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「21世紀のエネルギーを考える」

イタリア国立エネルギー研究機関総裁　ウンベルト・コロンボ

Profile of Lecturer

Professor Umberto Colombo

1927	Born in Livorno, Italy
1950	Doctorate in Physical Chemistry, University of Pavia
1953	Postdoctoral Research at MIT, Department of Chemical Engineering
1954-'78	Montecatini (now Montedison) Chemical Company: Research and Development Division, becoming its general manager, coupling this position with that of Director for Strategic Planning
1965-'72	Professor of Industrial Chemistry, University of Genoa
1972-'75	Chairman of the OECD Committee for Scientific and Technological Policy
1977-'78	Chairman of the European Industrial Research Management Association
1979	Chairman CNEN (The Italian Atomic Energy Commission). Under his chairmanship, the Commission has been relaunched as ENEA (The Italian National Commission for Nuclear and Alternative Energy Sources).

He is currently:
- President of the ENEA
- Chairman of the European Communities' Committee for Science and Technology (CODEST)
- Chairman of the United Nations' Advisory Committee on Science and Technology for Development
- Trustee of the Aspen Institute for Humanistic Studies
- Member of the Board of Wissenschaftszentrum Berlin

Honours

Many Scientific awards by various countries, such as the European Association of Exploration Geophysicists, and the American Institute of Electrical, Electronic and Metallurgical Engineers.

Member

A member of various national academies and international learned societies, such as the Club of Rome, the European Academy of Sciences, Arts and Letters and the Trilateral Commission.

Recent Monographs

"Science, Growth and Society"
in collaboration with H. Brooks, S. Okita and others; OECD, Paris, 1970

"Reducing Malnutrition in Developing Countries"
in collaboration with G. Johnson and T. Shishido; The Trilateral Commission, New York, 1977

"Beyond the Age of Waste"
in collaboration with D. Gabor; Pergamon Press, Oxford, 1978

"La Speranza Tecnologica"
in collaboration with G. Balcet, G. Lanzavecchia, G.B. Zorzoli; ETAS Libri, Milan, 1980

"II Secondo Pianeta"
in collaboration with G. Turani; Arnoldo Mondadori, Milan, 1982

講師略歴

ウンベルト・コロンボ

●学歴および経歴

1927	イタリア、リボルノ生まれ
1950	パビア大学（イタリア）物理化学博士
1953	マサチューセッツ工科大学化学工学部にて博士号取得後の研究
1954～1978	モンテカティーニ（現在のモンテディソン）社研究開発部に勤務 同部々長及び戦略担当役員を兼務
1965～1972	ジェノア産業化学大学教授
1972～1975	ＯＥＣＤ科学技術政策委員会委員長
1977～1978	欧州産業研究管理協会会長
1979	ＣＮＥＮ（イタリア原子力委員会）——現在ＥＮＥＡ（国立エネルギー研究機関）に改組——総裁
現在	ＥＮＥＡ総裁 ＥＣ科学技術委員会委員長 国連科学技術開発諮問委員会委員長 アスペン人文科学研究所理事 ベルリン自然科学センター評議員

●栄誉

ヨーロッパ地球物理学者協会、アメリカ電気・電子・冶金技術者協会等各国から数々の賞を受賞する。

●会員

ローマクラブ、ヨーロッパ科学芸術文学アカデミー、日米欧委員会等数多くの国内／国際学会に所属する。

●近年発表の論文

『科学、成長そして社会』
H.ブルックス、大来佐武郎氏他と共著
1970年、パリ、ＯＥＣＤ出版

『低開発国の栄養失調を減らす』
G.ジョンソン、宍戸寿雄氏と共著
1977年、ニューヨーク、トリラテラル・コミッション出版

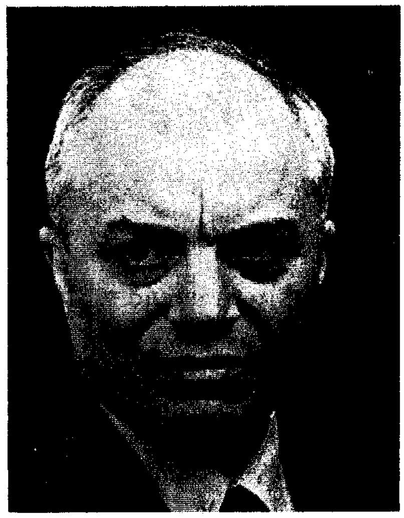
『浪費の時代を超えて』
D.ガボールと共著
1978年、オックスフォード、ペルガモン・プレス出版

『技術への希望』
G.バルチェット、G.ランザベッキア、G.B.ゾルゾーリと共著
1980年、ミラノ、ＥＴＡＳ出版

『第二の惑星』
G.チュラニと共著
1982年、ミラノ、アルノルド・モンダドーリ出版

このレポートは昭和59年11月16日、ホテル・オークラにおいて行なわれた1984年度本田賞授与式の記念講演の要旨をまとめたものです。

Facing up to Twenty-First Century Energy Problems



Lecture at the Conferring Ceremony on the 16th of November 1984, in Tokyo

Professor Umberto Colombo
The Winner of The Honda Prize 1984

1. INTRODUCTION

It is with great humility that I stand before you, to speak about "Facing up to Twenty-First Century Energy Problems". I believe this is the appropriate time for us to discuss our planet's energy future, to seek options, weigh alternatives. The energy crises of the 1970's caught the world unawares. The signs are that the blithe and irresponsible attitude which characterised our approach to energy problems until the OPEC-led shocks must be banished forever. The energy future is still not clear, even though the atmosphere of constant crisis which pervaded world councils until so recently has been seen to be excessive.

My country and your's have a particular interest in this topic. I am thus grateful to Mr. Soichiro Honda, and to the Honda Foundation, for this opportunity to talk to you. I hope that what I have to say will be of some relevance to the future of our two countries, so dissimilar in many respects, yet so alike in others.

In both our countries the industrialisation process began quite belatedly. The lack of domestic natural resources has compelled both Japan and Italy to rely heavily and increasingly on imported sources to feed their industries. But at the same time, we are both compelled to find export markets for our industrial goods. The Japanese presence in world markets is truly ubiquitous. Italy sells an even larger share of its national product abroad (figure 1).

Since the end of World War II, labour productivity in both countries has been rising and continues to rise at steep rates, on average higher than those of other Western industrialised economies. It is significant that our two countries have what has been described as a dual economic structure: an advanced prosperous sector coexisting side by side with a more modest one, with remarkable differences in terms of industrial relations, of productive capacity and of organisational structure. This could be one of the most important, even though inadequately explored, aspects of our extraordinary capacity to compete internationally.

In fact, Italy and Japan are tough competitors, rapidly adaptable to the requirements of export markets. Japan with its long-term strategy of

EXPORTS AS A PERCENTAGE OF GDP

	1970	1975	1980	1981	1982	1983
JAPAN, total exports	9.5	11.2	12.5	13.5	13.0	12.7
ITALY, total exports	13.1	18.2	19.7	21.4	21.1	20.6
ITALY, exports outside EC area	7.5	10.0	10.3	12.2	11.4	11.1

Figure 1

targeting specific objectives and with the strength of its research, industry, financial system and commercial services; and Italy with its creativity, flexibility, individual managerial and marketing skills and long recognised leadership in design. For each of our two countries, it can be said that from a unique respect for the past derives an insatiable curiosity for the future. Probably the key parallels linking us are high population densities and dependence on foreign raw materials, and the need to develop eco-technologies so as to minimize the negative impact of intensive domestic industrial activity on man and his environment.

The economic development of Italy and Japan has been conditioned since the beginning of the Twentieth Century by dependence on imported energy, neither possessing domestic supplies of coal or oil in sufficiency. Furthermore, of the major industrialised countries, Japan and Italy have the highest quota of their global domestic energy needs satisfied by oil (figure 2). Such energy insecurity has, at different times, led both countries to promote less conventional sources. Thus, Italy and Japan have needs which are inherently in excess of their domestic capacity to satisfy, needs deriving from the nature of their geography and lack of mineral resources, their populations, their economies. Both therefore could represent a model and guide for other countries facing problems of energy and, more broadly, of raw materials. This is particularly important now, with OPEC in difficulties, oil plentiful and decreasing in price on international markets, and attention unwisely distracted from energy problems and their long-term solutions.

