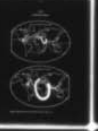
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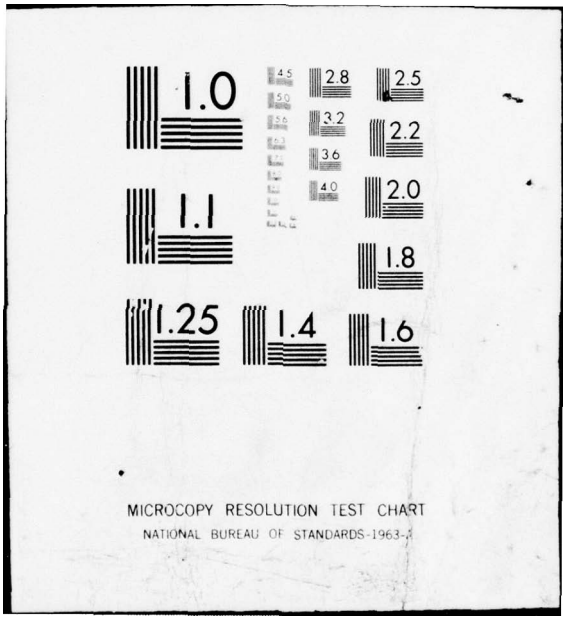
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THE IMPACT OF ENERGY ON STRATEGY: A CONSOLIDATED REPORT

By

LCOL JOHN W. STORR
DR ERIK SOLEM
LCOL M.V. CROMIE

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(6) # THE IMPACT OF ENERGY ON STRATEGY: A CONSOLIDATED REPORT

by

(10) LCol John W./Storr,
Dr. Erik/Solem
LCol M.V./Cromie

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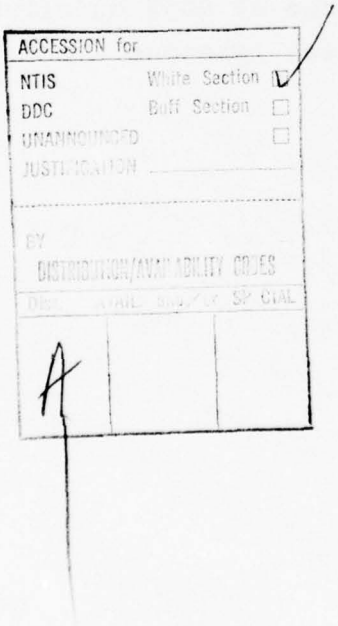
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ABSTRACT

This report deals with the effects of the growing energy shortage on the world strategic picture. Since 1973 both the supply and price aspects of energy have been factors of great importance in political, economic and military affairs. Over the past two years the Directorate of Strategic Analysis has studied future trends and interpreted events related to the energy crisis; the report summarizes this work. The importance of a firm US policy in the energy field is emphasized; however the implications of the new US policies announced in April 1977 have not yet been fully explored although it is clear that they show some concern for easing international tensions.



RESUME

Ce rapport traite des pénuries croissantes de l'énergie et de leurs conséquences en matière de stratégie mondiale. A partir de 1973, l'approvisionnement et le prix des ressources énergétiques occupent une place très importante dans les questions politiques, économiques et militaires. Depuis deux ans la direction des Analyses stratégiques étudie les perspectives d'évolution de la crise de l'énergie et interprète les événements qui y sont associés. Nous avons souligné la nécessité d'une politique américaine ferme dans le domaine de l'énergie; cependant nous n'avons pas encore étudié en détail les répercussions des politiques que les Etats-Unis annonçaient à cet égard en avril 1977, mais il apparaît d'ores et déjà qu'elles traduisent un net désir d'atténuer les tensions internationales.

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FOREWORD

This consolidated report presents an overview and conclusions from the D Strat A project Impact of Energy on Strategy. The paper is based on project work by LCol J.W. Storr, Maj. A. Nellestyn, Dr. Erik Solem and LCol M.V. Cromie. It draws from several reports and papers produced by the above mentioned, and from the general literature on energy.

Initial conclusions, based on ideas developed by LCol J.W. Storr and Dr. Erik Solem in discussions with the project sponsor, DSPP, were presented by LCol Storr to an ORAE seminar in December, 1974, (see D Strat A Staff Note 74/24). These views and ideas, modified in light of recent events, have been incorporated into this paper. It also draws from a talk on short and long term forecasts for energy supplies and the effect of the supply problem on military activities given by Dr. Solem to the Canadian Delegation of the NATO Parliamentary Assembly, and the subsequent briefing to the same group by Capt. (N) (retd.) B.C. Thillaye (DSPP) and Dr. Solem in Ottawa, 9 November 1976. As well, more recent work carried out by Dr. Solem and LCol Cromie is included.

As this report was written prior to the announcement of new U.S. energy goals in April 1977, no attempt has been made to assess Carter's policy goals in this area. We note in passing that his proposals are of the type which we have identified as necessary and that our assumptions in this sense have been proven right.

Due to the large amount of material already produced through this project, the consolidated report has been kept short. Some topics of concern are reviewed in the annexes, which also include a list of the D Strat A energy publications and a short bibliography.

THE IMPACT OF ENERGY ON STRATEGY:

A CONSOLIDATED REPORT

INTRODUCTION

BACKGROUND

1. Early in 1974, the strategic planning staffs in National Defence Headquarters and ORAE became concerned over the vulnerability of the Western world to the use of oil as a strategic weapon, and the grave challenge that energy shortages and high energy costs place before our economic system and our institutions. At that time, the security implications of this challenge seemed enormous.

2. Consequently, a project was initiated in the Directorate of Strategic Analysis to study the impact of energy on strategy between now and 1985. Its objectives were to examine the effects of the energy variable on global and regional balances of power, on international political, economic and security groupings, and on the likelihood of inter-state military conflict. This would provide a global frame of reference for the identification of energy-induced security problems specific to Canada.

3. The study focused on the decade up to 1985 for several reasons. First of all it is between now and 1985 that governments and institutions must respond to the interrelated challenges of population, food and environment, as well as energy supply. Second, a ten year time-frame is appropriate for military planning in terms of force structure, next generation equipment, and so on. And, finally, some significant energy milestones should have been passed by 1985 -- the full flow of North Sea oil and gas for Europe, a complete reassessment

of world energy resources, a firm policy for the development of long-term U.S. supplies, and possibly a significant contribution to the energy mix from coal, tar sands, shales, and nuclear fission.

4. In order to gather the best information for the study, contact was established early with a variety of agencies both within and outside of the Department of National Defence (DND). These agencies are listed at Annex A.

SCOPE AND METHODS

5. In a study of energy and strategy it is virtually impossible to separate the military aspects of the problem from the political and diplomatic ones. It is equally difficult to separate energy aspects of the economy from the total economic picture for, as we know, the drastic turn taken by the Western economic system in recent years was triggered largely by the four-fold increase in the world price of oil. Consequently, while the study is concerned with the identification of security implications of the energy problem, the term "strategy" is used in a broad sense.

6. The study started by establishing a set of data on supplies, demand and price. No attempt was made to compete with world wide batteries of experts in order to compile an alternative set of figures. Rather, the available estimates and projections were examined so that we might identify trends and patterns, and make several assumptions to guide the remainder of the study. In addition to conventional and synthetic hydrocarbon resources, a variety of alternative energy sources were examined: nuclear energy, both fission and fusion; bio-mass fuels; and solar, geothermal, hydro, tidal, wind and MHD power generation. A summary of energy resource information is given with sources, at Annex A, while the

several ORAE publications which contributed to this effort are listed at Annex E.

7. On this data base was superimposed various global issues and considerations which were thought to be important over the next 10 years - issues such as security of supplies, conservation, technology and alternative energy sources, balance of payments deficits and recycling of petrodollars, the connection between energy and agriculture, distribution and movement of petroleum, and the ability of institutions to deal with the problems they face. The next step was to overlay regional and national capabilities and objectives in the attempt to develop a balanced global picture.

TRENDS AND ASSUMPTIONS

8. From the overview of resources presented at Annex A, it seems clear that there will be no overall shortage of energy in the next century. The shorter range picture is murky, but several important trends in energy use and development are apparent:

a. New discoveries of oil in the Western world have declined and are below recent consumption levels, while consumption is once again increasing following the 1974/75 slump.

b. The life index or reserves-to-production ratio for oil in the West (now at about 30 years, or only 20 if the Middle East is excluded) therefore continues to decrease.

c. Exploration for new conventional supplies is hindered by problems of capitalization, materials and manpower. Technology cannot bring in synthetics as quickly as they are needed.

d. The installed nuclear generating capacity of the free world is not increasing according to previous plans. Even if nuclear power increased ten-fold by 1985, it would still provide only about 15% of total world energy consumption.

e. Development lead times will probably prevent coal from greatly expanding its share of demand by 1985, and no other alternative will make a significant impact by that time.

f. Oil, which now accounts for about 45% of world energy consumption, may account for 60% by 1985, and some 50% of oil supplies will be imported.

g. For all these reasons the price of oil should remain high and would surely not return to two to three dollars per barrel.

9. It is important to point out, however, that confidence in the continued operation of these trends depends on some important assumptions. It must first be assumed that no very large new discoveries of exploitable oil will occur, an assumption which is contrary to the history of the oil industry. Therefore, speculation on the potential of China and Mexico, for example, should not be discounted. Similarly, it must be assumed that no really significant breakthrough will be achieved in the U.S., either in developing new technology or in exploiting such possibilities as the gas-bearing geopressurized zones in the Gulf of Mexico. Finally, it must be assumed that the growth in energy demand for the industrialized nations will continue to be substantial;[1] that is, the effective

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1. Energy demand growth rates are expected to be 3-4% in the industrialized countries, and 5-6% in areas of the third world able to sustain industrialization. The rate could be very much higher in some countries, e.g. China.

conservation policies and technical fixes will not be implemented.

10. If these assumptions, taken together, should prove faulty, then the trends mentioned above would be a very uncertain basis for action: for instance, OPEC might break up and oil prices fall. Hence even now we find a very poor investment climate for most forms of energy development. Nevertheless, oil will clearly remain the most strategically significant source of energy over the next 10 years because it must remain absolutely vital to a large segment of industry, and to the military. There are few other constants in the energy equation.

