clude that our trade relations with the comecon countries, in spite of the bilateral relations, in spite of our endeavours to get included in the multilateral system of payment, have remained identical to those with the west European capitalist countries.

PREREQUISITES FOR AN EFFICIENT SUBSTITUTION FOR CRUDE OIL

THE GENERAL PROBLEM

The reserves of natural resources vital to our industrialized civilization, namely crude oil, are liable to run dry in the near future[1]). This holds true even if and optimum utilization of oil were to be conducted by economizing and conservation measures because the lifetime of the existing oil reserves would thus be extended by only a few years on perhaps by just a decade; the real problem, however, would not be solved. Thus, there is only one way out: oil substitution by the enforced development of alternative energy sources.

The urgency of such an undertanking may be shown by a deteriorating global economic development which presents the following problems:

— increasing imbalances of international payments by consumer countries due to rising oil prices;

— accelerated inflation in all world economies accompanied by a diminished economic growth in consumer countries;

— inefficient economic policy countermeasures to fight inflation, balance of payments deficits and unemployment.

The awareness of such problems has already induced the western consumer countries to search for solutions. Although the countries of the European Communities have not agreed on a joint energy concept as yet, initial steps towards self-sufficiency in energy supply have been taken in the form of Project Independence in the USA and the Sunshine Project in Japan. The declared aims of Project Independence were originally expected to be achieved by 1980, those of the Sunshine Project roughly by 2000[2]).

Even if energy experts deem it huite impossible for Project Indepen dence to be completed in such short time[3]), the decisive question still is: how can these projects be realized at all? Or, more precisely: how can an efficient substitution for crude oil be brought about?

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[1]) If oil production were maintained at the 1975 level, world oil reserves known to date would be depleted within 33 years.

(cf. ESSO, Oeldorado 75, Hamburg, 15. March 1976)

[2]) Cf. New energy sources will be developed in »Sunshine Project«. The Japan Economic Journal, Tokyo, No. 571, December 4, 1973.

[3]) Cf. Umformung des Project Independence, Petroleum Economist, London, No. 11, November 1974; and Gannon, J. P.: Energy Experts warn of costs and dangers in U.S. Independence, The Wall Street Journal, New York, No. 45, March 6, 1974.

[4]) Cf. among others: OECD, Energy Prospects to 1985: An Assessment of Long-term Energy Development and Related Policies, Vol. I and II, Paris, 1974; and Mandel, H.: Im Spannungsfeld der Energiepolitik, Süddeutsche Zeitung, München, No. 104, May 6. 1974.

The striking point about this is that most experts[4]) rely strongly on already — risen and rising oil prices. They are of the opinion that if oil prices should increase further, the development of alternative energy sources will be pushed on. This economic thesis is based on the fact that the high consumer price of energy will gear the users to a more economical consumption. At the same time, the outlooks for profit-making are bound to be so attractive as to stimulate energy producers and suppliers towards greater investment activities. This coincidence of both trends, the lower consumption and the expanding supplies, should enable domestic energy production to grow to such an extent that nearly total self-sufficiency will be achieved by 1985. In other words, rising oil prices will inevitably lead to a substitution for oil! This assertion is the principal subject of the following analysis.

The possible impacts of rising oil prices on substitution cannot be denied. However, they may not fulfill all expectations. The great efforts invested in the technological development of alternative energy sources could, just the same, be futile if these energy sources are not utilized at all. For an efficient substitution for oil cannot be conducted without complying with a number of requirements which are closely related to one another; partial aims only lead to dilemmas!

Therefore, the objective of this paper is to describe and analyze the most important components essential to conducting an efficient substitution for crude oil.