2. ENERGY TRANSITIONS

Today's transition does not only involve the energy picture, it is also technological and social. All three aspects are, moreover, closely related. We can find no equivalent in the past. Japanese and Italian energy problems are more severe than those now facing other countries, and hence could well stimulate innovative solutions.

The current energy transition is certainly not the first man has experienced. In the past, new sources represented a more convenient alternative once they were mastered. They allowed man to perform a variety of tasks – cook food, heat interiors, process materials, work – and to create multipliers of his own physical labour. They often marked a turning point in the development of society, as much as did the advent of new materials: the Stone Age, the Bronze Age, the Iron Age, for example.

Easy access to an adequate energy supply has been a key factor in the progress of mankind throughout its history. With only mild simplification, one may say that we live in a society which has its roots in the need for the early Eighteenth Century English ironmakers to find a way to produce iron without burning wood – the stock of which had already been depleted by overuse and which for strategic reasons needed to be preserved to build the timber hulls of the Royal Navy. When technological innovation introduced the Coal Age, a new form of civilisation arose founded on what then seemed to be cheap and abundant energy. With coal we see the rise of the factory, of centralised production processes, of a completely different conception of the use of labour, of massive conurbations tied to the coalfields (figure 3). The symbol of development was Manchester and its thousand chimneys belching black smoke, which so

OIL IMPORT AS PERCENTAGE OF TOTAL ENERGY REQUIREMENTS, SELECTED COUNTRIES

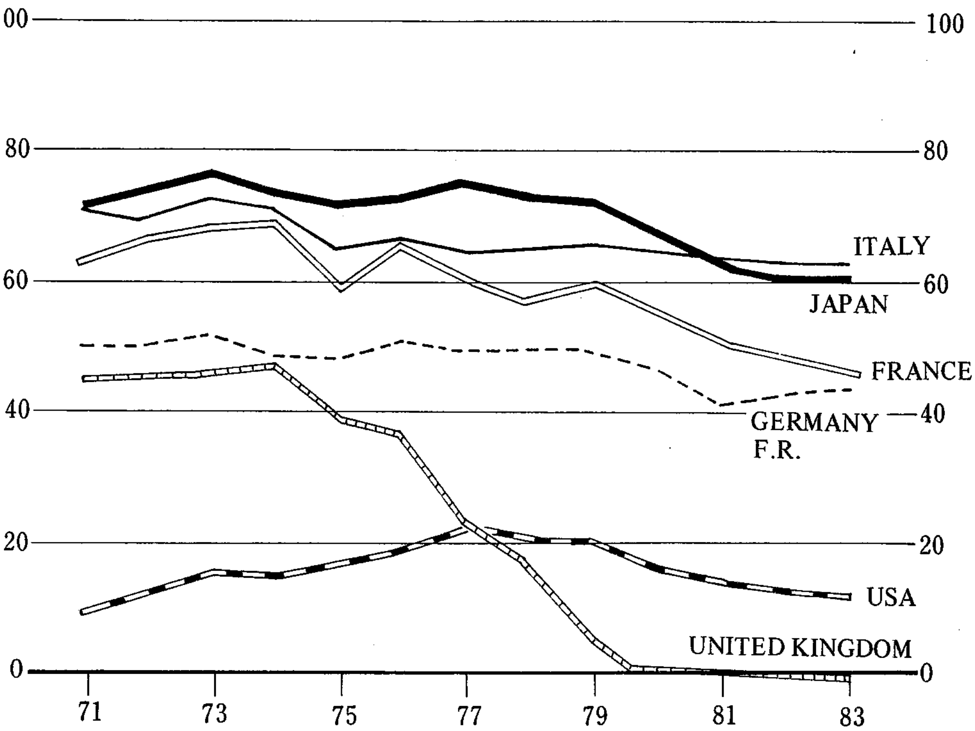
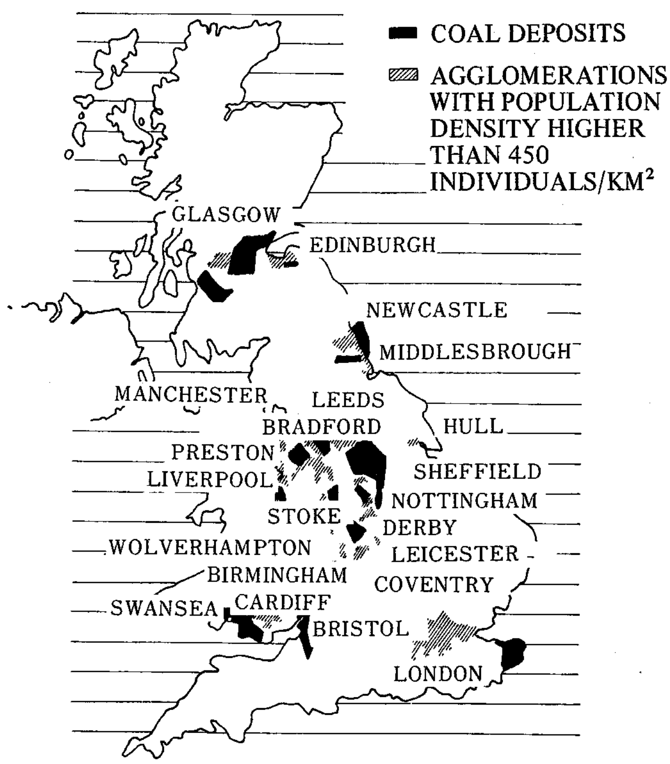


Figure 2

COAL DEPOSITS AND URBAN AGGLOMERATIONS IN THE UNITED KINGDOM



SOURCE: U. Colombo, C. Bernardini "A Low Energy Growth 2030 Scenario and the Perspectives for Western Europe"

Figure 3

impressed overseas visitors with their awe-inspiring, infernal power. They returned home in admiration and envy, determined to build another Manchester at home, in their own countries, in France, Belgium, Germany, the United States, Russia, and Japan.

The factory system meant urbanisation. For this transformation, a very high price was paid by the labouring classes in terms of quality of life, quality of environment and, indeed, personal safety. Still one should not forget that the industrial revolution of the Nineteenth Century also saw advances in education, health care and income distribution, which precipitated a population explosion and mass emigration. Urbanisation also led to the development of industrial democracy, the only political system capable of governing the complexity of such societies whilst at the same time safeguarding individual liberties.

The shift from coal to oil which followed nine decades later, was in no way related to a depletion of the former. Even today, coal exists in greater abundance than oil, and deposits are well-distributed worldwide. Instead, it was due to the fact that, once the relative technologies were developed, oil was found to be far more convenient in terms of overall costs, ease of extraction and transportation, distribution and application, having enormous flexibility. Unlike coal, therefore, oil was not used pre-eminently on a local basis, with the creation of cities and industries near the wells. On the contrary, the shift to oil provided the opportunity for areas culturally prepared to industrialise but lacking adequate local energy resources to take this step. This is, of course, the case for countries like Italy and Japan.

In particular, oil led to the development of the automobile with its enormous impact on the structure of cities and on our way of life. Road transportation gave new possibilities of mobility to classes hitherto restricted to occasional trips by railway. Could coal alone have brought this about? Oil has gradually supplanted coal both in strictly energy applications – even for the iron and steel industry – and as the main source of raw materials for the chemical industry.

The coal to oil switch demonstrates how naturally the last energy transition took place, new and more advantageous conditions being created which favoured the use of the new source. For this reason, I like to call this a "downhill" transition: a shift to an easier, more flexible single major source, supplanting a predecessor as chief energy vector.

2.1 Energy Transition and Technology

Today's situation is totally different. It is no longer a matter of merely finding new deposits of old sources, or of finding new energies to replace the old – such as oil – which are being depleted. In effect, we already possess large supplies of coal, of uranium, of gas, and even of oil. We have also identified other highly significant sources, such as those deriving from fast breeder reactor technology, the sun and controlled nuclear fusion. But now we must remember that given forecast demographic changes the overall level of energy consumption will be much higher than in the past, and that furthermore we must allow for factors concerning the security of supply. Above all, we must have to hand exploration and exploitation technologies that are economically viable, safe for man and for the environment, and acceptable to public opinion. This could require decades of research, development, demonstration and industrialisation, with complex systems analyses and colossal investment, all of which necessitates a coherent, long-term political strategy.