GLOBAL AND REGIONAL CONSIDERATIONS

11. The energy events of 1973 had long been foreseen by some observers, but few if any were prescient enough to date them earlier than the late '70s. Contrary forecasts of continuing cheap and abundant oil were the vogue in official circles until very late, providing a rationale for inaction. Yet it is fortunate that the crisis came early rather than late, before it had achieved its predicted potential for international mayhem. Disaster has been averted, to the surprise of some, by the honoured strategy of muddling through. We have had a breathing space sufficient to allow a number of false starts on energy policies and an ineffective if noisy start on the debate over a "New Economic Order".

12. Meanwhile, the private Eurodollar Market has adapted to financial tasks too new for the creaky machinery of the World Bank and IMF.[2] But the continued avoidance of calamity

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2. IMF - International Monetary Fund. A glossary of terms used in this paper is at Annex O.

still requires an orderly transition to new energy sources and technologies, and the mutation of official economic institutions. These are not mere technical problems but political issues of world wide scope, some aspects of which we shall consider before reviewing security problems in more detail.

THE OIL WEAPON AND OIL POWER

13. In any discussion of energy and security, the first topic for consideration is the oil weapon, by which is meant any actual as opposed to threatened manipulation of the price and/or supply of oil by the exporting nations with intent to alter the political behaviour of consumer nations.[3] Will the weapon be used, by whom and in what circumstances?

14. The diversity of political aims and economic circumstances within OPEC virtually eliminated any chance that the organization, although founded to exploit oil power, could ever use the oil weapon. Only the Arab states have potentially both the collective political will and a sufficient share of the world market for this. The forum for collective decisions on use of the oil weapon is therefore OAPEC, not all of whose members (notably Egypt and Syria) are either members of OPEC, or significant producers.

15. The members of the Organization of Arab Petroleum Exporting Countries (OAPEC) are: Saudi-Arabi, Kuwait, Iraq, United Arab Emirates (Abu Dhabi, Dubayy and others), Libya, Algeria, and Qatar all of whom are members of OPEC, plus Egypt,

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3. This definition follows Maull (1975), who also defines the more general concept of oil power as the power which stems from the oil dependence of consumer nations. The oil weapon is one way of using oil power; diplomatic exploitation of consumer dependence is another.

Bahrain, Syria, and the Neutral Zone[4] (Kuwait and Saudi Arabia).

16. Two attempts were made to use the oil weapon prior to the formation of OAPEC in 1968. In 1956, an Iraqi pipeline pumping station in Syria was blown up, and Syria unilaterally kept the pipeline out of service. In 1967, several Arab countries embargoed oil supplies to the U.S., Britain and West Germany following the Israeli attack on Egypt. Neither of these attempts had much success, and several points are noteworthy regarding the ill success of the 1967 attempt:

a. the embargo did not result from any long considered or well coordinated Arab plan;

b. a buyers' market still existed for petroleum;

c. the Arab states could not individually withstand the economic losses of an embargo, and did not in fact cut back production;

d. the Arab states were little disposed to make sacrifices for each other - in particular, Saudi Arabia and Egypt were at loggerheads; and

e. the U.S. was still virtually immune to an Arab embargo.

17. At the time of the 1973 embargo, by contrast, the change to a seller's market was evident (U.S. imports of Arab oil had more than doubled and were harder to replace from other sources), Arab monetary reserves were greater, Saudi Arabia

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4. Established in 1922 to allow for free movement of the nomadic tribes. Source Cline, Ray, World Power Assessment, A Calculus of Strategic Drift, Center for Strategic and International Studies, Georgetown University, Washington, D.C., 1975.

was reconciled with Egypt and active in Arab affairs, and production cutbacks accompanied the embargo so that an actual shortage of oil could be generated. But success of the oil weapon did not result from a well coordinated Arab plan; rather it depended on the willingness of Saudi Arabia unilaterally to employ it in the Arab cause, despite her conservative inclination not to disrupt the workings of the international system.

18. It remains true today that Saudi Arabia's unique combination of large market share, ability to forego revenue and proven willingness to do so, makes the oil weapon credible and gives the Saudi's almost unilateral control over it. It has also been made plain in the recent deliberations of OPEC that the Saudi's independence on price and new willingness to expand production are controlling factors for oil power in general.

19. Because the effects of the 1973 embargo were less precise and more devastating than was intended, and because the effects of a new embargo cannot be easily forecast, there is wide agreement that the threat rather than the application of the oil weapon is most effective. But under present circumstances, there is still a significant probability of embargo and production cutbacks during any threatened or actual Arab/Israeli hostilities unless the Saudis are satisfied with U.S. Middle East policies. We hope to show that any firm U.S. energy program would immediately reduce the credibility of the oil weapon by making visible the medium-term decline of oil power. Admittedly, for Japan and Western Europe, there can be no oil equivalent of the "nuclear umbrella", but excepting discovery of really large and easily exploitable resources within OECD,[5] it is hard to propose any peaceful alternative

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5. That the prospect for large new resources is not negligible is demonstrated, for example, by current speculation that Mexico may prove to have 100 million barrels of oil reserves.

which could equally restore western freedom of action in the short term.

THE MIDDLE EAST

20. Ensuring a continuous flow of oil from the Middle East calls for a stable political situation. By no means is stability threatened only by the Arab-Israeli issue, but the overriding consideration for all contending parties is their common interest in the oil trade. That and the possibility of super-power intervention are likely to preclude serious local confrontations. Hence the most important requisite for stability is settlement of the Arab-Israeli dispute.

21. Of the three underlying issues in the dispute - the territories (Sinai and the Golan Heights), Jerusalem and the holy places, and the Palestinian question -- it is the Palestinian question which has assumed first importance and which is critically dependent on U.S./Saudi interactions. If a settlement is reached against the background of a clear U.S. energy policy, the chances for continuing stability both in the Arab-Israeli relationship and the Persian Gulf will be greatly enhanced.

THE IMPORTANCE OF U.S. POLICIES

22. As a superpower, the U.S. is the only western nation to view the energy problem in global perspective, and her mere display or non-display of a resolute response must profoundly affect the national and collective strategies of oil producers and consumers alike. Some components of her superpower status will equally determine the stability of the energy transition in the coming decade:

a. As the largest single market for OPEC oil, the U.S. is vulnerable to supply restrictions, yet her vast domestic resource base and unused opportunities for reducing per capita consumption confer great potential leverage on world demand, even in the short term. In the future, oil supply and demand decisions for the western world may become virtually a function of U.S./Saudi discussion, for it is Saudi Arabia which has the leverage on supply.

b. As the richest and most technologically advanced nation, and the home of major oil companies, the U.S. can dominate the development of hydrocarbon and alternative energy technologies, and is also best able to afford contingency measures such as stockpiling on a scale sufficient to influence international politics. Again, she is best able to develop a stabilizing interdependence with the oil producers by providing development assistance and the most attractive market for investment of oil revenues.

23. It is not hard to believe that, without resort to arms or the food weapon, and without immediate acceptance of a New Economic Order, a well conceived U.S. energy strategy could both limit the freedom of action of the oil exporters and encourage their participation in the evolution of economic institutions.

24. The prospects for an effective policy declaration in 1977 are good, for the coincidence of the U.S. presidential inauguration, a new oil price rise and a new uncertainty about OPEC cohesion provides an unusually opportune moment for a

Presidential Program[6] on energy. It is significant that the president-elect had already, before the end of 1976, appointed a strong energy administrator in James Schlesinger, and has since emphasized his intent to impose strong conservation measures.

25. The alternatives to a U.S. Presidential Program are not encouraging. The Saudi's restraint in pricing, and willingness to expand production even at cost to her OPEC partners, are clearly tied to the expectation of reciprocal U.S. pressure for a Middle East settlement. Lack of a U.S. political response would, therefore, chance great economic and military uncertainty, while any response not backed by a strong U.S. energy policy would be undesirable because concessionary. The field would remain open for OAPEC actions or random events to trigger further crises, and perhaps a disastrous overresponse. Only within the framework of a credible U.S. energy strategy can the Saudis (or OAPEC) be influenced and accomodated in such a way as to enhance Middle East stability and world economic security.

PETRODOLLARS AND INSTITUTIONS

26. Following the oil price increases of 1973/74, the problem of petrodollars - the huge new profits of the oil producers - was soon recognized, but it has not been solved. The seeming resilience of the world monetary system cannot continue indefinitely, as many industrialized nations struggle with increasing balance of payments deficits, while those less

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6. The phrase has been used by Herman Kahn to describe a program of long-term importance which has the personal and dramatized attention of the U.S. president, and which exhibits great differences with normal decision-making in that it may ignore or even "hurt" special interests, and prefers "overshooting" to inadequate performance.

fortunate cannot handle even the servicing of their mounting debts. Clearly the rupture of the present economic system is a real threat to be added to the political problems which arise as self-interest comes to govern the sharing and distribution of energy supplies.

27. The EEC presently, too incoherent to substitute for national bodies and too limited in scope to compete with the OECD as a forum for discussion may be left floundering. The EEC will no doubt continue its debate on energy plans and policies, but little joint action can be foreseen unless new U.S. policies have a coercive or catalytic effect.

28. The International Energy Agency (IEA) may also prove to be poorly qualified either as a guarantee for equitable distribution or as a forum for the reconciliation of conflicting interests. To assume that a small number of officials in Paris can manage an oil crisis is a large assumption indeed. The agency's primary value seems to lie in its ability to link the majority of western energy consuming nations to the United States. This can prove to be its salvation only if the U.S. develops a comprehensive and well understood energy policy. Otherwise, the IEA could become simply a scapegoat for the political failures of its member states.

29. There is a second reason why oil-sharing through the IEA might fail. During the 1973 embargo, the distribution of oil was controlled only nominally by the OECD countries. In fact, only the oil companies had the information, the organization, the distribution system, and indeed the oil. During the next embargo, the companies will not have the oil, because more and more of it belongs to the OPEC governments. This participation oil[7] opens the door to government-to-

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7. Participation oil is the oil controlled by government of producing country.

government deals, an effective way of undermining a sharing agreement. In addition, increased Arab ownership of tanker tonnage could play havoc with the distribution system.