THE LIMITED ROLE OF INCREASING OIL PRICES IN THE SUBSTITUTION PROCESS

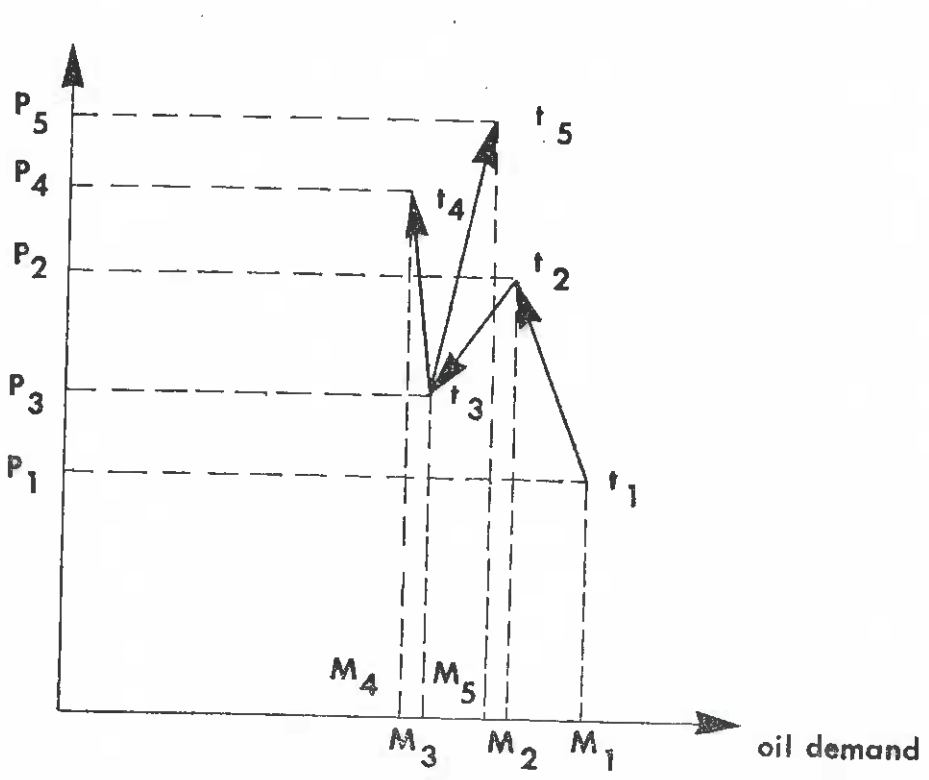
The argument often heard about rising oil prices causing a substitution for crude oil by other energy sources may be true in microeconomic terms if companies, on account of cost comparisons, prefer this or that energy source. However, in overall economic terms, this can be maintained only to a certain extent.

The opinion that rising oil prices will accelerate substitution is not even realistic in the case of a fully-functioning market economy which serves as a basis assumption. If oil prices increase, normaly the demand for crude oil would sink, at least as long as the possibility of substitution exists. Decreasing prices influence the substitution process and, at the same time, energy consumption rises so that oil prices, in the long run, will fluctuate cyclically with an upward tendency.

Demand elasticity at the time t_1 is, in the short run, relatively low. Thus, an increase of oil price from P_1 to P_2 results only in an insignificant reduction of oil demand from M_1 to M_2. At the time t_2, the process of substitution commences, leading to a reduction of demand in spite of the lower oil prices at t_3. Since the possibilities of substitution are, for the time being, exhausted at t_3, the demand again becomes huite unelastic with respect to price fluctuations; the price of oil may be set up to P_4 without bearing upon demand too much, and/or the upturn of energy demand brought about by economic growth will raise both oil sales from M_4 to M_5 as well as prices.

(P_5). In any case, the development traced out above will start anew from this constellation t_4/t_5 but at a higher price level.

The extent to which the substitution for crude oil by other energy sources is feasible depends primarily on the answers to the following questions:



— When will the substitution be possible?
— Will the resources required for crude oil substitution be adequate in quality as well as quantity?
— What will the price of this energy substitute be?
— To what extent will substitution be detrimental to the environment and how high will the eventual social costs be?

However, it must be pointed out beforehand that an efficient substitution for crude oil can only be ensured if these substitutes are sufficiently available, both in quantity and quality. In any case, prior to this, the closely interrelated economical, technological, and ecological problems must be solved. A favourable compromise of solutions will require much time; especially since there still exist many uncertainties about the interdependencies between the relevant problems.

THE SIGNIFICANCE OF TIMING

Nonetheless, crude oil can only be substituted if exchangeable energy sources are available. However, should the amount of such substitutes be insufficient, it will be quite impossible to conduct an efficient substitution. Substitution would then have to be postponed.

The possibility of intensifying the development of alternative energy sources depends mainly on the extent of research efforts which, in turn, is determined by economic factors[5]). Attempts to accelerate the substitution process by applying still not mature technologies may cause difficulties later on[6]). In any case, the necessary development work on alternative energy sources will require some time, depending on the difficulties involved, even if financial means are available. Furthermore, it may be affected by:

— additional research work on improving the environmental effects of energy sources; and
— outstanding large-scale operation[7]) of new energy sources.