The role of technology and of innovation in exploiting energy sources is certainly no novelty: it is as old as man himself. Up to the middle years of this century technology and innovation were applied better to exploit energy resources which already existed naturally. The new energies, for example energy from nuclear fission, are the result of highly complex scientific technologies.

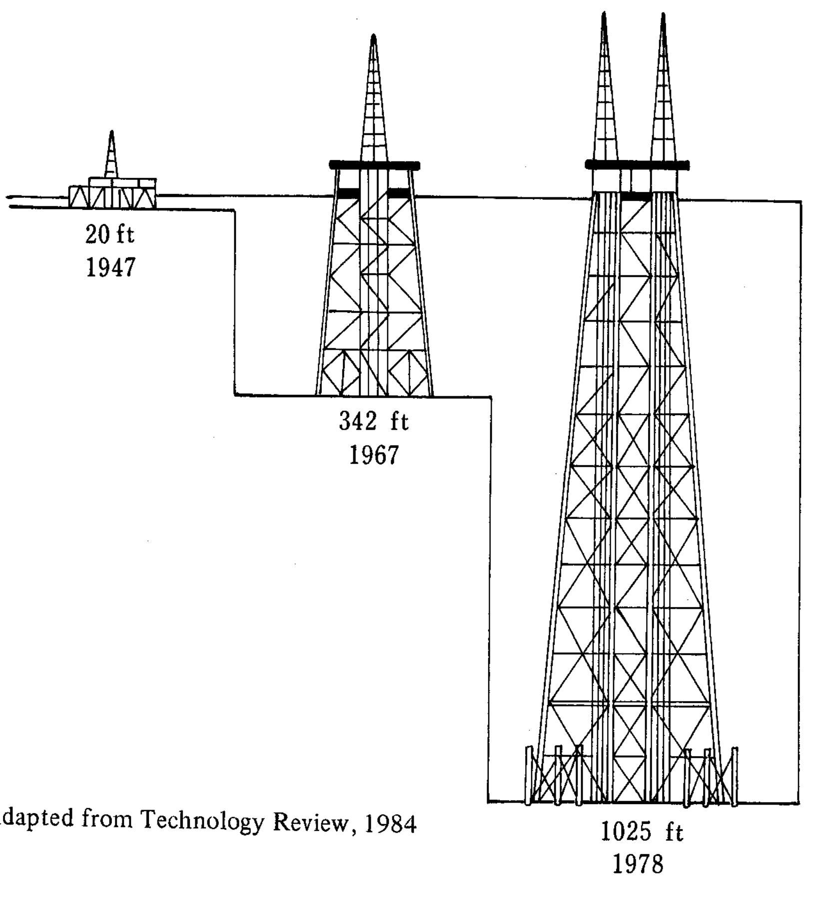
Uranium became an energy source only when man was able to understand the nature of matter and of elementary particles, and more specifically when the Chicago group led by Enrico Fermi demonstrated in 1942 the feasibility of exploiting controlled chain-reaction fission processes. One of the most interesting developments in the field concerns fast breeder reactors, which permit the energy output from the original uranium to be multiplied by a factor of fifty to sixty. The role of technology assumes far greater importance than that of the original energy raw material which, in terms of quantity and value, becomes entirely negligible. These reactors could help nuclear power become an important source of energy not only for the next decades, but for many centuries to come.

Solar photovoltaics developed when solid state physics explained the behaviour of electrons and of impurities in solids, and the interactions between matter and light. This enabled man to invent semiconductors and produce solar cells with the help of technologies for hyper-purification, doping, the growth of large crystals, and thin films. Again the production of energy derives from technology, since the sun is a free resource. Microwave relay of solar energy captured by photovoltaic cells on a space power plant in a geo-stationary orbit above the planet remains perhaps the most futuristic aspect of the solar option.

A very ambitious goal is that of achieving the production of energy by exploiting the technology of nuclear fusion, that is, reproducing in large industrial plants the conditions, in terms of temperature and material density, occurring under the surface of the sun, where at about one hundred million degrees centigrade nuclei of light atoms fuse together liberating enormous amounts of energy. The creation of such an environment is a highly challenging task. It is even more challenging to keep fusion reactions under control, thus converting the heat produced into steam and then into electricity. The raw material, whose value for this purpose is essentially nill, consists of hydrogen – from water – and lithium; transformation into energy is the result of a complex technology based on extremely advanced scientific concepts.

The ever-growing and pervasive role of technology, today touching every aspect of human life, also affects the exploitation of traditional sources— oil, gas, coal, geothermal, oil shales, tar sands and biomass. Given the depletion of the richest oil reserves, and in order to guarantee security of supply, we must now explore areas under more difficult and high cost conditions than in the past: increasingly smaller or more meagre deposits, offshore deposits in deeper and deeper water or in the open sea (figure 4), marginal and impervious parts of the globe, such as Alaska and perhaps soon the Antarctic. This increasingly calls for the development of highly complex specialised technologies – sea platforms, pipelines, secondary and tertiary

PRODUCTION PLATFORMS IN OPEN WATER IN THE GULF OF MEXICO



Adapted from Technology Review, 1984

Figure 4

recovery processes, cryo-resistant techniques. From the beginning of the energy crisis 'till now, proven oil reserves have not diminished, but their exploitation has certainly become more arduous.

Let us turn to the possible alternatives to oil. Natural gas is chiefly used by producer countries. A greater penetration of gas worldwide, which did not occur after the 1973 crisis (figure 5), would require the realisation on a massive scale of costly transportation systems – gas pipelines and LNG supertankers. The penetration of coal and the expansion of the international coal trade has been hampered not only by the difficult economic situation of the last few years, but also by financial, economic, environmental and technical problems, all of which were previously underestimated.

In its most conventional forms – steam or hot water which, under pressure, is forced out of fissures in the Earth's surface – geothermal energy is a rather modest source of energy production. The exploitation of deep, dry, hot rocks is a potentially significant option but it entails the development of new technologies.

The exploitation of tar sands and shale oil pertains to the broader problem of obtaining synfuels – liquid fuels able to substitute oil and its by-products – from unconventional sources which may otherwise remain unutilised. In addition to the two sources mentioned above, we can also cite syngas, very heavy crudes and cellulosic biomass. Complex technologies requiring sophisticated know-how in chemistry, physical chemistry, engineering, biochemistry and biology must be developed.

This rapid survey – even if we leave aside such potentially valuable sources as the wind, the waves, the tides and the ocean's heat gradients – indicates a broad range of options already or soon to be