30. In general, it can be said that neither the economic nor the political institutions of the western industrial society have yet shown the flexibility needed to cope with the large and rapidly developing problems of the post-1973 energy situation. Western governments have so far been unable to make the unpopular decisions and take the long-term actions which may be necessary for their survival, but which seem to threaten personal and market freedoms. Paradoxically, this reluctance to act could lead to the imposition of truly authoritorian regimes in some western countries.

31. On the other hand, as the transfer of wealth from the developed OECD countries to the less developed OPEC countries continues, these countries are becoming increasingly dependent on the OECD world for investment opportunities and for the whole range of goods and services necessary for their development. Hence, not only Saudi Arabia but all the major producers might develop a serious concern for the political and economic health of the OECD countries. Given the primacy of oil as an energy source to the turn of the century, and its continued control by OPEC, an OECD/OPEC interdependency will surely develop although not necessarily smoothly. Given OPEC knowledge of the sure decline of oil power (at an uncertain date dependent not only on old oil depletion and non-OPEC oil discoveries, but also on energy technologies), and cohesive OECD policies, this interdependency could develop under the virtual control of the OECD, but still with substantial long-term benefits to the OPEC countries. Unhappily, such an outcome must be counted as unlikely, hence, the prospects for the various OECD members are not encouraging.

EUROPE

32. European solidarity may benefit from recent experience and new leadership and from the efforts of the Eurocrats in the EEC, yet there are many forces at work to undermine it, primarily serious economic difficulties in the U.K. and Italy, and political and economic instability in the rest of the EEC countries and their associates.

33. Recent finds of oil and natural gas in the North Sea, although very promising in terms of numbers, are beset by a list of potential technical problems, mostly related to their extraction. The recent Philips blow-out in Norwegian waters demonstrates the seriousness of this type of problem. In addition, there is lack of general agreement concerning the future role of North Sea oil and gas.[8]

34. Chinks in the mortar or Western European solidarity translate directly to the strength of NATO. Balance of payments deficits and high oil prices tempt NATO nations to reduce defence spending and detente provides the rationale. If defence commitments are further reduced by the members of NATO, the West will be meeting the objectives of the Soviet Union without exacting any corresponding concessions. NATO could begin to deteriorate, as national differences promote rivalry and competition for oil deals and export markets. Thus, failure to deal with energy problems can play directly into Soviet hands in many ways. In the absence of national energy policies and their effective coordination through the EEC, all the USSR need do is wait on the sidelines and watch the West grow weaker.

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8. For a much fuller treatment of this subject, see The Impact of North Sea Oil on Norway's Economy, by Dr. Erik Solem, Directorate of Strategic Analysis, ORAE, Ottawa, Staff Note No. 76/8, June 1976.

JAPAN

35. Japan will remain dependent on foreign suppliers of oil until such time as her entire energy base can be changed, but she is attempting to reduce her dependence on Middle East sources. The USSR, China, Indonesia and North America are targets for her diversification of supply. To further reduce her vulnerability, Japan is pursuing conservation and the restructuring of industry to reduce energy-intensive manufactures. She will invest heavily in energy R&D, and will wish to develop closer ties to littoral states along the supply routes. Japan's indispensible military and economic ties to the U.S. make her, relative to some European nations, reluctant to adopt policies of expedience in the Middle East. Her resistance to pressures towards independence and a stronger military posture will be in good part a function of the strength or weakness of a coherent U.S. energy policy.

36. Also of fundamental importance to Japan will be the scale of energy trading which may be undertaken by the Soviet Union and China.

THE SOVIET UNION AND CHINA

37. The Soviet Union and China are both basically self-sufficient in primary energy supplies, including oil. However, both countries must undertake large scale exploration and development to meet future needs, and will very likely need to import Western technology and capital to bring their potential oil and gas supplies on stream.

38. Soviet oil reserve figures are a state secret, but official statements imply that new discoveries have recently been less than the rate of extraction. The oil prices charged to the USSR's Comecon partners are increasing, and

may reach world levels by 1980. At the same time, the Soviets are reducing exports to Comecon members (notably to Czechoslovakia) who must therefore import more Middle East oil, with inflationary effects. Meanwhile the USSR seems anxious to increase exports to the West in order to ameliorate her own huge and growing trade imbalance. But the ability of the USSR to sustain a large export market through the 1980s remains in doubt.

39. As an export commodity, natural gas may prove to be more valuable than oil for the Soviet Union. Although U.S. government interest in the development of Siberian gas would seem to have waned, American and Japanese enterprises are already engaged in exploration, and the USSR is known to be planning a large LNG (Liquid Natural Gas) export industry.

40. The true extent of China's oil reserves and her intentions for their development and use are both mysteries. In recent years, both her production and consumption of oil have grown at rates on the order of 20%, and such rates could continue if she proves to have the vast resources sometimes ascribed to her. Her huge population and tiny per capita oil consumption give her an unlimited capacity for absorption of her own oil production. On the other hand, her political system and her extremely high current dependence on coal (over 80%) would allow her to hold down domestic demand in order to become a first rank exporter. Her oil trade with Japan has been hampered by Japan's dislike of the high wax content of Chinese oil, but it is of interest that the Chinese have recently offered more than the Japanese have been willing to take.

41. It is unlikely that China will become a major world supplier by 1985, but even by becoming a major supplier to Japan, she could profoundly affect the world energy trade.

Again, if she were to extend her selective offers of cut-rate prices to developing nations, she could influence OPEC policies. Neither can surprising developments such as oil-for-arms deals with the West be ruled out. Clearly, energy developments in China are worth watching.

THE LESS DEVELOPED COUNTRIES (LDCs)

42. It is by now quite impossible to consider all the LDCs as a single bloc. To the third world of a few years ago must now be added a fourth world, and possibly even a fifth world of those few oil producing countries whose revenues greatly exceed their capacity to absorb them.

43. The new third world, according to this analysis, consists of those developing countries of Africa, Latin America, Asia and the Pacific which have a viable agricultural base and exports of raw materials which enable them to pay for their oil. This group of countries faces serious but not desperate economic problems. However, the industrial ambitions of this group will most likely be frustrated as the gap continues to widen between it and the industrialized world. This process may also be aggravated by lower prices, relative to oil, for virtually all industrial commodities, giving rise to problems which may spill over into the internal and regional politico/economic scene. Hence instability could increase, governments fall and regional conflict become common.

44. The fourth world is made up of the Indian subcontinent, sub-Sahara Africa, and parts of Latin America and the Caribbean. Equipped with an inadequate agricultural base and insufficient export or foreign exchange reserves to allow them to purchase enough food, fuel and fertilizer to meet their basic needs, the populations of these countries face severe problems. With the exception of India and Pakistan, they may well be too weak

to vent their frustrations in conflict, but they could be ripe for Communist takeovers. Recent events in Mozambique, Somalia and Ethiopia seem to indicate that neither the strength nor the duration of an LDCs commitment to a USSR version of Marxism is to be counted upon, but the Soviets clearly recognize the strategic benefit of establishing their presence in African states which overlook the oil trade routes.

45. It might seem that the best hope for the LDCs lies in the channelling of Middle East oil profits through these countries. They might then be able to buy industrial machinery from the developed world to establish industries which would in turn produce consumer durables for the markets of Europe and North America. But the likelihood of a general OPEC initiative is small, for Europe and North America are still expected to show the way. OAPEC members are under fire even from their Arab brethren for the stinginess of their aid programs. Meanwhile, Iran has reduced her planned aid program as a result of her failure to obtain a large oil price increase at the December, 1976, OPEC meeting. It may be that the rhetoric of the LDCs will soon be directed as much against OPEC as against the industrialized western nations. It also may be that time has run out for some members of the fourth world. Although bankers maintain a calm front, large defaults by fourth world nations are possible, and could have serious repercussions in the OECD economies.

ENERGY AND WESTERN SECURITY

46. If the oil weapon is still credible, it follows that the threat of its use could set off a chain of events leading to general war: "Quarrels with suppliers, and another oil embargo, is the most readily conceivable possibility for the start of World War III."[9] Yet this speculation now seems more bizarre

9. Emile Benoit, "First Steps to Survival", Bulletin of the Atomic Scientists, March 1976, p. 44.

than it did in 1973/74. Hence, with the caveat that the world-wide alert of U.S. forces at the time of the 1973 embargo once again proved the need for direct and unambiguous USSR/U.S. communications, it is more useful to consider the lesser range of security problems related to the energy transition through 1985. We first consider the background problem of ensuring the supply of military fuels, and then review some energy-related aspects of security during peace and war.

MILITARY FUEL SUPPLIES

47. Since WW I, the military strategic importance of oil has continued to increase with advances in mechanization and mobility. Without oil, no modern defence system can be maintained and no wars fought. It therefore comes as a surprise to many that military POL (Petrol Oil Lubricants) consumption is only a small fraction of national demand in industrialized economies.

48. U.S. Senate hearings in recent years have dealt with the military POL needs of various countries. For instance, the total U.S. Department of Defense (DOD) petroleum usage during the Korean and Vietnam wars amounted to only 6-8% of U.S. national consumption. At these rates, even in the face of some restriction on supplies, no insupportable burden is placed on domestic oil resources. There is no detailed estimate of POL requirements for a major and prolonged conventional war in the 1970s or 1980s. However, DOD experts have testified that even if these were twice the peak Vietnam requirements, they would be less than 10% of projected total U.S. demand, and less than one-fifth of domestic production. Of course, oil poor countries which have been cut off from supplies could be severely hurt unless they had large stocks on hand.

49. In a limited war, the burden placed on domestic resources would probably be less. Stockpiles would still be vital, of course, even as they now are in peacetime, as a buffer against supply embargo. Neither does the assumed brevity of a nuclear war detract from the need for stockpiles, for the probability of interdiction of supply is greater, as is the necessity for post-war reconstruction.