QUANTITATIVE AND QUALITATIVE AVAILABILITY OF CRUDE OIL SUBSTITUTES

In considering the possibilities of substituting crude oil, it is wise to distinguish between qualitative and quantitative substitution. Qualitative limitations for substituting crude oil arise from the fact that crude oil is not only an energy source but also serves as a raw material for major industrial branches.

For example, of the available alternatives for substitution, nuclear energy may replace only one derivative of crude oil, that is heating oil for producing thermal and electric energy, whereas tar sand, shale, coal and natural gas may substitute crude oil qualitatively as well.

Although a transformation of organic substances into synthetic oil and gas may be achieved through applying electric energy, whereby both a quantitative and qualitative substitution for crude oil is demonstrated this does not alter the fact that electric energy itself cannot replace crude oil in quality. Therefore, an efficient substitution for crude oil implies sufficient quality and quantity.

POTENTIAL ECONOMIC FACTORS

Rising oil prices have only a limited effect on substitution — at best in microeconomic terms, as already mentioned above. In an overall economic light, an efficient substitution for crude oil must ultimately meet the following requirement: the development of crude oil substitutes in sufficient number, their prices being equivalent to those of crude oil[8]).

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[5]) For instance, insufficient investments resulting from lacking finance, conflicting targets in economic policy, etc.

[6]) For example, if atomic energy should serve this purpose, the building of conventional type reactors must be intensified. But since construction works for nuclear energy plants usually require six to ten years and electricity consumption may, in the meantime, double, the production capacity of nuclear energy plants draughted at the beginning will only cover half the required amount at the time of completion. Therefore, this shows that there is a need for intensified building of conventional nuclear energy plants.

If, however, the building of nuclear energy plants is inevitable and overhasty, large sums of money will be wasted on applying not fully developed technologies. The social costs arising later on will not only be a result of deficient technological development, but also of environmental pollution due to the application of nuclear energy.

[7]) It does not suffice if prototypes of alternative energy sources prove to be successful only in laboratories. They must be tested by large-scale operations.

[8]) If a country uses even costly energy derived from domestic resources it is still liable, for example, to suffer balance of payments deficits — due to its worsening international trade position as well as to if the same country would import expensive crude oil.

Theoretically, the following situations may arise:
Description of various substitution possibilities.

substitute energy volume	price	description of substitution process
sufficient	higher than oil price	no substitution — oil prices may still rise until they reach the price of the substitutes
insufficient	higher than oil price	no substitution — oil prices may rise further
insufficient	lower than oil price	no substitution — the prices of substitute energy approach oil prices
sufficient	lower than or equal to oil price	total substitution of crude oil or oil price falls

A fast development of alternative energy sources, by which a high standard of self-sufficiency may be attained, requires huge investments. For example, according to the computations of the Federal Energy Administration in America[9]). Project Independence will involve investments amounting to 450 to 700 billion US Dollars during the period 1970 through 1985; in comparison, the Apollo Project cost only 24 billion US Dollars.[10])

The high investment costs for achieving self-sufficiency in oil and energy supply give rise to the problem of financing these large amounts of money. Furthermore, the intertemporal distribution of the burden[11]) is an issue to be discussed. An example may illustrate this: although the USA might finance their short-termed Project Independence through tax revenues, putting up with ever-growing inflationary rates, there is no justification to adopt similar financing methods for the Sunshine Project in Japan, which will provide benefits only after the year 2000.

In other words: from a social point of view it seems unjust to burden a generation which neither gained in times of cheap energy nor will benefit from the future. In economic policy, such considerations might lead to conflicting objectives which are aggravated further by existing economic interrelationships. The extent of such incompatibilities must be included in economic assessments[12]). Thus, rising oil prices is only one of a number of economic factor wich should be studied when developing alternative energy sources.

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[9]) Cf. Financing Project Independence: Tough Questions Demand Answers, in: Commerce Today, Washington, No. 25, September 16, 1974.

[10]) Cf. Energieautarkie bis 1980 nicht erreichbar, in: Finanz und Wirtschaft, Zürich, No. 31, April 24, 1974.