PRIMARY SOURCES SHARE IN WORLD ENERGY CONSUMPTION
in %

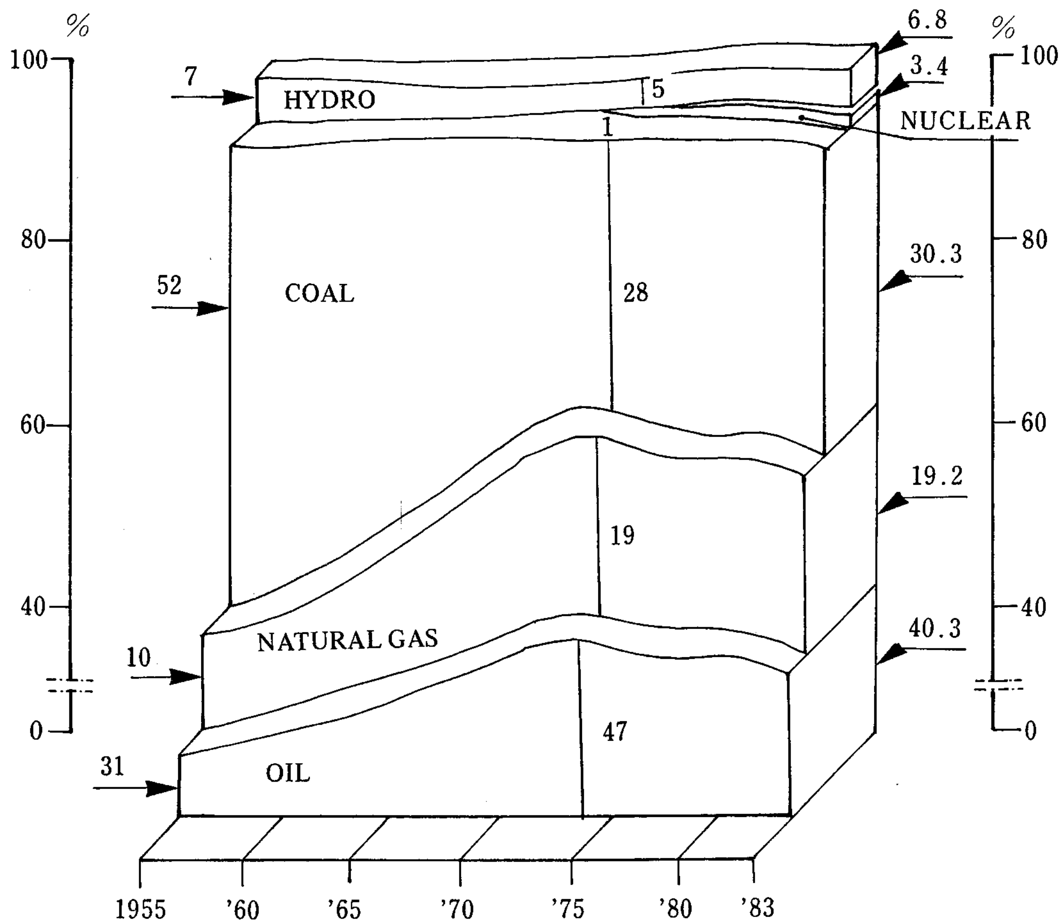


Figure 5

available. But this survey also reveals that to make these options operative significant new technologies must first be developed, requiring enormous investment and long years of hard work. In the past, the necessary technologies could be perfected gradually as penetration of the new source expanded. The sources emerging now as alternative options for the future are virtually dependent on the technologies which have invented them. Our traditional sources are no longer free from technical constraints, imposed by more arduous conditions. The new oil reserves are skimpier and harder to exploit; gas and coal must be transported long distances; extremely tough natural conditions – climatic and otherwise – must be faced; ecological and environmental factors must be considered a new priority, and so on.

Moreover, strategic decisions are conditioned by the instability of international relations: and there is no doubt at first also to potential destabilisation resulting from movements in the price of oil. Take the example of a strategic decision on a massive investment in coal import and utilisation by a consumer country. Who is to pay for all the necessary infrastructures? Is the producer or the consumer to assume the burden of investment and the attendant risk for the opening of mines, for transportation systems in producer countries, for ocean transport (or for land transport, as in the case of the projected coal pipeline from Poland to the countries of Western Europe) and for construction of the coal chain? (figures 6 and 7).

The picture of coal is further complicated by the intricacy of the relationship between conventional and novel uses of this fuel. On the one hand, massive investment in conventional solid-coal technologies already menaced by decreasing public acceptance could some day be threatened by the emergence of a competitively priced new technology (in this instance, coal liquefaction or gassification at the minehead. This suggests prudence in making major investment commitments in traditional technologies).Further, if any such commitments were to be made on a large scale, their very existence and the vested interests thus created would constitute a barrier to the commercial development of a new technology. A situation of deadlock could arise: major departures in new technology may appear prohibitively expensive, but a heavy programme of investment in revamped conventional sources (the example is solid-coal as opposed to liquefied or gassified coal) could prove equally problematic.

2.2 The Influence of Concern for the Environment

The problems surrounding the new energy sources and the use of conventional ones have today grown more difficult because of mounting demands for safety and for greater respect for the environment. It can be seen that negative environmental effects are no longer local; the phenomenon of pollution ignores national boundaries and involves the entire globe. Public opinion must be informed of the various options – including that of doing nothing, with consequent deterioration in the quality of life and the added long-term risk of impoverishment. This is why we urgently need to introduce eco-technologies in all sectors of activity – and especially in those concerning energy, given their major impact on the environment.

For instance, the side effects of coal are manifold. From mining to combustion, coal is a polluting substance, with effects which are not localized. Some effects, such as ashes and acid deposition, are with us now and can be controlled, at a cost. Carbon dioxide accumulation in the atmosphere is slow in developing and not yet fully understood. Given that this effect seems however irreversible, it is important that we improve our understanding of it through eco-climatic studies at the international level. Should these studies indicate that the environmental impact of carbon dioxide accumulation is undesirable, this would be a severe counter-indication to the continued burning of coal.

Oil is somewhat less offensive to the environment on a global scale, though it contributes to the carbon dioxide problem and has a role in acid deposition. However, marine pollution through tanker spills or well blowouts and, of course, direct effects through automobile exhausts, are substantial in the first instance and ubiquitous in the second.

So far, there has not been a major accident involving gas pipelines or liquefied gas transportation. A LNG supertanker has – at least in theory – an enormous explosive potential, in the range of one megaton of TNT. Loading and unloading facilities must be sited and managed with care.

The drawbacks of nuclear energy are too well known to need elaborate detail. Its development encounters great difficulties in a number of countries, not so much at the strictly technical level as due to a multitude of other factors. The foremost