50. In peacetime, for NATO countries, the proportion of national POL consumption devoted to military activities averages only about 5% (less in Canada). This is nevertheless a large amount of fuel, and an obvious target for conservation measures, as was shown within NATO during the 1973 embargo. Such cut-backs are politically expedient, but since normal military consumption is relatively small, they do little to help the overall national fuel situation. Instead, they have a significant adverse effect on military posture. In the first place, restrictions are placed on training, and operational efficiency is degraded as a result. In the second place, exercises are cancelled or impaired and the credibility of the NATO deterrent can no longer be demonstrated. For example, during November 1973, it was reported that the Danish government had asked its NATO partners to bring their own POL to the NATO exercise ABSALOM EXPRESS, as she was unable to meet their requirements.

51. Also during November 1973, there were reports that the Philippines, Japan and Singapore had restricted oil supplies to U.S. forces in the Far East, forcing the U.S. to draw upon its wartime reserves of oil in the Pacific to meet the needs of its South Vietnamese and Cambodian allies.

52. Both in peace and in war, such gaps in energy supply are likely to recur due to the poor international coordination of energy policies, which are in any event still

rudimentary. Existing difficulties within NATO and OECD could worsen and lead to a reduction of defence expenditures and a tendency for defence and economic partners to drift further apart.

53. From this point of view, NATO is in danger of disintegration, and NORAD, while it might continue in name, would be ineffective due to deteriorating U.S./Canada relations. It is well to observe, however, that it is only the exposure and not the creation of weak seams which we should ascribe to energy problems; detente and inflation were both hindering national commitments to community goals before October 1973. Furthermore, as we have already pointed out, a less gloomy view is possible on the assumption that the U.S. will soon develop a comprehensive energy policy which would stimulate international cooperation.

THREATS TO INTERNATIONAL STABILITY DURING PEACETIME

54. In peacetime, both the price and supply of oil continue to be major determinants of international stability. In NATO and throughout the OECD, competition for preferred status with the suppliers is a divisive factor, while high prices decrease both the desire and the ability of individual governments to agree on or finance common objectives. Even the distribution or development of new supplies from the North Sea and Aegean Sea have become points of contention within the EEC and NATO. Furthermore, notwithstanding the central importance of U.S. policies, increased American influence on supplies would be unwelcome in some European capitals. Hence,although national stockpiling and the emergency allocation planning of the IEA may be thought of as contributions to preparedness, the general lack of cohesion in facing energy adversities has probably resulted in a net loss to NATO's deterrent.

55. Japan's position is distinctly different than that of any other OECD nation. She is the most vulnerable both to embargo and to disruption of supply routes, but the least able to independently secure supplies by bilateral dealings (notably in arms and nuclear technology) with the oil producers. Neither does she have any military capability to protect supply routes. Hence, if Japan does not feel protected by U.S. energy and defence policies, the next decade could well see the conversion of the Japanese Self Defence Force and the emergence of stronger conventional military forces.

56. The rhetoric of calls for a New Economic Order is sometimes taken to portend a vast uprising of North against South, but this threat is preposterous in military terms. Internal social chaos is also a common forecast for those nations which are reaching their credit limit and seem to face economic breakdown. But usually it is ethnic differences which spark internal strife in the third and fourth worlds; the link to economics is weaker the less developed is the country. Thus the dangers both of external aggression and internal strife, insofar as they are attributed to energy, may have been overstated, and the effectiveness of anti-western agitators should decline as OPECs culpability comes to be recognized by the destitute nations.

57. In line with these remarks, one observes no new or greatly increased terrorist activity motivated by the economics of energy. Yet terrorism is undeniably connected with energy in several ways. For anti-Israeli, pro-Palestinian terrorists, at least, several OAPEC members have provided both financing and sanctuary. Except in the most radical of these, however, this era seems now to be ending (temporarily?) as the PLO is subdued in Lebanon and heavily pressed to agree to Middle East settlement terms worked out by Egypt, Syria and Saudi Arabia.

58. For any terrorist group, whether operating within or outside national boundaries, the growing number of vulnerable and high-profile energy targets (off-shore oil rigs, energy distribution centres, super-tankers, etc.) must look very attractive, even if nuclear facilities are excluded. As to the prospects of nuclear terrorism, the literature contains many unresolved problems pertaining to the security of facilities, the availability of nuclear materials, and the feasibility of their use. The fact that these arguments are unresolved is sufficient indication that a whole range of threats could be effective, even in the absence of a workable nuclear device or sabotage plan. Unless terrorism fades from the international scene, as did the peaceful demonstrations of the 1960s, it can hardly be expected that the growing number of nuclear opportunities will remain unexploited.

59. Energy facilities, both conventional and nuclear, also offer more general threats to security. Whatever the success of the Law of the Sea conference, disputes over off-shore rights are likely to occur when important resources are discovered in boundary areas. As we have seen, such disputes already pose a problem even within NATO. They could cause serious international tensions where the interests of OECD countries, OPEC and Communist powers intertwine, for instance on the Asian littoral all the way from Indonesia to Sakkalin. Where jurisdiction is not in dispute, the vulnerability of off-shore installations will still be a matter of military concern for many nations, and has already spurred the development of a new class of patrol vessel in the United Kingdom.

60. An increased likelihood of nuclear weapons proliferation, or at least latent proliferation,[10] is a hazard which can fairly be blamed on the energy squeeze. In the development of fission power, only the USSR appears to be marching ahead without trepidation. Elsewhere, there are increasing pressures both to restrict trade in the materials and technology needed for weapons and to tighten safeguards nationally and through the International Atomic Energy Agency (IAEA). Also, most national programs have been much reduced by steeply rising capital costs, uncertainties as to supply and price of uranium, and a newly cautious approach to waste disposal and siting problems, as well as by the public debate on social costs. But these developments cannot eliminate the hazard, only reduce it.

61. The risk of weapons proliferation to nations or terrorist/criminal elements will sharply increase if and when currently proposed breeder reactors come into widescale use, for then the opportunities for misappropriation of weapons-grade material will multiply. For this reason, strong opposition to breeder technology is now becoming apparent, not only from environmentalists, but also from within the nuclear establishment. A brief review of the debate is given at Annex **β**.

62. A final set of peacetime energy/security problems is centred on the Middle East: the growing size and sophistication of armed forces, the continuing antipathy between radical and conservative regimes, and the renewed uncertainty of OPEC's future are factors which will ensure continuing tension in the area even if an Arab/Israeli settlement is reached.

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10. "Latent proliferation" is an apt term used by Feiveson and Taylor (1976) to describe the condition of a nation or group which acquires the ability to build weapons and to divert nuclear materials from peaceful uses so that it could become nuclear armed in days or even hours.

63. Whereas the USSR has up to now supported OPEC unity as a disruptive force working to her advantage, it has now been rumoured that the Soviets are exploring the possibility of forming a new oil producers union between herself and the more radical OPEC members. If true, this could indicate not only a Soviet design to accelerate the development of her own resources for export, but also a wish to exploit an OPEC dispute for fear that all OPEC members may eventually be coopted by the western economic system.[11]

64. An ever present danger in the Middle East is the attempted overthrow of the monarchies in Iran and Saudi Arabia. For Iran, already missing her development targets by a wide margin, non-increasing oil price or market share losses could trigger serious discontent. Saudi Arabia, in assuming price leadership, risks the wrath of other Arab producers, and an Arab/Israeli settlement might serve to concentrate the attention of Libya and Iraq on the overthrow of King Khalid. Any peace agreement is unlikely to satisfy all Palestinian factions, and consenting Arab nations, notably Saudi Arabia once again, could fall victim to terrorist activity. Excepting perhaps a quick, clean coup d'etat, any serious threat to the Iranian or Saudi regimes would invite U.S. intervention and super-power confrontation.

65. The external effects of Iran's growing military strength are hard to foresee. At best, her impressive inventory of weapons should serve to dissuade agression from any neighbour, including the USSR, and to secure her U.S. supported role as guarantor of the vital Persian Gulf oil trade. Any menace which Iran may seem to offer to her neighbours over the next decade should be moderated by her internal problems

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11. This has been called "The Merrill-Lynch-Yamani Solution".

and her reliance on western, particularly U.S., development assistance. But her neighbours will take a less sanguine view because, even now when her advanced weapons are far from being assimilated, Iran could control or block the Gulf trade. Given further erosion of the major oil companies role as arbiters of oil production, such an outcome is conceivable as a result of competition for markets if OPEC were to collapse.