[11]) The problem of intertemporal distribution of costs has been discussed extensively in specialized literature and various theories have been developed. A general survey is given by Gandenberger, D.: Ist es möglich, durch die Aufnahme von öffentlichem Kredit die Last einer öffentlichen Ausgabe in die Zukunft zu verschieben? in: Jahrbuch für Sozialwissenschaften, Göttingen 1970, Bd. 21, Heft 2, S. 87—98.

[12]) The following statement can be found in a reserarch study by Packer, A.: Living with oil at $ 10 per barrel, in: Challenge, Jan./Febr. 1975: »If the upset in international markets leads only to a worldwide two-year zero growth recession, it will be as costly as four years of the »extra« oil payments«.

Degree of environmental deterioration caused by various primary energy sources[1])

primary energy sources	pollution of air	pollution of water	noise	waste volume	waste costs	heat	landscape pollution
crude oil & derivatives	very high	very high	very high	small	high	high	moderate
coal	very high	low	moderate	large	moderate	high	high
tar sand	very high	high	very high	large	high	high	very high
shale	very high	high	very high	large	high	high	very high
waste	very high	low	very high	moderate	moderate	high	none
uranium	very high	high	none	small	very high	very high	moderate
geothermal	high	high	none	none	none	high	none
natural gas	very low	none	none	none	none	moderate	none
sun	none	none	none	none	none	none	high
wind	none	none	none	none	none	none	high
water	none	none	none	none	none	none	moderate

[1]) A distinction should be made between primary and secondary energy sources. All secondary energy sources have no effects upon environment, whereas all primary energy sources do. For example, the generation of electric power by applying uranium (nuclear power) or the production of synthetic oil and gas by using coal, tar sand, shale and waste causes the highest environmental pollution. However, electric power or synthetic oil and gas on their part do not deteriorate the environment.

Sources: This chart is based on own assessments. The following literature has been used as references:

— Hammond, A. L., u.a.: Energy and the Future, a.a.O.
— Hottel, H.C./Howard, J.B.: New Energy Technology — Some Facts and Assessments, Massachusetts, 1971.
— Drake, R.J.Jr.: Energy: Technology for Self-sufficiency, Stamford, Connecticut, o.J.
— National Technical Information Service, Report to the Secretary of the Interior of the Advisory Committee on Energy, Springfield, 3. June 1971
— Bowen, D.H.M. (Hrsg.): Air Pollution, Washington, 1973.
— Mills, G.A./Perry, H.: Fossil fuel power + pollution, in: Chemical Technology, Washington, Nr. 1, January 1973.

ECOLOGICAL COMPATIBILITY OF ALTERNATIVE ENERGY SOURCES: SOME VIEWPOINTS

Although the applied methods of energy production usually provide an answer to the question of whether or not an energy source is detrimental to the environment[13]), it must be pointed out that the ecological incompatibilities of energy sources being developed will strongly influence the progress of substitution. An overall look at environmental influences resulting from primary energy sources can be shown in the following comprehensive review:

The intensified development of alternative energy sources, especially nuclear energy, solar energy, nuclear fusion..., at the same time implies the increasing generation of electric power resulting in certain environmental effects. Although the consumption of electric energy — as shown above — does not lead to any environmental pollution, the fact cannot be denied that the landscape will still be disfigured[14]) through the increasing installation of surface cables for energy transportation. Underground cables are inadvisable due to the number of handicaps offsetting the advantages of this method. The transmission of electric power via microwaves is still at an early stage of development. Thus, future social costs will also arise in this respect if a change in transportation methods of electric energy becomes necessary.

Due to the direct interactions[15]) between energy consumption, economic growth and environment, some basic aspects on the development of alternative energy sources will be described in the following.

If an economic growth policy is adopted, increased energy consumption will be the result. At the same time, heat emission and environmental pollution will increase. Efforts to restore the environment require rising energy input. However, the incurred social costs reduce the achieved growth effects. This shows that, on the one hand, increased environmental pollution results from the environmental side effects of the applied energy source. On the other hand, rising energy consumption diminishes the existing energy resources or, respectively, necessitates the development of new resources and/or energy sources. Since, in turn, economic growth is essential to meet high investment costs, further energy input becomes inevitable. This circulation begins anew. Obviously, there exists a circulus vitiosus among these three compoments which may be shown in a simplified diagram (Diagram 1). The described movements always result first in an increase of energy consumption. However, from a certain point on, each additional energy input

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[13]) Solar energy is known to be the purest energy source. And yet, the applied methods of energy production from solar radiation may have some environmental effects. If solar energy were produced on solar farms, the landscape would be disfigured. (According to experts assessments, roughly 14,000 square miles of land are needed for setting up a solar farm which could cover America's consumption of electricity until the year 2000. This would correspond to the combined area of Connecticut and Massachusetts.)