COAL CHAIN

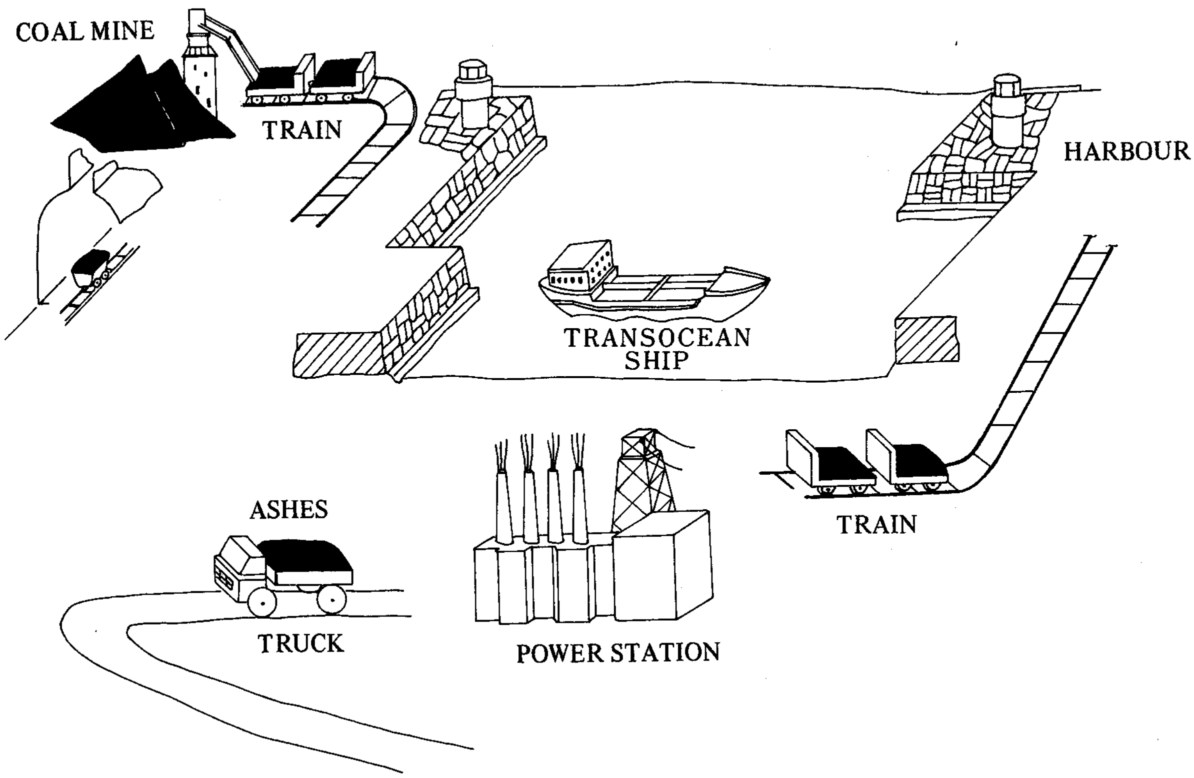


Figure 6

LIQUEFIED COAL CHAIN

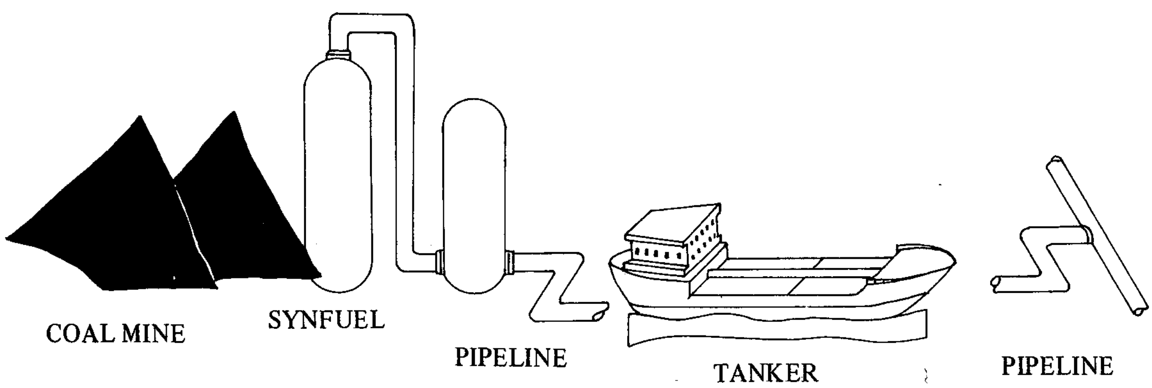


Figure 7

of these is public resistance to this energy source, based on fear of the risks that it involves and of their persistence over time, and on the great complexity of its management – not so much and only the plant, but the system as a whole: land management, accident management, the fuel cycle down to reprocessing of waste. There is also the separate, yet related, problem of nuclear weapons proliferation. Because of its high degree of centralisation, its capital intensity and the peculiar nature of its risks, the production of nuclear electricity has become the main target of radical fractions of society opposed to those hard technologies which they see as inevitably determining a centralised model of societal organisation.

The search for consensus is an almost universal feature of Western industrialised countries. Consensus becomes difficult to maintain with the occurrence of incidents generating much adverse publicity, even if these have not affected the health of the population. Unfortunately, the 1979 Three Mile Island accident in the United States and the continuing problems at Sellafield in the United Kingdom have created the impression of a certain difficulty in anticipating and managing emergencies. Public concern, coupled with the reduced growth in electricity demand given the economic recession, has led to a scaling-down of programmes. Cancellation of orders and prolongation of power station construction times is eroding one of the most advantageous aspects of the nuclear source: the competitive cost of electricity produced when compared to coal and still more so when compared to fuel oil. Nuclear's economic advantage can only continue if there is a sufficiently large and dependable programme for its development, so that the sizeable investment in the industry, in safety systems and in the search for improvements, can be justified.

Nuclear energy represents virtually a domestic source, the importation of raw material, uranium, being a minimal fraction of the whole cost. The producer of the electricity is in essence the associated technology, so that countries developing these technologies can be said to possess the energy source. With fast breeder technology other problems arise concerning the plant and the fuel. Plutonium is toxic. It can also be used for the construction of nuclear weapons. Yet by utilising the plutonium produced by the reprocessing of irradiated fuel from the fission cycle, breeder technology multiplies the energy content of uranium, and puts to peaceful use what is at present a potentially dangerous waste product.

There are also doubts about nuclear fusion, especially about the behaviour of neutron irradiated materials, which could cause problems beyond the range of our present knowledge, not only to solve but also fully to identify.

The main problem blocking the widespread exploitation of solar energy remains the low energy density of radiation which reaches the Earth and, therefore, the vast area required for a power plant. This problem assumes particular importance in densely populated and economically advanced areas, acting in competition with other claims on the land. A further environmental impact is the effect on the microclimate.

2.3 An Up-Hill Transition

There are many reasons, therefore, why we can say that our present situation is one of "up-hill" transition. We must turn our backs on the easy search for single alternatives, the down-hill option if you will, of an almost automatic switching from one source to a cheaper, more convenient, easier source: from wood to coal, from coal to oil. The up-hill transition now underway depends on conscious choice, on the application of political and economic will. We must analyse our needs, and apply science and technology to confront them, with no guarantee of sure or rapid success. It is likely to be a long, hard road. Our problems are compounded by past mistakes, by ingrained habits. For many years there was a general belief that the down-hill path represented by an energy system based on cheap oil not only was the right one, but would continue to serve us. Our production systems, our distribution networks, all our infrastructures, were modelled in this mould. Thus we are facing the future with a simplified system which must be adapted to a very different energy situation and to the flexible needs of a post-industrial, information-based society.

Can we not hope to return to another down-hill path? I say we cannot. Just as we cannot resolve the problem of Third World urbanisation by simply returning the citizens of Mexico City to the countryside, or that of world hunger with good intentions and increased food aid, so we can no longer think of relying on a single energy solution to our present and future difficulties.

Neither politicians nor economists, nor indeed the man in the street, have fully understood all the implications of the fact that the energy transition is inexorably up-hill. The continuity of supply following the 1973 crisis, the present period of potential oversupply not to say glut, and the steadiness, or even reduction, in real terms of the price of crude oil has led many people to hope that the need for its substitution as the main source could be avoided. But let us remind ourselves that every event which could discourage or postpone the search for effective solutions to the energy problem is dangerous. In this context, the OPEC crisis and the consequent fall in the price of crude oil act as a dissuading factor to energy decisions requiring high investment and/or lengthy and onerous research.

The fact remains, however, that our energy-based economies will have to change radically in the Twenty-First Century. Currently predominating energy sources – oil, natural gas, and coal – are exhaustible. Coal has a long term horizon, measurable in centuries, but oil and gas could fail us in less than one century, and become very expensive long before that. Moreover, oil's lopsided geographical distribution, with the major known reserves in the socially and politically unstable Middle East, presents a continuous threat to world peace. The strategic dimension of natural gas lies in the fact that the main exporter – both to Western Europe and perhaps to Japan – would be the Soviet Union, thus creating the basis for another energy dependence which could prove politically unwise. Thus while all the available sources suffer from one or more handicaps, the options provided by new energies (typical is the case of nuclear fusion) involve very long time scales, very high costs and in some cases considerable difficulties.

It follows that we would be wrong in abandoning any source of energy prematurely, for we need to take out insurance, keeping as many options open as we can, being limited in our choice only by the financial and technical resources at our disposal. The diversification principle is a useful guide not only in matters of different sources, but also in geographic origin. As energy importers, Japan and Italy are now painfully aware of the penalties that derive from excessive reliance on any one exporter, country or region. No single source or exporting country can in the future be regarded as absolutely dependable, or entirely safe. We must build into our thinking the possibility that hard times can well come about in the energy field and be prepared for them.

In the past, we greatly underestimated the complexity of possible solutions and for this reason we now have no set of abundant, environmentally benign, affordable energy options. There are many solutions but they all call for compromise. The economist's old saying that "There is no free lunch" is one of the few verities that we can all agree on. Not only do we need compromise, to be reached largely in the social and political arenas, but also it is necessary that any identified solution should be carefully articulated. What we leave to chance often comes to plague us later.

3. ENERGY SOURCES AND CONSUMPTION

Up till now I have discussed the energy problem in terms of supply, but the demand side also has to be examined, in both its qualitative and quantitative aspects. The various energy sources and the various carriers are not, in fact, equivalent or interchangeable.

3.1 The Industrialised World

The energy intensity of GNP is falling steadily in industrialised countries. It has been falling in the United States for over half a century. Many industrial processes which are heavy energy users are relocating away from the industrialised world, toward the new industrial countries – the so-termed NICs – and the Third World. This is true not only for ferrous and non-ferrous metals, but also for petrochemicals and other energy intensive products. Furthermore, basic industries which are large energy users, as well as many industries producing mass consumer goods, have reached saturation in industrialised countries with market trends dominated by replacement demand rather than increased market share. At the same time, the new, low energy-intensive technologies are gaining ground in industry and services. Production is increasingly "dematerialised", that is, depending more and more on technological and software inputs than on raw materials or other goods. These areas of actual and predicted major growth for the industrialised world – the next Kondratieff upswing's likely carriers, if you will – such as informatics, robotics, the biotechnologies, new materials – all are low energy-intensive, low raw materials-intensive, and they will completely transform our economic system.