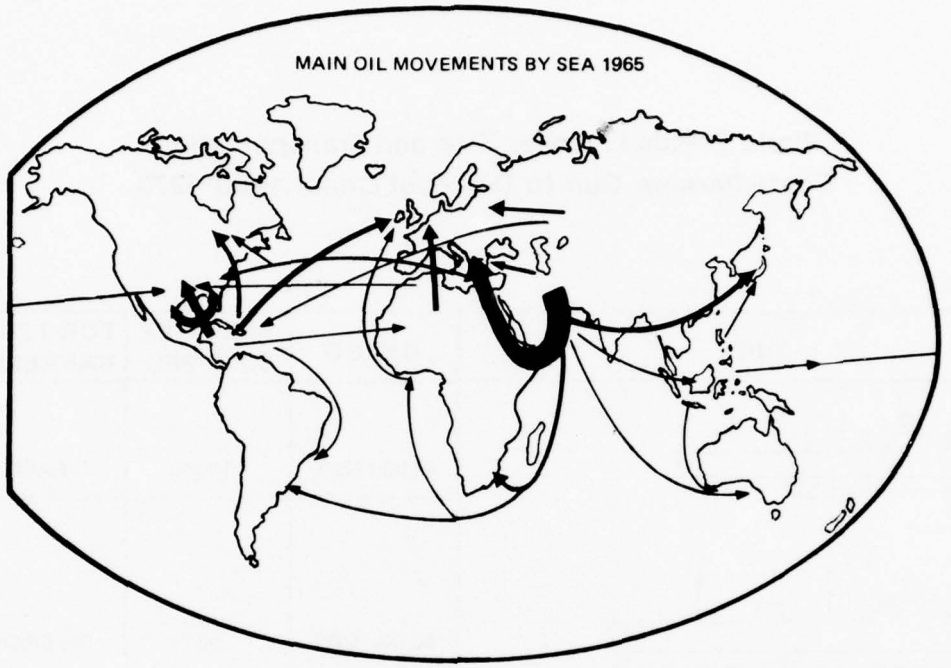
ENERGY AND SECURITY DURING INTERNATIONAL CRISES

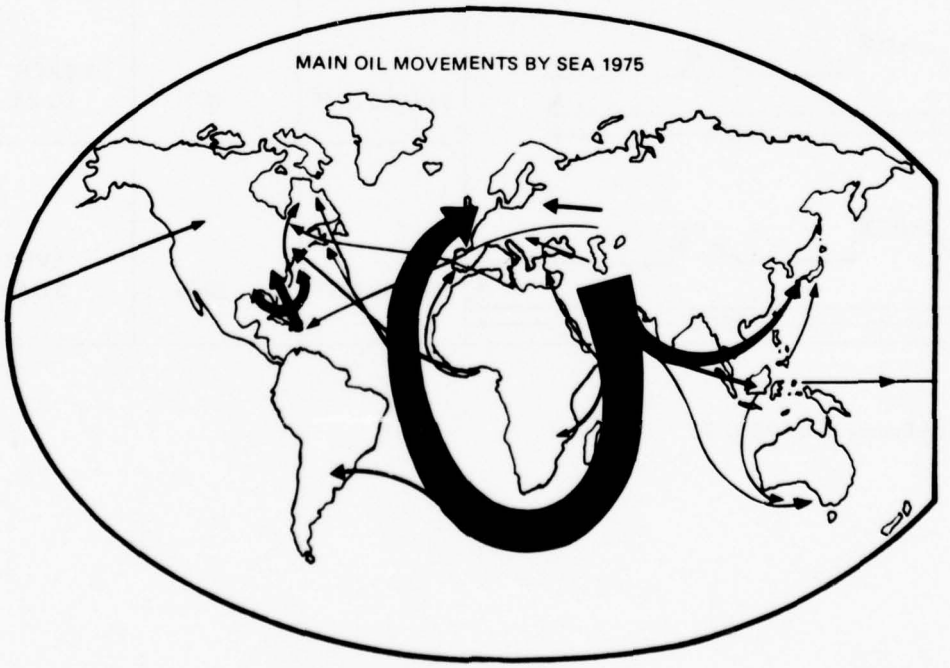
66. The security of the oil shipping trade has not been emphasized as a peacetime energy problem, for any serious disruption of this shipping could quickly change the situation to crisis. Also, crises arising for other reasons would often leave the security of energy shipments (chiefly oil, but also Liquified Natural Gas) in doubt.

67. The accompanying figures show how the magnitude and location of the energy shipping problem has changed. Since 1965, the volume of oil shipments has more than doubled, and a larger percentage (about 75%) originates in the Persian Gulf. With the closing of the Suez Canal in 1967 and the advent of supertankers, the Cape Route, once only a pathway, became the vital superhighway for oil movements to Europe and North America. Little wonder that Soviets have shown an interest in the Indian Ocean and its bordering states, for this is now the least protected part of the western economic system. Little wonder that Iran, with western approval, aims for a blue-water naval capability well beyond the confines of the Persian Gulf.

Figure 1

Oil Movement Patterns



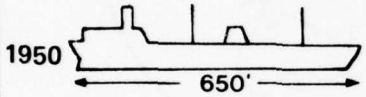
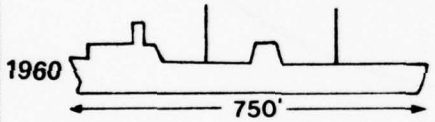
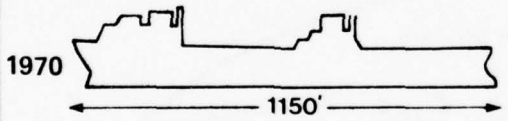
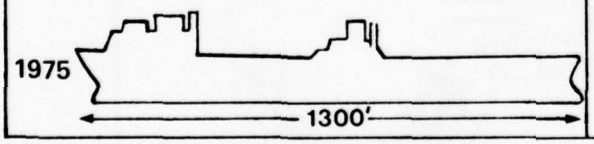


Source: BP Statistical Review of the World Oil Industry 1975, p. 15.

Figure 2

Tanker Trends

World Trends in Tanker Size and Transportation Cost–Persian Gulf to U.S. East Coast, 1950-1975

SHIP	CARGO	RELATIVE COST/BBL	FOR 1,300,000 BARRELS/DAY
	30,000 DWT	100 %	6 EACH DAY
	50,000 DWT	88 %	3½ EACH DAY
	250,000 DWT	45 %	1 EACH 1 TO 2 DAYS
	500,000 DWT	38 %	EVERY 3 DAYS

Source: The Energy Index 75, p. 73.

68. There is a notable trend to increased Arab participation in the ownership of oil tankers which, though ill-defined in scope, will further reduce the ability of the major oil companies to provide equitable distribution of oil supplies as they did during the 1973 embargo. Confidence in the emergency allocation plans of the IEA is thereby diminished, while the effectiveness of the oil weapon is increased.

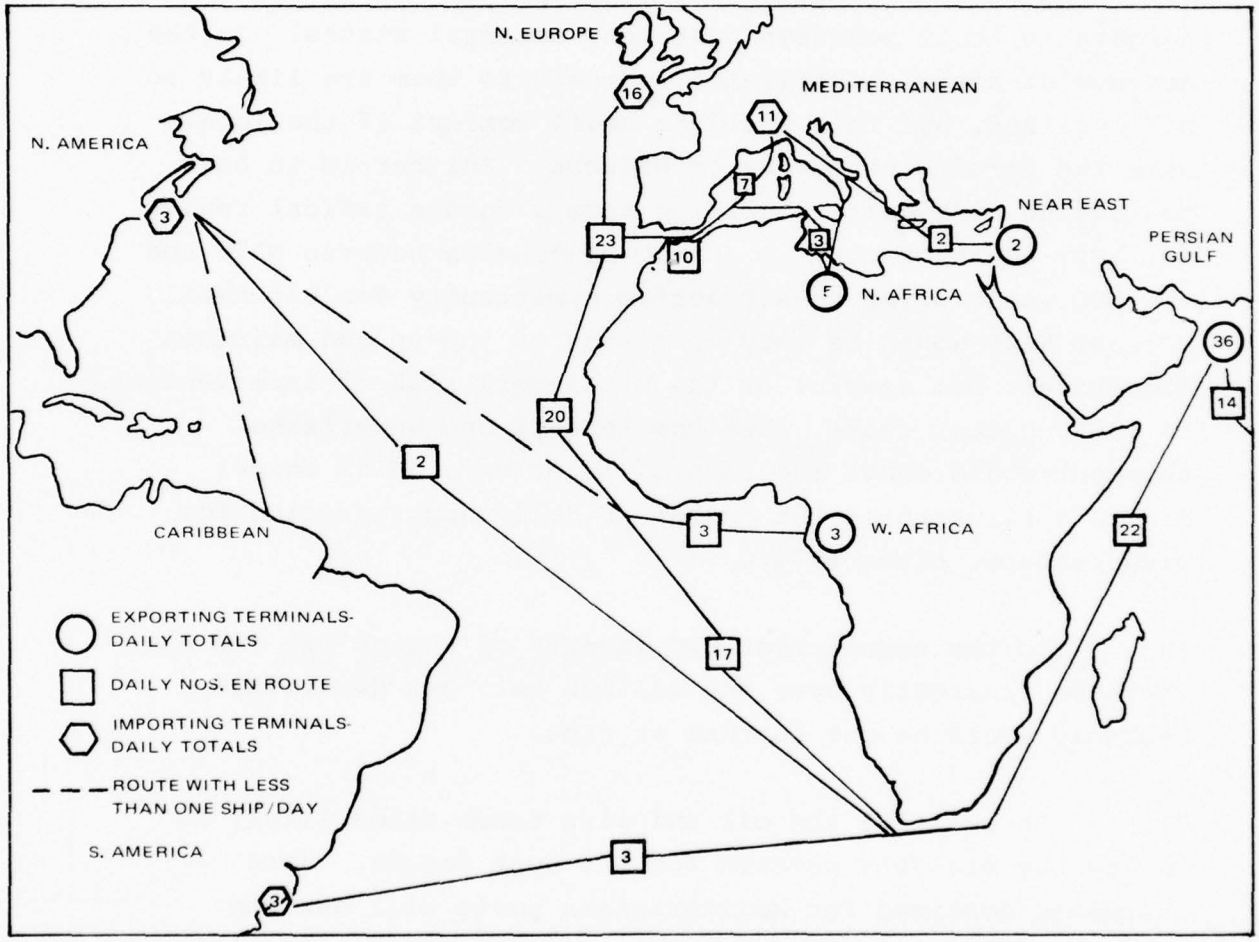
69. More generally, supertankers provide large and lonely targets in their journeys past many littoral states. In the absence of actual hostilities, threats to them are likely to be localized, but this would be small comfort if the locale were the Straits of Hormuz or Malacca. Neither is it hard to imagine difficulties arising from a future radical regime in, say, South Africa. A period of tension between NATO and the WPO would offer an attractive opportunity for blackmail, because NATO would be very concerned to top-up and maintain stockpiles, but fearful of the escalatory risk of intervention in a WPO client state. Yet the loss of one supertanker shipment would equal the loss of 10 or more WW II ships. Figure 3 illustrates the number of daily opportunities for misadventure, circa 1974.

70. To the extent that EEC imports of Soviet oil and gas increase (currently over one million bbl. per day), NATO resupply would be put further at risk.

71. In outline, the oil shipping trade seems likely to follow the mid-70's pattern for the next decade. More shipments destined for Mediterranean ports will use the reopened and improved Suez Canal, but the Cape Route will remain more economical for North European and American destinations. North Sea oil will reduce the shipments to Europe somewhat, but only a very determine U.S. resource development and conservation program is likely to reverse the

Figure 3

Large Crude-Oil Carrier Routes & Daily Ship Numbers



Source: Burton, "Trends in World Shipping with Particular Reference to Large Crude-Oil Carriers", SANCLANTCEN Memo SM-50, 15 July 1974.

compensating increase in shipments to North and South America. Shipments from the Gulf and S.E. Asia to Japan can be substantially reduced only by a scale of imports from China and the USSR which is unlikely by 1985.

