooked over charcoal in the future. Above, charcoal manufacturing ovens in Argentina.

Source : *Energy in a Finite World*, 1981, IIASA, Laxenburg, Austria

Photo Jonathan Blair © Woodfin Camp, New York

The most popular but not necessarily the most economic biomass conversion process is undoubtedly the production of ethyl alcohol (ethanol C_2H_5OH) from sugar-cane and maize. The world's leading producer is Brazil, above, producing 3.2 billion litres of alcohol from sugar-cane, sorghum and cassava. The alcohol can be blended with petrol to a proportion of up to 20 per cent alcohol and run in a conventional car engine without adjustment. However, in case of need, cars can run on pure alcohol after adjustments.
The cost of alcohol in Brazil is higher than most gasoline sold in Europe in 1980. Nevertheless, the indirect benefits are judged very beneficial to Brazil. They include the saving of foreign exchange, the creation of new employment, the encouragement of domestic technology and industry.
The United States is also deeply involved in the promotion of ethanol production and has set a target of approximately 3,477 million litres a year of alcohol for fuel use by 1982. Most of the distilleries use corn as feedstock. Other countries known to be interested in bioconversion to ethanol include Australia (cassava) and New Zealand (beet).
Some economists feel deep disquiet at the use of food grains to produce motor spirit. They feel that it will lead to the rich getting transport and the poor getting starvation with land currently used for food production being used for fuel. Several situations can be envisaged in which production is economic. The developing countries with a surplus agricultural production but an energy deficit, such as Brazil, Sudan, and Thailand, are likely to have the strongest incentives to develop large biomass energy programmes in order to reduce their dependence on imported energy. Most of the countries with viable alcohol programmes are likely to belong to this group. Many of the large developing countries, such as Bangladesh and Pakistan, however, are net importers of both agricultural products and energy. In most of these countries ethanol production is likely to be attractive only if based on surplus low-cost biomass materials such as molasses and agricultural crop residues (or sugar-cane during periods of world sugar surpluses). In countries with surplus energy, such as Mexico, Nigeria, and Venezuela, there is little incentive to launch major biomass energy programmes.

Sources : United Nations *Development Forum,* 1981, and *Finance and Development,* 1980

Brazil's green gasoline

by Benedicto Silva

TODAY, in a world threatened by the exhaustion of oil as an energy source, Brazil is well placed to become the first country to enter the post-petroleum era without abandoning its network of highways or cutting back on the manufacture and use of motor vehicles. The Brazilian way of facing the energy crisis is to transform vegetable matter into ethyl alcohol, or ethanol, in such quantities that as of this year the country has the capacity to supply at least 20 per cent of its automotive fuel needs in this way. It is expected that ethanol production will continue to mount until Brazil achieves self-sufficiency as a non-stop producer of renewable energy.

It has been shown both theoretically and experimentally that alcohol can compete on equal terms with gasoline (petrol) as a fuel, although it has a lower heating value. An engine specially designed to run on alcohol can be regulated in such a way that ethanol has a slight edge on petrol in terms of kilometres per litre. Ethanol also has the outstanding advantage of reducing pollutant emissions by half.

The raw materials Brazil needs for large-scale ethanol production are sugar-cane, manioc and other plant products. Sugar-cane is more productive than manioc in the sense that it is a better agent for photosynthesis; in other words it produces more energy per hectare under cultivation. However, it is a seasonal crop and its production cycle is less than six months a year. The advantage of manioc is that it enables the distilleries to run continuously. In other words it is useful to rely on both plants to guarantee an uninterrupted flow of automotive fuel.

It has been calculated that by using scarcely two per cent of its cultivable land Brazil could achieve the enviable position of being the first country in the world to be self-sufficient in indefinitely renewable fuel.

Moreover, the efforts needed to carry out such a programme would probably be big enough to absorb all the available manpower in Brazil. Besides, planting, cultivating, harvesting, transporting, milling and fermenting sugar-cane and manioc provide jobs which require little more than basic training. Preparing the necessary work-force does not require long and costly training programmes.

As far as transportation costs are involved (the creation and operation of an ethanol distribution network) they will be lower than for petrol since the new fuel can be produced in virtually all the States of Brazil.

Finally, it is hoped that the alcohol programme will generate between 250,000 and a million new jobs in the next few years, especially in the agricultural sector. The creation of new employment opportunities in rural areas will in its turn help to brake the urban migration which is one of the major problems facing Brazil's cities. ■

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Biogas: the Indian experience

Technical feasibility alone is no guarantee of success

by Tushar K. Moulik

FACING the inflationary consequences of a rapidly mounting import bill for oil, the Indian Government some years ago launched an all-out compaign to promote the use of biogas produced by "gobar" gas plants. Various incentives such as subsidies and low interest credit facilities were offered to householders willing to invest in the family-size units, which produce two to three cubic metres of gas per day.

Nevertheless, the results of the campaign fell far below the Government's targets, with not more than five to six thousand plants being installed annually. What is more, as many as 50 to 70 per cent of India's reported 70,000 gobar gas plants today are thought to be inoperative.