They also show what enormous scope there is for reducing the requirements of raw materials and of energy resources and for containing man's impact on his environment, while maintaining the same level of GNP. The tendency of wealthy societies to improve the quality of goods rather than their quantity – that is, improving them in terms of technical performance, esthetics, functionality, personalisation – and to supply goods and services increasingly of a non-material kind relating to education, culture, health and leisure, must be kept in mind.

This is why, quite apart from energy conservation policies, energy consumption remained stationary or fell slightly in Western industrialised countries in the decade following the 1973 energy crisis (figure 8). The change in the trend of consumption that occurred after 1973 must be attributed to a profound economic, structural and social transformation, not merely to the energy crisis. There are structural changes in societal activities underway which are progressively leading us toward lower energy use. For these reasons I believe that energy consumption in the West is not destined to increase in the immediate future, unless to some very slight extent. Such trends

ENERGY CONSUMPTION IN INDUSTRALISED COUNTRIES, 1960 – 1983
million toe

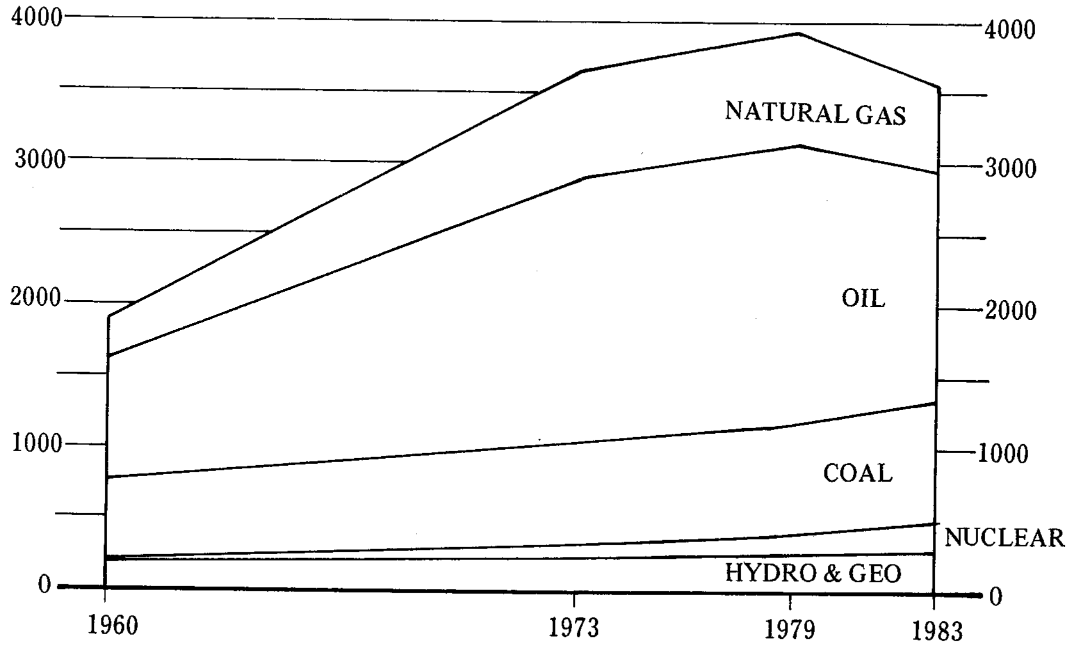


Figure 8

ENERGY CONSUMPTION IN WESTERN INDUSTRIALISED COUNTRIES*
million toe

	1960	1973	1979	1982	1983	Yearly Average Growth Rates in the Periods: 60-73	73-79	79-83
Oil	764	1955	1985	1625	1592	+7.5%	+ 0.3%	– 5.4%
Coal	663	681	739	783	786	+0.2%	+ 1.5%	+ 1.5%
Natural Gas	318	753	784	722	701	+6.8%	+ 0.7%	– 2.7%
Hydro-Geo	158	236	271	282	291	+3.1%	+ 2.3%	+ 1.8%
Nuclear	1	44	133	184	200	–	+20.2%	+10.7%
TOTAL	1904	3669	3912	3596	3570	+5.2%	+ 1.1%	– 2.3%
Yearly Average Growth Rates of Real GDP						+5.1%	+ 2.7%	+ 1.0%

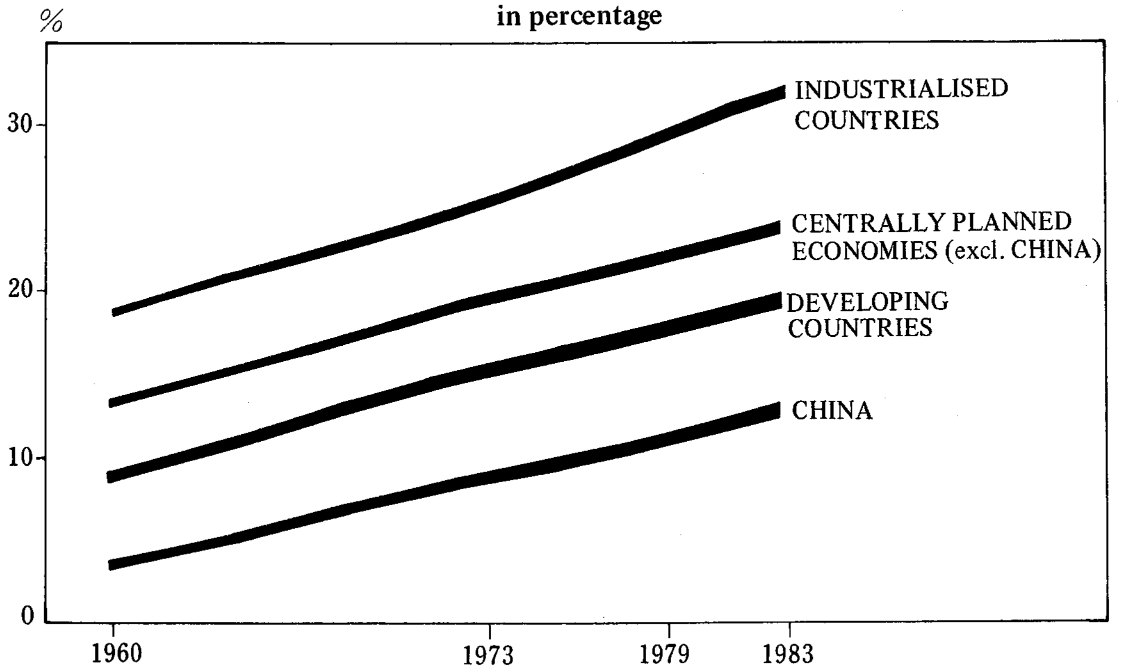
* Not including U.S.S.R. and Eastern Europe

SOURCES: ENEA figures based on data from BP Statistical Review – OECD Energy Balances et al.

allow us to appreciate how new eco-technologies are entering the world's economic system. A base aim of eco-technology is to make an ever more pervasive use of all the technological options; that is, not only to reverse pollution, but also to create an efficient, secure and harmonious environment for mankind today and for future generations.