72. The next decade is likely to see the introduction of very large nuclear-powered tankers, and will certainly see a large increase in the number, size and variety of specialized LNG carriers, adding to the energy traffic from North Africa, Alaska, the Persian Gulf and possibly the USSR. Both nuclear powered tankers and LNG carriers are designed for speeds higher than conventional tankers (22 knots vs. 15 knots), a possible security advantage since none of these very large ships is thought suitable for manoeuvre in convoy.

73. It seems unnecessary to dwell on the effects which international crises or local wars will have on concern for multiplying off-shore facilities, and the limited number of specialized ports available for oil and LNG unloading. Also obvious is the fact that as the number of countries having civilian nuclear programmes increases, so does the probability that any international crisis may pressure one or more nations towards virtual or actual weapons proliferation. This problem is likely to take on added importance after 1985.

ENERGY AND SECURITY DURING GENERAL WAR

74. One may reasonably propose that POL stockpiling can allow the prosecution of a war even in face of the interdiction or embargo of ocean-born supplies. Unfortunately, this is less than the whole truth, not only because the duration of the conflict must be unknown, but even more because precision guided conventional munitions will increase the probability of destruction of rear-area stocks and the theatre POL distribution system. This means that the vulnerability of supertankers and

their ports might be critical even in a short war, that a European war might quickly encompass sources of supply in Africa and the Middle East and that NATO might more quickly be forced to consider nuclear escalation. Highly decentralized stockpiling and a larger POL transport capability for lower echelons would seem wise, but the extent to which this has been considered and found impracticable in a peacetime economy is unknown. The related problems of distributed supplies for naval use and military/civil fuels standardization have certainly been under study since 1973.

75. The status of nuclear power plants as targets in a conventional war is peculiar. Would their destruction in such a way as to maximize radioactive contamination be considered an escalation to be countered either in kind, or by use of nuclear weapons? It has been suggested that nuclear plants could be more a liability than an asset in time of war. At the least, a declaratory policy statement at the commencement of hostilities would seem to be in order.

ENERGY AS AN INPUT TO DEFENCE PLANNING

76. This survey of energy-related security problems has aimed to be non-alarmist. For example, the full range of potential problems in the Middle East has not been introduced because energy wealth (particularly that of Saudi Arabia) has given evidence of dampening both Soviet influence and the territorial, dynastic, and ethnic disputes which are endemic to the region. We have nevertheless indicated energy's important bearing on world-wide military security for the foreseeable future.

77. It may therefore be thought surprising that, beyond budget adjustments necessary to cover increased POL costs, and minor restructuring of maritime forces for the protection

of enlarged economic zones, energy's independent ability to cause mischief has had little positive effect on western defence establishments. Yet few of the problems we have reviewed have of themselves both the gravity and the probability of occurrence necessary to influence budgets or force structures (such problems as shipping protection and POL stockpiling being more a matter of national concern). A public perception of increased menace may have an important bearing on future force levels, but energy's contribution will not be extricable from the whole complex of problems which we face. Energy's effects may be felt more directly in the area of military tasking for quasi-military activities as suggested by these two items:

a. of 926 collisions, rammings and groundings of tankers recorded up to 1974, over 85% occurred at locations (piers, harbours, entrances, coastal) where risks of environmental or property damage were high.[12]

b. for nuclear facilities in the U.S., U.K., FRG, France, Canada and Argentina, 11 instances of attack (all but one involving explosive or incendiary devices), 13 instances of vandalism or sabotage and 15 instances of security breaches have been recorded.[13]

78. Although the military does not have clearly spelled-out responsibility for day-to-day civil security, or for the prevention of disasters which may occur in its absence, it is expected to maintain an integral capability to contain and

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12. Adapted from the chart "Location of Tanker Accidents" in Energy Index 75, p. 166.

13. Michael Flood, "Nuclear Sabotage", Bulletin of the Atomic Scientists, October 1976, p. 29. The only Canadian instance was a security breach carried out by Morton Shulman, MP, at Pickering in 1975.

relieve both nuclear and marine events. It is none too soon for Canada to review the place of the armed forces in securing energy installations. For instance, the need for pre-planned emergency assistance for nuclear plants may be at least as great as that for Penitentiary Assistance Teams.

79. Finally, although military POL supplies are assured to and beyond 1985, long development lead times dictate an immediate military interest in transportation efficiency, alternative fuels, and unconventional and portable power sources. Better ideas could be vitally important before the latest generation of fighting vehicles are due for replacement, and it is in these areas that one would hope to see increased military funding for and participation in Research and Development.[14]

ENERGY AND THE FUTURE OF THE DEVELOPED WORLD

80. In a recent semi-annual review of economic prospects for the developed nations, the OECD presents a gloomy conclusion for 1980: economic policies and planning will continue to be ineffective because economists have failed in their efforts to influence political behaviour.

81. The central problem in economic and social evolution between now and 1985 may be inflation. Although the rate of increase of prices has subsided in most countries, inflation is still running at a level higher than at any time since World War II, with disquieting recent trends both in finished goods and prices and raw materials costs.

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14. For more detailed discussion of the need for energy facilities protection and military R&D, see: Jones, "Energy Patterns: A perspective for DND", Ottawa, 1976.

82. There is a high degree of synchronization of the business cycle with many countries entering an expansionary period together. The result is that the international transmission of demand and inflationary pressures is greater than expected. Hence, western governments must maintain cautious demand management policies for at least the next decade to avoid a renewed burst of inflation and to ensure sustained economic growth through investment.

83. According to the OECD a substantial shift will be needed in the share of output devoted to gross fixed capital formation, particularly in North America. The main investment effort will have to come from business to meet such new needs as pollution control and energy development, as well as to make up losses incurred in capital stock through obsolescence and inadequate investment in past years. An additional 4% of U.S. GNP would have to be devoted to fixed investments over the next five years, up from the 1.7% increase noted from 1967-73. For Canada, an additional 2.5% of GNP would need to be invested, up from the 0.8% increase noted from 1971-73. The OECD questions whether the U.S. and Canada can obtain such sharp changes in the short time available.

84. If the projected investment and export requirements are to be met, the rise in private and public consumption must be restrained. How can this be achieved? It would seem that the tools of fiscal and monetary policy will not be enough. What is required is a social consensus on priorities for resource allocation shifts, and for temporary restrictions on the rise of living standards. Such a consensus will not be arrived at spontaneously: only very homogeneous communities in times of extreme crisis have managed to muster this sort of collective will. Therefore, unusually creative and decisive political leadership will be essential to marshall the support even of a politically enlightened public. In some countries,

the required social consensus will not be possible without determined action to reduce extreme inequalities of income and wealth, and to establish or strengthen consultative bodies without creating unnecessary bureaucracies. At this stage of social and political evolution in the western world, it is easy to find reasons for pessimism on these points.

85. Unemployment rates in nearly all western countries will probably be high relative to past standards. In addition, according to the OECD, there are the makings for very serious politico-economic problems in Turkey, Greece, Yugoslavia, Spain and Portugal.

86. The dependence of the industrialized countries on raw materials imports from the LDCs will continue, but the degree of dependence will vary as shifts occur in demand and supply elasticity due to the development of possibilities for materials substitution and recycling. It is important to point out that physical shortage of non-energy resources is not really a problem for the foreseeable future. Technological change should be able to keep shortages at bay, though raw materials costs will probably continue to rise, even in the long term.

87. For energy resources, however, availability rather than price is the key problem and a way must be found to phase out finite resources in an orderly fashion.

88. Energy will continue to be a seller's market for the next decade, and the great imbalance in the international oil market may provide the producers with enough leverage to irreversibly change some of the present world hierarchies. On the other hand, the long-term energy problem is one of transition away from dependence on oil, and therefore the long term balance of power between oil producers and consumers may

not change. In any case, continued price increases for energy resources are to be expected, and will mean a continuation of the major economic problem of inflation.

89. The development of appropriate institutions to manage the economic problems of the energy transition, both for the developed and less-developed nations, will remain one of the major issues of world politics for the next decade or more.

CONCLUSIONS

ENERGY RESOURCES AND SECURITY

90. Amongst all energy commodities, oil is by a wide margin the most important one for the period under consideration and the one whose availability and price movement will remain most in doubt. Installed world oil production capacity should nevertheless continue to exceed demand up to the early 1980s. Many important changes in the pattern of energy supply could be emerging by 1985, for oil as for alternatives such as nuclear power, but the convolution of political and technical uncertainties makes any prediction hazardous. Oil demand could exceed total production capacity by 1985[15] if western economic growth continues in the absence of effective measures to conserve energy, increase efficiency and begin the conversion to other primary energy sources. But the continued concentration of oil power in the Middle East may be no more disruptive in world affairs than would be its too sudden demise. Certainly changes such as the emergence of China or the USSR as major energy exporters may increase the likelihood of undesirable economic and political realignments.

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15. For a recent analysis proposing this result, see: Rustow, "U.S.-Saudi Relations and the Oil Crisis of the 1980s", Foreign Affairs, April, 1977.

91. In any case, the price and availability of oil will be governed by OPEC and OAPEC policies for some years to come, and these policies will be much influenced by independent Saudi Arabian decisions on use or non-use of spare capacity. The OECD nations, and NATO, will remain vulnerable to OPEC oil power, and to the possible threat of general or selective embargo by the Arab producers (that is, the OAPEC oil weapon). But for the immediate future, while Western policies remain in disarray, the incalculable results of employing the oil weapon will tend to make it self-deterring so long as it remains under virtual control of a conservative regime in Saudi Arabia. At the same time, the seriousness of this threat and of high oil prices provide the essential pressure towards consumer policies which, sooner than major technological advances, can signal the eventual decline of oil power.

92. It should be noted that the coupling of the oil weapon to the urgent tensions of the Arab/Israeli dispute would seem to argue for a resolution of the embargo problem, for good or ill, well before 1985. Thereafter, with determinedly optimistic assumptions on western policy initiatives and with a clearer picture of world resources and the direction of energy technologies, one might expect the diverse long-term interests of the individual producers to undermine the common front of OPEC.