If solar energy were produced by the satellite solar power system, the microwaves transmitting the solar energy would bear hazards. On the other hand, such problems do not arise in the case of solar homes.

(Cf. Hammond, A.C., Metz, O.W., Maugh, T.H.: Energy and the Future, Washington 1973, S. 61—71; and: Power from sun: The search picks up, in: U.S. News & World Report, Washington, No. 16, April 16, 1973.)

[14]) Cf. New Power Problem: »Visual Pollution«, in: U.S. News & World Report, No. 18, May 6, 1974.

[15]) Cf. Schurr, S.H. (ed.): Energy, Economic Growth, and the Environment, Baltimore/London 1972.

is succeeded by diminishing returns. This may be explained by the social costs involved.[16])

The following conclusion may be drawn from the above considerations:

— Economic growth is a desirable target only if it can be achieved without a negative impact on the quality of life.[17])

Static model of consumption of polluting and non-polluting energy sources

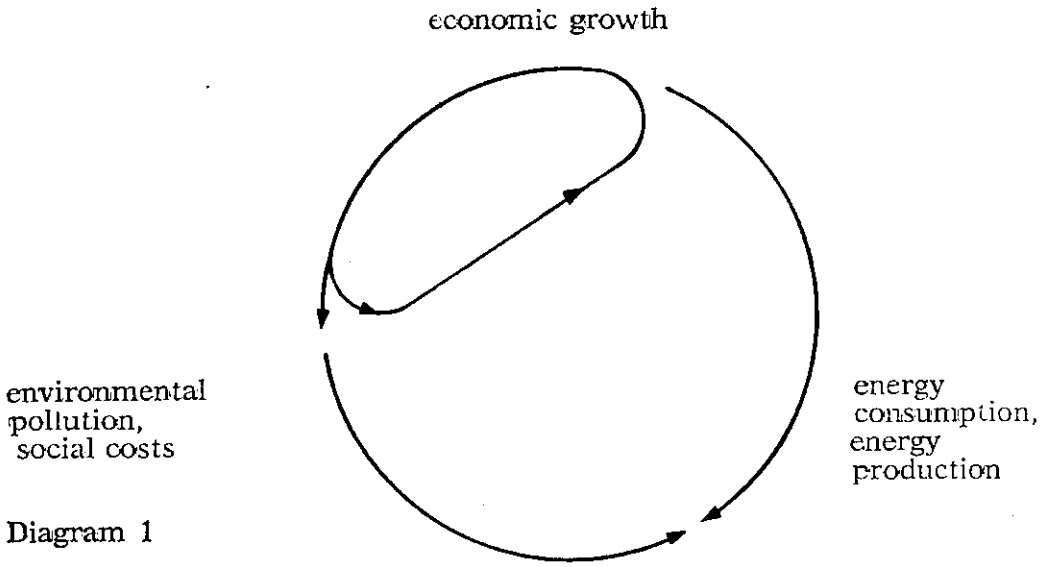
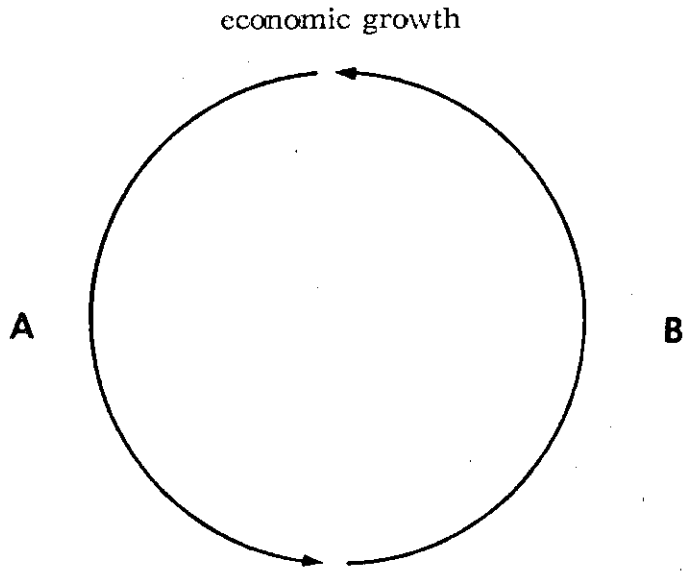