There is another aspect of energy demand which must be discussed, and that is the growing penetration of electricity (figure 9). The electricity intensity of GDP has been invariably increasing in all countries since the beginning of electrification

ELECTRICITY PENETRATION*
in percentage



* In terms of primary sources, assuming 1 KWh=0, 22 Koe

Figure 9

WORLD ELECTRICITY PRODUCTION, 1960 – 1983
billion KWh

		1960	1973	1979	1983	Yearly Average Growth Rates in the Periods: 60-73	73-79	79-83
Industrialised Countries	West. Europe	432	1396	1726	1797	+ 9.4%	+ 3.6%	+ 1.0%
	U.S.A.	892	2000	2360	2426	+ 6.4%	+ 2.8%	+ 0.8%
	Japan	116	470	590	600	+11.3%	+ 3.9%	+ 0.7%
	Other Countries	144	350	431	535	+ 7.1%	+ 3.5%	+ 5.5%
	Total	1584	4212	5107	5358	+ 7.8%	+ 3.3%	+ 1.2%
Centrally Planned Economies	U.S.S.R.	292	915	1240	1358	+ 9.2%	+ 5.2%	+ 2.3%
	Eastern Europe	114	301	404	430	+ 7.8%	+ 5.0%	+ 1.6%
	China	40	150	282	324	+ 7.0%	+11.1%	+ 3.5%
	Total	446	1336	1924	2112	+ 9.0%	+ 5.9%	+ 2.4%
Develop. Countries	OPEC Countries	–	50	93	137	+13.6%#	+10.9%	+10.2%
	Other Countries	–	419	686	893	+ 9.6%#	+ 8.6%	+ 6.7%
	Total	–	469	779	1030	+10.0%#	+ 8.8%	+ 7.5%
	TOTAL WORLD	–	6017	7810	8500	–	+ 4.4%	+ 2.1%

Data 1970–1973

SOURCES: ENEA figures based on data from OECD Energy Balances, UN-Yearbook Energy Statistics et al.

a century ago, as part of the attainment of relatively advanced degrees of industrial development, of the consequent increase in well-being, of the demand for and development of public services – light, transport – and domestic services. Even during the early stages of growth, represented today by lesser developed countries and in the past by the present industrial countries, growth in electricity consumption (with only very few exceptions due to particular local circumstances) has been considerably greater thän that in energy consumption in general. This is true even though during the early stages of economic growth overall energy consumption tends already to increase considerably faster than DGP.

The unique position of electricity relative to energy as a whole is further emphasised by developments subsequent to the energy crises of the 'seventies. At a time of rising energy prices, electricity consumption continued to grow faster than GDP in almost all countries, while overall energy consumption remained at a standstill or even declined. Figures for several industrialised countries (the United States, Japan, the Federal Republic of Germany, France, the United Kingdom, Italy) show a substantial decoupling of the growth of GDP and the consumption of total energy, but a close parallel between the trends of GDP and electricity consumption. As for the future, I am persuaded that in real terms the price of electricity in most countries will tend to decline, so strengthening this trend. Further reinforcement comes from the unique advantages of the electric vector: its versatility of use; its easily controllable nature; its relative safety in end uses and its ability alone to supply certain specific essential requirements.

On the supply side, electricity is attractive because it can be produced from many different sources: hydro-power, nuclear, fossil fuel, geothermal steam, and tomorrow also solar, and nuclear fusion. This is a matter of strategic significance, as it favours the possibility of geopolitical diversification of energy supplies and recourse to technologies that have substantially no requirement for prime energy sources. Even the new decentralised technologies – urban and agricultural wastes, biomass, wind, photovoltaic solar – can conveniently produce electricity and, if desired, be connected to large scale distribution grids. These different technologies for electricity production and transmission have many elements in common, another factor that makes the electricity vector extremely attractive and leads to greater simplicity through unification of supply infrastructures. But perhaps the most critical feature in determining the level of penetration of the electric vector lies in its convenience of transport and distribution, from producers to consumers. In making his energy decisions, the consumer give gréater consideration to available quantity, quality, ease of use and high yield of the energy forms with which he comes into direct contact, and such considerations frequently override what price differentials alone might suggest.

The process of penetration by electricity is therefore destined to continue. I have mentioned previously the emerging sectors linked to the new technologies, and how the whole economic and social structure of industrialised countries is being transformed. Modern societies require a high degree of reliability, controlled and flexible production processes, decentralisation of production and of decision-making. Electricity is the energy vector which best satisfies these conditions.

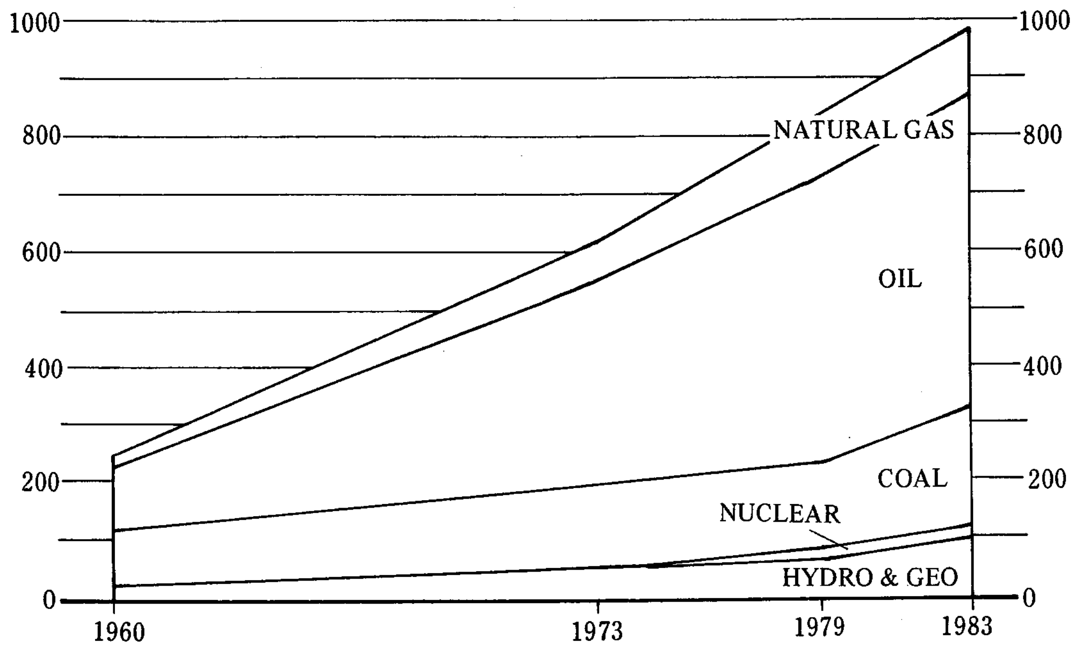
3.2 Less Developed Countries

The energy demand pattern is totally different in developing countries where the consumption of energy has continued to grow even after the energy crisis (figure 10). Their need to develop and to industralise, to produce more, to create infrastructures (roads, railways, ports and cities, as well as communication systems, education, health and other basic services) – all this with a still rapidly rising population – leads to the forecast of a sustained increase in energy consumption projected into the foreseeable future.

It is to be hoped that the Third World can develop and industralise without following too closely the road already trodden by our own socieities, avoiding, as far as possible, excessive and uncontrolled centralisation of production, gigantism and the building up of huge megalopoli. It is clear, that if people in the Third World are to have at their command those goods and services nowadays considered primary, their countries will have to produce more, and to build infrastructures which at present are lacking. Information technologies, flexible production systems and others which permit advantages of small scale, decentralised technologies, are emerging. These could facilitate a "softer" type of development.

Nevertheless, the Third World needs the support of countries already industrialised, and this is in their mutual interests. The North requires the raw materials of the South and increasingly also its

ENERGY CONSUMPTION IN DEVELOPING COUNTRIES #, 1960–1983
million toe



Not including China

Figure 10

ENERGY CONSUMPTION IN DEVELOPING COUNTRIES *
million toe

	1960	1973	1979	1982	1983	Yearly Average Growth Rates in the Periods: 60-73	73-79	79-83
Oil	130	375	503	549	549	+ 8.5%	+5.0%	+ 2.2%
Coal	80	117	173	200	213	+ 3.0%	+6.7%	+ 5.3%
Natural Gas	15	66	109	135	138	+12.1%	+8.7%	+ 6.1%
Hydro-Geo	20	48	72	86	91	+ 7.0%	+7.0%	+ 6.0%
Nuclear	–	1	3	6	7	–	–	+23.6%
TOTAL	245	607	860	976	998	+ 7.2%	+6.0%	+ 3.8%
Yearly Average Growth Rates of Real GDP						+ 6.5%	+5.2%	+ 4.0%

* Not including China

SOURCES: ENEA figures based on data from BP Statistical Review.

semi-manufactured and manufactured products. The South is becoming an outlet for the North's industrial products (figure 11). These now account for 27% of the industrialised countries' exports.