What are the reasons for this lack of performance? After all, the technology of the gobar gas plant as promoted in India is said to be simple enough to allow the units to be constructed and handled efficiently by village craftsmen.

However, an evaluation of India's gobar gas programme clearly reveals that it is subject to four major constraints related to: 1) the prevailing social and economic structure; 2) cultural practices and values; 3) information about and knowledge of the technicalities of the process of anaerobic digestion; and 4) the availability of skilled manpower.

The small, family-size biogas plants promoted in India require three or four cattle to provide the necessary input of dung. A plant of a size requiring less than this number of cattle for dung-input is economically not profitable. In addition to this technological requirement, the cost of each plant, around 5,000 rupees, is prohibitive.

The Indian families which fulfill these financial and cattle ownership requirements cannot account for more than 10 to 15 per cent of the rural population. The technological requirements thus exclude a significantly large proportion of India's population, comprising small and marginal farmers and landless labourers, from using family-size biogas plants.

Closely related to this basic question are the two important constraints of space and water. A three-cubic-metre family-size plant would require about 27 square metres of land area for the plant and the compost pit. It is also advisable to build the plant within a six-metre radius of the kitchen in order to provide an efficient supply of gas for cooking. But in many villages in India dwellings are clustered so closely together in a network of narrow lanes and alleys that it is often rare to find a villager who owns and can spare the minimum required land area near his homestead for the biogas plant.

Scarcity of water is an equally serious resource constraint in many villages. To enable a biogas plant to operate smoothly, cow-dung and water are mixed in the ratio of 4:5 by volume and the resulting slurry is fed into the digester. Where water is scarce

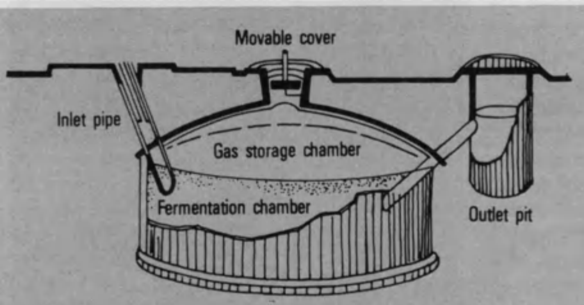

Photo top of page, an Indian woman cooks on biogas. Right, an Indian biogas digester installation. Water has to be added to ensure the smooth operation of the installation and this can be a serious constraint in areas where water is scarce. With some seven million biogas digesters already installed, China leads the world in biogas development. Above, cross-section of a Chinese-designed biogas digester.

Photos Mark Edwards © Earthscan, London

Drawing Unesco Courier. Source : A. Van Buren, London and has to be carried from a far-off well or other source, bringing the necessary number of buckets for the biogas plant adds another burden to an already arduous task.

Lastly, and perhaps one of the most important economic factors accounting for the non-adoption of biogas plants, is the way in which villagers perceive the opportunity cost of the available alternative fuels used for cooking and heating, mainly firewood, dung-cakes and agricultural wastes.

"Why bother about a gobar gas plant when we can get firewood (thorny bushes) around the village to be used as fuel?" asked a farmer in Rajasthan. When reminded that very soon the available firewood source would be exhausted, the farmer replied: "So far it hasn't happened. We've been using the same firewood source for ages. Why should it run out now?"

Another factor is that the direct benefits of a biogas plant in the form of cooking gas and manure are perceived to be notional since there is no direct cash-flow of income from the plant. Since cash income is the crucial motivating force for a large section of the rural population, its absence removes any immediate incentive to adopt a biogas plant.

Linked to these socio-economic forces, there is a host of prevailing cultural practices and norms which seriously inhibit the promotion of family-size biogas plants in India. Firstly, there are strong inhibitions about the use of human excreta as feeding material for biogas plants, and about cooking food over gas generated from slurry containing human excreta.

The second and perhaps one of the most serious cultural constraints is the role and status of women in decision-making. The most conspicuous and immediate beneficiaries of biogas plants are the village women. Not only does biogas save them from the arduous job of cooking for hours in a smoke-filled kitchen, with the consequent health hazards, it also provides them with more leisure because they spend less of their time cooking and cleaning soot-stained utensils. The household is also likely to economize because the utensils last longer. But these benefits are not usually given high priority in the rural households, essentially because the decision-making for investment is generally done by the men, who do not consider the benefits for the women as an urgent necessity. Because of this attitude, when plants break down, in many cases they are allowed to remain out of order for a long period without attention and repair, and eventually many of them are irreparably damaged.

But a still more serious constraint faced in the rural areas stems from the adjustments and changes required in various traditional habits and practices in order to use biogas efficiently. It is often complained, for example, that *chapatis* cannot be properly roasted on a gas burner, and that *dals* (pulses) take a long time to cook on gas. Gas has also been found to be inappropriate for preserving milk, which for this purpose is generally kept heating over a slow, steady fire for a whole day. Thus the introduction of biogas requires a series of interrelated changes and adjustments in certain deep-rooted norms and practices.