Diagram 1



Dijagram 2

[16]) Etimates of the Environmental Protection Agency in America show that investments amounting to at least 284 billion US Dollars are needed until 1985 to restore the environment in the USA.
(Cf. New Hurdles in the Drive against Pollution, in: U.S. News & World Report, No. 5, July 30, 1973.)

[17]) A precise definition of »quality of life« cannot be given as yet. However, among the various concepts, the factors determining quality of life may be divided in to two groups:
— The direct factors, such as environmental pollution issues, wars, accidents, . . .
— the indirect factors, such as education, humanity, etc.
Quality of life is used here as determined by the first group of factors, the direct factors. In this connection, a misleading feature related to economic growth should be pointed

Dynamic model of consumption of polluting and exhaustible or, respectively, non-polluting and inexhaustible energy sources

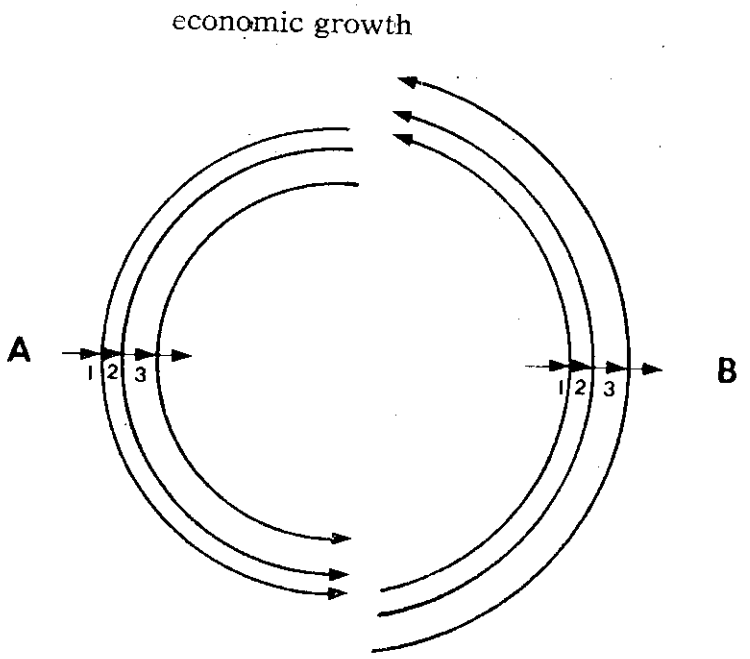


Diagram 3

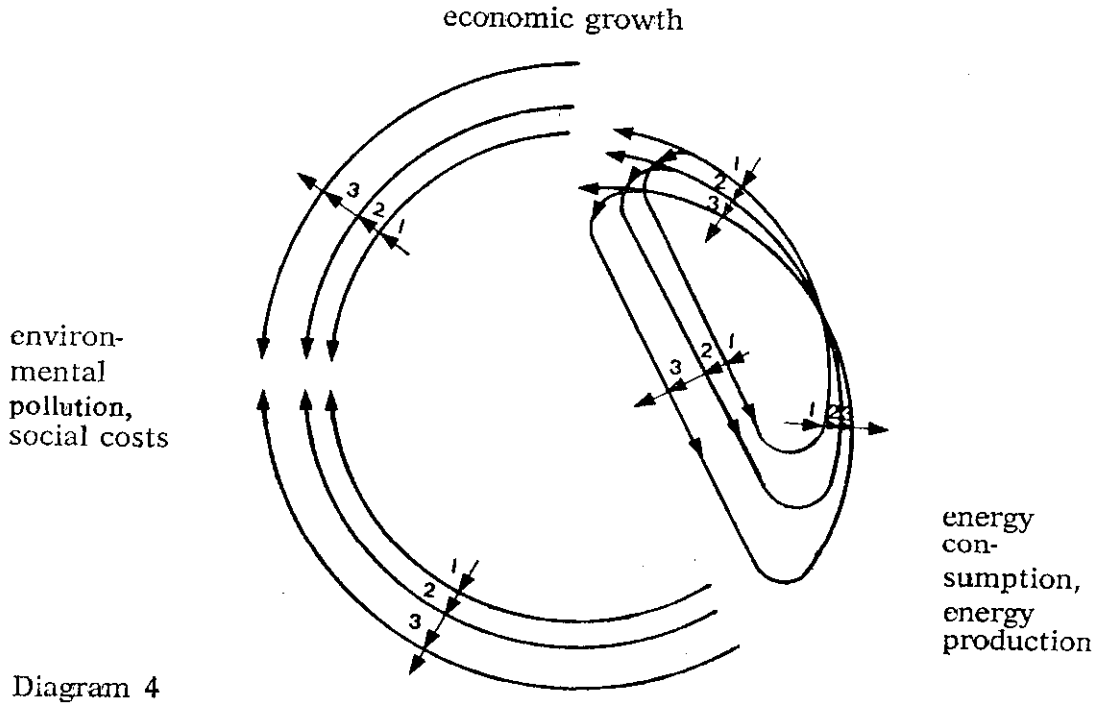


Diagram 4

out: Economic development may be measured in terms of gross national product (GNP) consisting of the production of goods and services in one year. However, it is somewhat surprising to find that any expenditures for restoring the damages of war, accidents and environmental pollution are included in the measure of GNP. Instead of deducting the incurred social costs from GNP, these are added on.

— To prevent any deterioration of the quality of life it is necessary to develop only non-polluting energy sources.
— Should high investment costs be commercially justifiable in the long run or, respectively, be held within tolerable limits, it would be, necessary to develop not only non-polluting but also inexhaustible energy sources.

Should mankind be successful in developing and applying exclusively non-polluting and inexhaustible energy sources, it would then be possible to offset the direct factors determining the quality of life and, thus avoid the social costs. The result would be a circular movement as shown in Diagram 2. In other words, energy consumption leads to economic growth. However, part of the achieved output growth is needed for reinvestments. Reinvestment costs arise because technological developments require certain adaptations. Otherwise, maintenance costs may be incurred. The semicircle A becomes smaller and smaller in the course of time but it will never disappear. On the other hand, the semicircle B continues to grow steadily (cf. Diagram 3).

The conclusion may be drawn from this that the benefit per unit of energy input for achieving economic growth increases continuously. Constant economic growth may be attained with a lesser amount of energy. Rising energy input will lead to a progressive rate of economic growth.