In our world today, aid to development policies are not a zero-sum game: everyone can win, everyone can benefit. Here Japan's strategy appears to me to be quite appropriate, leading to an increasing interdependence whilst rejecting a neo-colonialist rapport. This implies a new way of conceiving the utilisation and transformation of the natural resources of the Third World, the transfer of industries which are no longer economically viable for a rich and densely populated country like Japan, plus substantial technological support for development.

EXPORT STATISTICS – WESTERN INDUSTRIALISED COUNTRIES *

	1974	1979	1983
Total exports			
Industrialised countries **	368.4	1052.8	1139.9
Exports to LDCs **	133.7	272.8	303.2
GNP, industrialised countries**	3568.5	6727.3	7728.5
Total exports/GNP percent	10.3	15.6	14.7
Exports to LDCs/GNP percent	3.7	4.1	3.9
Exports to LDCs/total exports percent	36	26	27

* OECD member states, excluding Greece, Turkey, Portugal
** in billions US dollars current

Figure 11

Italy, too, has in recent years greatly increased its support to the developing world. Between 1979 and 1983 in fact, Italian allocations to governmental development assistance increased from 0.08% of the GDP to 0.34%, a figure comparable to that of Japan. Total funds for 1981-1984 are about 5 billion dollars, covering agriculture, health, energy, training and industry.

The role of energy is of prime importance in the pattern of Third World development. Developing countries do require large scale energy structures for the exploitation of local resources and their downstream processing; the accelerating relocation of basic energy-consuming industries in developing countries; industrial manufacturing for local markets (and for export); and also for their cities. They also need a decentralised energy system, suitable for the multiplicity of rural areas which need to be assured of an adequate standard of living to halt the drift towards chaotic and uncontrollable urbanisation.

For most countries starting out on industrialisation, the first set of requirements necessitates the development of energy structures typical of the industralised world, specifically electrical grids and power stations. Where practicable, these should be supplied from hydro-electric resources. Fuel oil for electricity generation is no longer favoured in industralised countries, for cost and strategic reasons, nor can it have an important role in the developing world, except in the oil-rich producing countries. Coal will be more important, even though it will bring its own transport and environmental problems. Nuclear power is a source which presents a number of difficulties for small or developing countries, both because of the complexity of the technology and management of the system, and because commercially sized nuclear power stations are relatively large, over 600 MW, and now typically 900-1000-1200 MW. Considerably smaller, modular, nuclear reactors of around 200 MW capacity are at the study stage.

It is probable that an increasing number of Third World countries will be able to acquire the technological know-how to manage them.

The crucial problem for rural areas, hitherto reliant on non-commercial traditional energy sources, is to make energy available on site in a decentralised way, using a variety of sources, both conventional and renewable. These last are particularly promising: biogas generators, mini-hydro systems, wind and sun. If means can be found to make energy available in its most flexible form – electricity – for illumination, pumping, refrigeration, mechanical energy for craftsmen, local industries and telecommunications, so much the better.

Electricity distribution through grid networks may remain a distant goal, for financial, technical and practical reasons, but electric power can be provided at the village level with the introduction, for example, of photovoltaic units which require minimal maintenance. Such decentralised systems can be most helpful only if a high degree of technology transfer, for operation, maintenance and eventually production, can be achieved. The failure of certain kinds of technology transfers – an evident example is the diesel generator – demonstrates that the best technology is the one most easily absorbed by the local culture. This technology need not be the least sophisticated nor the least novel: photovoltaic energy could, in fact, have the widest and most lasting application in these countries. I believe strongly in the blending process, the blending of traditional technologies with the emerging ones, to stimulate Third World development, vital if we wish to return to sound economic growth. Rural electrification is a prime example of this blending.

4. LOOKING TOWARD THE TWENTY-FIRST CENTURY

In 1985, the Twenty-First Century will be closer to us in time than man's first landing on the moon. The next century's energy scenario will be profoundly different from that in which we are now living. The global transformation of the energy system is intrinsically slow. But the process is underway and is moving toward clearly identifiable goals.

We are dealing primarily with quantitative changes which will radically alter the geographical distribution of consumption. In 1973, OECD countries accounted for 52% of world consumption and the developing countries (including China) barely 24%. By the end of this century these figures will be about 40-45% and a little under 35%, respectively. In fifty years, the relationship between these two geographical areas will be reversed, with the older industralised countries probably accounting for less than 30% of energy consumption and today's developing countries for about 50%.

Even if this result is achieved through an overall growth. in consumption – primarily in the developing countries – tomorrow's inhabitants of the world will use very much less energy per capita than ourselves. Energy requirements will be radically different; ways of approaching the energy issue will have to change. Information technologies require so small an investment of energy, yet have an extraordianry capacity to influence the efficiency of economic activities, reducing energy consumption and waste. Energy and information, as we see, are strictly interconnected.

The changes will be even more conspicuous in qualitative terms. The penetration of electrical energy will continue. I believe it is destined to rise to above 50% of primary energy consumed. There will be an enormous development of energy services, especially in advanced countries, in order better to satisfy the requirements of an ultra complex, ever richer, highly automated, but flexible and adaptive, post-industrial society.

Flexibility will be ensured by a mixture of factors extending from a wide variety of sources available: varied technologies, and a balance between centralised and decentralised systems; by the use of highly versatile and efficient final vectors; and by recourse to appropriate services. But perhaps the most interesting aspect of the Twenty-First Century energy system will be its increasing pluralism: not only given the wide range of old and new sources available, but also because each of these will have substitutes with similar utilisation characteristics.

Another fundamental aspect will be the role played by technologies which invent resources. These will allow a country to make the choices most appropriate to its conventional reserves, to cost, and to its need for security of supply and international interdependences. Countries poor in resources will be able significantly to reduce their dependence on foreign suppliers, and also to contain risks. The role of these technologies is thus destined to grow.

The world energy system is not only destined to become more efficient and safer in terms of the service supplied, but also much more attentive to the health of the population and to the environment through the development of energy ecotechnologies. These will have a far from negligible impact on the selection of technologies, on analysis of costs, on the determination of the structure of the energy system itself. The need to reduce the environmental consequences of energy production could, in the long run, make it advisable to restrict the use of sources which are burnt to release CO_2 into the atmosphere.

With the advent of new energy sources, the fossil fuels – coal, gas, oil – will decline in terms of relative importance within the global energy scenario. This is good news for our two countries – Japan and Italy suffer greatly from the burden imposed by their lack of these energy sources. Our research efforts must be dedicated specifically toward the achievement of greater energy independence. This means, for example, the continuing use of nuclear technologies. Nuclear power may well be able to settle at a level comparable to that of oil and gas, or perhaps even higher still due to the extraordinary importance of electricity. The Twenty-First Century is also destined to see the effective take-off of renewable sources – especially solar--of non-conventional natural sources, such as shales and tar-sands, and of nuclear fusion.

5. CONCLUSION

A greater availability of energy and of other resources, and a more equitable distribution of them, is the prospect before us. The waste of resources, both material and human, which characterised much of Twentieth Century development can no longer be tolerated. Technological advance – the eco-technologies which are going to help us out of our current impasse – will help us to unify the world, bringing the developing countries nearer to that prosperity which we in the industrialised nations have since the war come to regard as our due.

Throughout its history, mankind has had to struggle against adversity, to struggle for its very survival. Enormous effort has had to be dedicated to ensuring the satisfaction of basic needs. The industrial revolution started a process by which the average man no longer spent most of his time on the immediate concerns of food, shelter, personal defence, but rather could start accumulating durable goods and, more recently still, rewarding his labours with adequate leisure. The technological advances, the birth of which we are witnessing today, mark another major shift. The mere accumulation of goods can no longer satisfy us.

A society based on possessions – be they either necessary or superfluous – is giving way to a society liberated from such needs. Our responsibility towards future generations is to ensure that this passage leads to a freer society, a creative society, where that potential which each individual uniquely and inherently possesses can emerge, using the advances of science and technology to create a better life, a better environment for each man, each family, each nation. With Nature in harmony with man's calls upon its abundant resources, and man in harmony with himself, the world can look forward with confidence to a future of prosperity even in the absence of quantitative growth; a future permitting the satisfaction of our real needs as people; peace and security, personal expression, the raising of our children, and the interdevelopment of our cultures.