But in spite of the limiting factors described above, more and more villagers in India are becoming aware of biogas plants. However, there is a striking lack of knowledge of the essential facts about biogas plants not only among interested potential users but also among those who have already adopted the system. In many rural areas there seems to be a persistent myth about the "magic" of the biogas plant, a technology which is alleged to produce fuel and fertilizer from waste, free of charge and without any effort. This fashionable myth about biogas plants is clearly the result of inadequate and distorted information.

Given the exploratory state of biogas technology and the consequent lack of dependability in its performance, the negative attitudes of the users are bound to be aggravated unless there is a thorough sharing of knowledge and experience between users and promoters. False promise and inadequate information can only breed unrealistic expectations and lead ultimately to extreme distrust.

The question of manpower is crucial in the process of promoting the use of biogas. An assessment of the problems involved in promoting family-size biogas plants as part of a decentralized energy system in rural India reveals that there is an enormous constraint in this field. In spite of continuing claims about the simplicity of current biogas technology, it requires very careful technical supervision and guidance in order to install, repair and maintain. The technical expertise of this kind is simply not locally available in most Indian villages.

The list of constraints outlined above looks formidable, but many of them can be surmounted over a period of time provided that appropriate organizational efforts are made in a planned manner. Operationally, one of the important goals of such efforts should be to develop local skills and knowledge through a sustained education and training programme. For in the last analysis a decentralized energy system of family-size biogas plants in rural India can only operate successfully when it is least dependent on external resources.

The example of China is perhaps most relevant here. Through a continuous process of technical training, China has been developing a small pool of skilled manpower in each production team to administer and monitor the biogas promotion programme. India needs a similar strategy.

What is required is planning at the local level, using local resources and promoting the fullest participation of the local people in the whole process of planning, education and monitoring. In order to develop sustained local participation, a carefully designed massive training programme is absolutely imperative. Such a programme should not only include the technical aspects of biogas production but also other related aspects of the question such as analysis of local constraints, local energy planning methods, data collection and monitoring, and methods of integrating biogas energy into other development activities.

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BOOKSHELF

RECENT UNESCO BOOKS:

■ **Solar Electricity. An Economic Approach to Solar Energy**, by Wolfgang Palz. A survey of all the known ways in which the sun's radiation can be converted into power. Already published in English, Spanish and Portuguese. French, Dutch, Italian and Bulgarian editions will be published shortly. English edition is co-published with Butterworths, London, who have exclusive sales rights in the U.K.

■ **Impact of Educational Television on Young Children**, edited by Wayne H. Holtzman and Isabel Reyes-Lagunes. 1981, 60 pp. (12 F).

■ **Community Development**, edited by Ronald Dore and Zoë Mars. An analysis of cases of community development experience in India, the Republic of Korea, Mexico and Tanzania. 1981. 446 pp. (170 F) Co-published with Croom Helm Ltd., London, who have exclusive sales rights in the U.K.

■ **Women and Development: Indicators of their Changing Role**, edited by Mayra Buvinic and Ilsa Schumacher. (No. 3 in Unesco's "Socio-Economic Studies" series) 1981, 112 pp. (20 F).

■ **Self-Management in Education Systems.** 1981, 48 pp. (12 F) ■ **World Problems in the Classroom.** 1981. 59 pp. (12 F) Nos. 39 and 41 in Unesco's "Educational Studies and Documents" series.

■ **World Directory of Peace Research Institutions.** An alphabetical listing of all international and regional institutions, and national institutions in 44 countries. 4th edition revised, 1981, 213 pp. (26 F).

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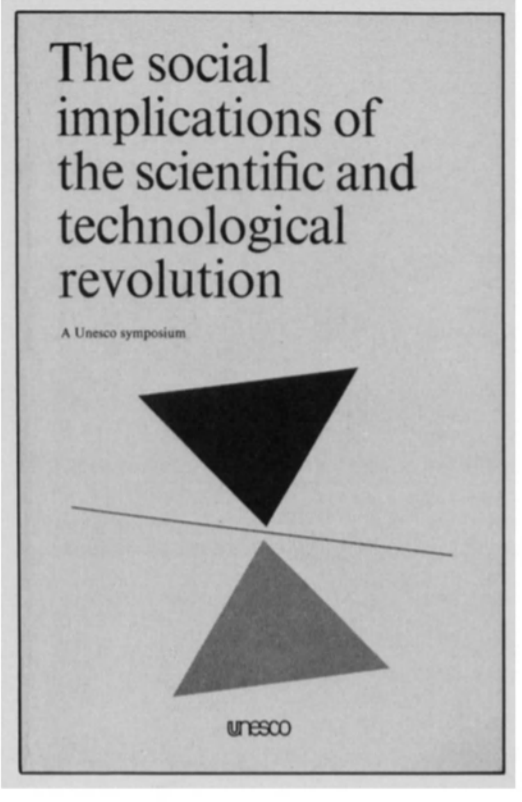

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