The development of exclusively polluting and exhaustible energy sources presents a circular system as shown in Diagram 4. Energy consumption will increase steadily to attain economic growth and to restore the environment. And economic growth will diminish due to the social costs and the investments required for producing sufficient energy supplies. Environmental destruction and social costs may infinitely increase.

CONCLUDING REMARKS

The preceding analysis still leaves three specific problems unsolved:
— How should priorities be set up among the energy sources?
— How should the development of alternative energy scources be carried out?
— How should the projects be financed?

The development of new energy sources should not be an arbitrary act and it also should not favour the interests of certain social groups. Moreover, the choice of an energy source or technology should depend on the following factors:
— environmental compatibility[18])
— safety, and
— inexhaustibility.

Furthermore, the primary energy sources concerned should possibly be available everywhere.

However, it is quite obvious that only very few energy sources possess all these qualities or are designed to cover the needs of world energy con-

[18]) Certainly, the maintenance of already achieved economic standards is essential. However, it would be senseless if polluting energy scurces were to endanger the quality of life.

sumption. One inevitably depends on other energy sources. In such cases, it is only natural that energy sources bearing the least negative features should be applied.

This approach is recommended, especially since none of the alternative energy sources is presently in a good starting position with regard to technological perfection. One may only observe that the responsible authorities pay more attention to a particular energy source, for example nuclear energy, which ultimately serves only their own interests.

In developing new energy sources, the national authorities responsible for such projects are faced with the following problems:
— Which types of energy sources (fuels) are available in the country?
— Which technologies are essential for developing these energy sources?

An example may illustrate this approach: If Western Europeans should develop technologies for large-scale utilization of tar sand, this would be not as useful to them as intensifying the development of technologies transforming coal into synthetic oil and gas. Especially so as the largest tar sand resources are situated in Canada and the economic policy issues cannot be neglected.