93. Similar optimism is not warranted in regard to the likelihood of strife within and between the LDCs nor is it warranted in regard to the problems of protecting energy facilities and the shipment of liquid hydrocarbons and nuclear materials. Developments in South Africa, for instance, will pose delicate strategic problems because of that country's position astride the oil routes, its important uranium resources, and its ability to build nuclear weapons. Such problems are likely to require an increasing share of military thought and resources in Canada as elsewhere.

POWER BALANCES

94. If present trends continue, shifts in balances of power will occur, and will not be favourable to the West. The erosion of European solidarity weakens NATO, and economic problems could create power vacuums in Europe into which the Soviet Union will wish to move. Even if vacuums do not occur in Europe, they are occuring in Africa and throughout the LDCs and the USSR is attempting to take advantage of these at a time when the U.S. finds even proxy involvement distasteful. The USSR, unhampered by a coercive link between energy and foreign policy in the Middle East, can await opportunities there, while the U.S. must act without any guarantee of favourable consequences.

95. Arab solidarity may develop from the links now forming between Saudi Arabia, Egypt, Sudan and Syria, increasing the pressure of OAPEC for correct U.S. attitudes towards Israel. OPEC will probably survive but could come partially under the influence of the USSR if that country's oil export potential is realized. Japan, influenced strongly by her energy dependence, may see less value in her ties to the U.S., and this in turn would influence other nations in the Pacific trade area towards ties with the USSR or China.

96. Other economic alliances may also undergo drastic change. The OECD, since it has little real authority, could continue in its present form, but the EEC could very well become unrecognizable. It might be dominated by West Germany with a possible decline of influence and interest by Britain, Italy, and conceivably France. GATT negotiations may become more cumbersome and stagnate owing to growing insularity and competition for export markets. The IMF and World Bank, unpopular with the Arabs and unable to cope with OPEC oil profits, may disappear to re-emerge as similar organizations in which the Arabs have more influence.

97. All of this being said, it should be noted that none of this is necessary, at least as a direct consequence of energy problems, and indeed developments such as the restructuring of the IMF should be welcomed. We have seen how energy uncertainties give any prediction for 1985 a very dubious merit, despite the fact that few technical developments not visible today can come to fruition by that time. But such is the power of the available (if difficult) policy options that it is not unrealistic to remain optimistic about the adequacy and continuity of energy supply for the West. On current evidence, it may be more unrealistic to expect the USSR, Comecon or China to be independent in liquid hydrocarbons beyond 1985 unless they obtain western help. Thus we see once again that while the energy transition is inevitable, its outcome is not yet determined. If the United States soon develops lasting energy goals, much needed improvements in the coordination of policies may follow within NATO, and between the OECD and OPEC countries. The result could be the orderly decline of oil power, and a manageable transition to new economic and energy norms.

POLICIES

98. Well before 1985, fundamental western policies to reduce uncertainties and guide the transition must be made and adhered to. Nowhere is this more true than in the United States, where a policy vacuum has existed despite a level of funding for energy R&D which exceeds that of all other OECD nations combined. Only in part is this due to the inability of the experts to agree on technological issues. Equally important are vested rights in and fear for the demise of the free enterprise approach to energy. Consider for example the following questions which list the kinds of considerations which ideally ought to be answered by any comprehensive policy.

a. Can the major oil companies be allowed to gain domination over the whole field of energy supply while still subordinating the public good to the profit motive? Can horizontal divestiture of their interests in solid fuels, natural gas, nuclear and alternative energy industries be undertaken even now without serious harm to energy R&D, and perhaps the national economy?

b. Can the government provide or guarantee the vast investment sums now necessary to optimum resource development, without intervening in operations or participating in profits as well as losses? Can it control or take part in operations without irrepairable damage to the frayed image of free enterprise?

On no such question is a concensus, even within one political party, likely to occur. Hence a strong U.S. presidential initiative on energy is of pivotal importance.

99. In this paper we have of necessity sidestepped the discussion of policy specifics, noting only the central importance of conservation and stockpiling. Current U.S. plans call for the stockpiling of 500 million bbl. of oil by 1982, or about 30 days domestic demand. A conservation

plan is to be announced in April, 1977.[16]

100. In the North American context the issue of independence vs interdependence is hard to avoid. Canada has opted for "self-reliance",[17] a fuzzy concept which may also encompass the only practical goal for the U.S. up to 1985. The opportunity for independence by that date would seem to have been lost. Besides, the relatively abrupt closure of the U.S.

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16. After this report was completed, U.S. President Carter has announced his energy goals for 1985. They are, in summary:

- Reducing the annual growth in energy consumption from 4.6 to 2%.
- Reducing gasoline consumption by 10 per cent below current levels by means of encouraging production of smaller, hence more consumption efficient cars.
- Reducing oil imports from the current 8 million barrels a day to 6 million.
- Creating a strategic petroleum reserve of 1 billion barrels, which exceeds a six-month supply.
- Increasing coal production by two thirds to 1 billion tons annually, hence shifting industrial consumers to coal instead of gas and oil.
- Requiring insulation of all new buildings and 90 per cent of all houses.
- Installing solar energy devices in 2.5 million homes.

According to President Carter, the achievement of these goals would be accompanied by:

- Continued economic growth and maintenance of current living standards.
- Protection of the environment.
- Higher prices for all kinds of fuel.
- Penalty taxes on gas-guzzling cars.
- Protection against profiteering by oil companies.

See International Herald Tribune (IHT) April 20, 1977.

17. "Means supplying domestic demands from domestic resources to the greatest extent practicable in the light of economic, environmental and social considerations and, further, assuring that adequate protection exists to safeguard Canadian energy requirements that are met from imported supplies in the event of supply interruptions." See "An Energy Strategy for Canada", p. 168.

oil market, if it were possible, would surely depress the price of OPEC oil below the cost of any replacement energy, with poor consequences for the U.S. economy and international stability in the long run.

101. On the other hand, the long-standing U.S. interest in a continental approach to energy, sure to be maintained due to Arctic developments and to be augmented by the potential of Mexico, would make the goal of net North American self sufficiency[18] attractive for the medium term.

102. This would free the U.S. and to a great extent her allies from producer blackmail, while leaving plenty of scope for the orderly development of the world energy trade and economic reform. It would also serve as a precursor to a continental water management program which lurks as a longer term U.S. requirement.

103. To overcome nationalist opposition to this policy in Canada and Mexico, it is just conceivable that the U.S. would offer no-strings financing both for Arctic pipelines and for exploration and development carried out by the national companies PetroCan and PEMEX. With domestic developments in coal, oil shales etc., thus supplemented, the U.S. might even aim to preserve some options, such as Naval Petroleum Reserve No. 4. The recoverable oil in NPR No. 4 has been estimated as high as 35 billion barrels, greater than the total proven reserves of the U.S. in 1976. Canadian/U.S. defence sharing agreements could provide a rough model of such developments in energy.

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18. Self sufficiency, as defined for Canada, implies producing at least as much total energy as is consumed, without necessarily excluding imports of some energy commodities. See "An Energy Strategy for Canada", p. 168.

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ENERGY RESOURCES

GENERAL

1. Vast amounts of historical information are available on energy demand, production and reserves for all types of fuel, but much of this information is conflicting because there is no agreed set of standards for measurement. This information available on future demands or projected reserves is at once less extensive and more confused; the conflicting methods of measurement and the subjective nature of forecasting lead to a range of estimates from extreme optimism to neo-Malthusian worst cases.

2. In this Annex, we do not attempt to give an exhaustive description of all energy resources, nor do we analyze the best or worst possible future cases which have intuitively the least probability of occurrence. Rather, we concern ourselves with a middle range of estimates so that important trends and problem areas may be defined with a modicum of confidence. High confidence is seldom justified, however, as we indicate below and in the report proper.

ENERGY MEASUREMENT

3. Published figures for proven reserves of petroleum are normally associated with a probability figure, which is unstated and which may depend on the advantage which the publishing authority perceives in inflating or deflating his estimate. Proven reserves also fluctuate with estimates of the current economic feasibility of recovery, and hence are dependent on current technology and price movements.

4. Similarly, unproven reserves may be estimated in various ways, with divergent results. Neither is it always clear whether a published figure represents proven or unproven resources. Nowhere has the interaction of these factors caused more confusion than in Canada: in 1970, massive long-term exports of Canadian oil were being forecast; in 1973, government and industry spokesmen still agreed that Canadian crude resources were substantially in excess of Canadian requirements, even at prices which now seem low; but by 1974 there was suddenly agreement that Canada faced shortages even in domestic supply by the 1980s.

5. There is also the problem of standardizing units of measure across the spectrum of energy sources. Where possible we have used tonnes (metric tons) or million tonnes of oil equivalent (mtoe) to facilitiate comparisons. Where this has not been done, the reader will find Table I below to be a useful conversion aid.

6. We have attempted to compare resource figures which have been estimated in the same way, or by the same sources, since it is the relative and not the absolute amounts that are important to our purpose. Not all the figures quoted in this Annex are the latest available, but we are not aware of any cases where later figures would alter the inferences drawn. The cited references are listed at the end of this Annex. Other references are given in the Bibliography.

THE WORLD TOTAL DEMAND FOR ENERGY

7. The average rate of increase of global energy consumption until 1973 was about 5%, and of this approximately 60% was consumed by OECD countries. Following the 1973 embargo, reduced oil consumption in the West slowed the world growth rate to about 1%, although total consumption in the communist countries

TABLE I

ENERGY CONVERSION GUIDE

Crude Oil	1 tonne	=	7.33 barrels
		=	256 Imp gallons
		=	308 US gallons
		=	41 million BTUs
	1 tonne/year	=	0.0201 bbl/day (B/D)
Natural Gas	1,000 cu.m.	=	0.86 tonnes of oil
	1,000 cu.ft.(mcf)	=	0.024 tonnes of oil
		=	1 million BTUs
Coal	1 tonne	=	0.67 tonnes of oil
		=	24 to 28 million BTUs
Lignite	1 tonne	=	0.20 tonnes of oil
Electricity	10,000 kWh	=	0.82 tonnes of oil[19]
		=	34.12 million BTUs

19. Note: 1 million tonnes of oil produces about 4,000 million kWh in a modern power station.

continued to increase at about 6%. Oil consumption was clearly on the increase in OECD again in 1976, and it is estimated that the growth rate for total world primary energy consumption will stabilize at about 4%. In 1975, consumption was 6,155 million tonnes oil equivalent (mtoe) hence the 4% projection for 1985 is 9,111 mtoe, and for 1990, 11,085 mtoe.[20]

8. The mix of primary energy sources comprising total global demand is shown in Table II below. World wide, we can see that oil is by far the most important primary energy source.