The development of large-scale technologies, especially for utilizing solar energy and nuclear fusion, would require an international co-operation providing for a division of labour.

If the alternative energy souces which are possibly partial substitutes for crude oil are mainly to be put into large-scale operation, it can easily be perceived that the energy produced will chiefly be electricity. This would require a gradual accommodation of industries in respect to the new situation. In other words, their production methods would have to be adapted in such a way as to operate on electric energy. The same goes for their products. Furthermore, the search for efficient methods of transporting electric energy over long distances must be intensified.

The state of affairs allows for project finance by tax revenues or profits of companies operating in this particular field which are ultimately supported by the population of the country.

However, the appropriate financial means should be the Petro-dollars of the oil producing nations. However the Petrodollars acquired from oil sales give rise to two basic problems: on the one hand, they are a hazard to the world economy since they may cause a global crisis; on the other hand, they do not bring forth the benefits which could have been expected under normal circumstances. How this target may be achieved remains to be seen. The best solution would be a co-operation between industrial and producing nation. In other words, they may help to fulfil a task which is a matter of subsistence for both sides by investing the Petrodollars as well as utilizing the existing research facilities of the Western world.

The starting point of such co-operation is most likely to be the development of energy technologies applicable to fuels which are available everywhere.

In any case, mankind is confronted with the choice of rational and deliberate decisions or continuing misinterpretation of the situation. The present oil and energy crisis is the result of short-sightedness on the part of leading business men and politicians since crude oil was once abundantly

and cheaply available. Thus, engineers were never in a position to solve energy problems because their initiative has always been confined by the profit-motivated decisions in business and politics; there was never a lack of inventiveness.

Although human inventive faculties still flourish, it cannot be denied that without an optimum of harmony between technological facilities, ecological compatibilities and economic realities of the energy source being developed, there is hardly a chance for efficient crude oil substitution. These factors determine the timing of realization. The effects of rising oil prices are by no means a compelling force in solving present problems.

Teheran, Iran *Farid AKHTAREKHAVARI*

PREDUSLOVI EFIKASNE SUPSTITUCIJE SIROVE NAFTE

Farid AKHTAREKHAVARI

Rezime

Rezerve sirove nafte su ograničene i biće iscrpljene u bliskoj budućnosti. Zbog toga bi već sada trebalo obavezno pristupiti razradi alternativa u pogledu izvora energije. Značaj i hitnost ovog problema jasno se ilustruje naglašenim poteškoćama plaćanja sve skuplje nafte u međunarodnim okvirima, stalno prisutnim inflacionim pritiscima u zemljama potrošačima nafte, kao i neefikasnim merama ekonomske politike u cilju obuzdavanja inflacije, smanjenja deficita platnog bilansa i smanjenja nezaposlenosti.

Analiza je skoncentrisana na izučavanje osnovnih komponenata koje su relevantne za uspešnu supstituciju sirove nafte kao izvora energije. Prva od tih komponenata je cena nafte i pokazano je da njeno povećanje ima ograničen domet u pogledu angažovanja novih izvora energije. Drugi, zaista važan momenat je vremensko usklađivanje napora za iznalaženje novih energetskih resursa. Tako npr. veliki japanski projekat u tom domenu »Sunshine« treba da dâ određene efekte tek nakon 2000-te godine. Treći elemenat, koji treba imati u vidu, jeste da treba razumno oceniti kako kvantitativnu, količinsku raspoloživost alternativnih izvora energije, tako i njihovu kvalitativnu komponentu, jer se sirova nafta ne javlja samo kao izvor energije nego i kao sirovina u industriji. Naredna komponenta je pitanje zaista visokih troškova u vezi sa razvojem novih izvora energije i nužno se postavlja pitanje: na koji način obezbediti tako velika sredstva? Uz ovo treba imati u vidu i probleme zagađivanja okoline koji se takođe javljaju na putu traženja pogodnih rešenja.

Ovako veliki problem može se rešiti samo onda ako se koordinira akcija na polju tehnologije i ekologije i uz poštovanje postojećih ekonomskih realnosti. Rastuće cene nafte nisu ona sila koja bi mogla individualno da reši sadašnje probleme u ovoj oblasti.