TABLE II

WORLD PRIMARY ENERGY CONSUMPTION - 1975

(% of Total Consumption)

Oil	Natural Gas	Solid Fuels	Water Power/ Geothermal	Nuclear
44	18	31	6	1

Source: Reference 3

9. Tables III and IV summarize energy consumption patterns for important "Consumer" areas, giving where possible the changes likely to occur by 1985.

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20. A recent OECD forecast (Jan '77) gives, for OECD, a growth rate of 3.6% from 1974-1985, hence a total OECD demand in 1985 of 5,094 mtoe, of which 1,750 mtoe (34%) will be oil imports.

TABLE III

PRIMARY ENERGY CONSUMPTION % BY SOURCE

	Year	Oil	Natural Gas	Solid Fuels	Water/ Geothermal	Nuclear
Canada	1975	39	21	8	29	2
	1985	40	24	9	17	10
USA	1975	44	30	20	5	2
	1985	35	27	22	2	14
W. Europe	1975	56	13	21	8	2
	1985	48	22	15	2	13
Japan	1975	70	2	20	6	2
	1985	64	7	13	2	14
USSR	1975	36	22	37	4	1
E. Europe	1975	21	12	65	2	-
China	1975	14	1	83	2	-

Sources: References 2, 3, 10.

10. For the western world as represented by the OECD, the share of oil is about 50%, and 70% of this is imported. It can be seen from Table III that all the non-communist countries aspire to a significant decrease in percentage dependence on oil, and count on a greatly increased input from nuclear power. Yet in absolute terms, OECD oil demand will rise by some 28% by 1985, and the bulk of this also will be imported, accentuating the sensitivity of western economies to the policies of the oil exporters. An increased share for natural gas is expected in the western countries, excluding the USA, where the use of coal should be increased.

11. Neither the Soviet bloc countries nor China have any net need for OPEC oil at present. Their plans for oil use and development are not available, but they will certainly not have a significant dependence on OPEC oil by 1985.

TABLE IV

CONSUMER COUNTRIES PRIMARY ENERGY CONSUMPTION (%) BY ECONOMIC SECTOR

	Year	Energy	Industry	Transport	Residential/ Commercial
Canada	1972	10	27	25	35
	1985	11	27	28	33
USA	1972	7	32	29	28
	1985	8	30	28	31
W. Europe	1972	7	34	22	32
	1985	11	33	22	30
Japan	1972	8	44	19	17
	1985	7	40	21	20

Sources: References 2, 3, 10.

12. Projections for the pattern of consumption by economic sector (Table IV) do not show very large changes from 1972 figures. It is notable that transportation will still consume about one-quarter of all energy used, and will remain almost fully dependent on oil, the principal portable fuel. We will now look more closely at the projected availability of this key commodity.

WORLD PRODUCTION AND RESERVES OF CRUDE OIL

13. Tables V, VI and VII summarize world prospects for production, reserves and consumption of crude oil. Table V shows that the reserves of those regions we call producers are large (with the exception of the Asia-Pacific Region) both in absolute terms and relative to their domestic consumption. Their production budgets give each of them a reserves-to-production ratio (R:P) in excess of 25. Table VI gives the same information for those areas we have called consumers. For western nations, the figures for reserves and for reserves-to-production ratios are small, relative not only to the producers, but also to the Soviet bloc and China.

14. Table VI also shows, for the consumers, the net petroleum surplus/(shortfall), and the share of petroleum as a percentage of total primary energy consumed. The latter figures, all decreasing, indicate the efforts which western countries are making to reduce their dependence on oil. But these figures may be heavily dependent on major conservation and development efforts whose success is far from assured, hence the real picture for 1985 is likely to be less favourable. In the USA, for example, it is clear that the goals of PROJECT INDEPENDENCE will not be met, but the amount of the resulting shortfall in the U.S. for 1985 is difficult to estimate, particularly since new U.S. policies are being formulated at time of writing. At best, for the western nations as a whole, the huge total shortfall is unlikely to decrease, and this is in striking contrast with the self-sufficient position of the communist states. Japan is particularly ill-favoured: her shortfall is likely to increase by an amount close to the total production of the Latin America/Caribbean area.

TABLE V

CRUDE PETROLEUM PRODUCERS

(Quantities in million metric tons)

	Year	Production	Reserves	R:P (YRS)	CONS	1972 Surplus
Saudi Arabia	1972	297				
	1974		17,800	47		
	1980	658				
	1985					
Iran	1972	248			59	860
	1974		8,100	27		
	1980	398				
	1985					
Other Gulf	1972	374				
	1974		21,200	31		
	1980	438				
	1985					
Africa	1972	279			47	232
	1975		9,100	33		
Asia & Pacific (excl Japan, PRC & USSR)	1972	92			131	(39)
	1975		2,800	33		
Latin America & Carribean	1972	238			160	78
	1975		5,700	26		

Sources: References 1, 2, 7.

TABLE VI

CRUDE PETROLEUM CONSUMERS

(Quantities in million metric tons)

	Year	Production	Reserves	Reserves/ Production (Yrs)	Consumption	Surplus/ (Shortfall)	% of Total
Canada	1972	76			80	(4)	52
	1975		1,100	10.5			
	1985	70			100	(30)	45
USA	1972	466			776	(310)	46
	1975		5,300	10.5			
	1985	650-825			821	?	35
Western Europe	1972	18			704	(684)	63
	1975		3,500	15.5			
	1985	300			967	(667)	48
Japan	1972	0.7			237	(236)	76
	1975						
	1985	3.0			456	(453)	64
USSR	1972	389					
	1975		11,400	25			
	1980	600					
Eastern Europe	1972	19			396 (1972)	42	26
	1975		400	23			
	1980	20					
China	1972	30					
	1975		3,400	65			
	1980	400					

Sources: References 1, 2, 3, 5, 6, 7, 8, 10.

TABLE VII

CRUDE PETROLUEM PROSPECTS BY BLOCS

(Quantities in Tonnes)

	Year	Production	Consumption	Surplus/ (Shortfall)	% of Total Energy
Middle East	1972	919			
OPEC	1972	1,359			
	1985	1,355			
OECD	1972	578	1,917	(I,339)	47
	1985	1,354	2,452	(1,098)	35
EEC	1972	11	589	(578)	61
	1985	180	760	(580)	47
North America	1972	542	909	(467)	47
	1985	1,055	971	84	35
NATO	1972	555	1,640	(1,085)	53
	1985	1,355	1,888	(533)	36
Communist	1972	438	396	42	25
	1980	1,020			

Sources: References 1, 2, 4, 6, 7, 10.

15. From a different perspective, Table VII also shows how current economic and security groupings of non-communist nations, regardless of efforts to change their patterns of consumption, will remain dependent on oil imports over the next 10 years.

16. During this time the rate at which new reserves are discovered is likely to taper off. The world's proven reserves (excluding the Socialist countries) peaked in 1967 and have tapered off by about 1% per year since. Substantial further discoveries are possible in Mexico, South America, Southeast Asia, China and possibly Africa. Less substantial discoveries, which would directly ease the Western dilemma, are possible in the North Sea, and North American continental shelf and Arctic North America. But oil from these frontier areas is difficult to find, difficult to extract and difficult to transport, hence costs are enormous. For example, the cost of lifting a barrel of oil from the Arctic is over $7.00 compared with about 15 cents per barrel around the Gulf, and this does not include the cost of exploration or distribution.

PROSPECTS FOR SHALES AND TAR SANDS

17. The figures in the above tables do not include the contribution from shales and tar sands, but this will not be large before 1985. While considerable reserves of shale and tar do exist in North America and elsewhere there are enormous environmental problems associated with their extraction. Further, the technology to carry it out on a massive scale must be developed, and the capital costs, not only in dollars but also in manpower and materials, are extremely high and must compete with other high priority programs.

18. The U.S. government has estimated that up to 50 million tonnes of oil can be extracted from Utah and Colorado oil shale deposits by 1985, but other forecasts are less optimistic and suggest that the real figure will probably be less than half that amount. By the end of 1976, poor economic prospects for the short term had led all holders of shales leases to voluntarily relinquish their development rights, so that future programs will depend on federal government initiatives.

19. The Athabaska tar sands in Alberta are currently producing about 250,000 tonnes of oil a year, but there is a sharply decreasing trend in estimates for production in 1985, as seen in the following table.

TABLE VIII

1985 PRODUCTION ESTIMATES

ALBERTA OIL SANDS

(million tonnes)

National Energy Board (1972)	60
Canadian Petroleum Assn. (1973)	36
Clay (1974)	32
National Energy Board (1974)	21
Energy Mines & Resources (1976)	14

Sources: 1972-73 Reference 9
1974-76 References 8, 9, 11.

PROSPECTS FOR NATURAL GAS

20. In 1974 natural gas provided 19% of world primary energy requirements. This share is projected to taper off slightly by 1985, but natural gas will remain an important energy source in the Western world for the foreseeable future

(Table III). In Western Europe, as potential gasfields in the North Sea are developed, production is expected to roughly double between now and 1985, but Europe will then still depend on imports from the USSR, North Africa and Iran for about 25% of its gas requirements because of the depletion of supplies from the Netherlands. The vast gas potential of Canada's frontier areas will not have much impact before the early 1980s. There are significant technological and environmental problems to be overcome in bringing Arctic gas to market, and the required capital will be difficult to find. However, unless frontier developments are aborted, Canada should have no difficulty meeting her domestic and export commitments into the 1990s.

21. In the USA, long standing price controls have discouraged natural gas development, but the eventual removal of price restraints and the development of Alaskan fields is expected to increase the US supply of natural gas by about one-fifth by 1985. The projected increase in Japanese demand will have to be met by imports, with a substantial input from the USSR.

22. In 1972, the USSR accounted for about one quarter of world natural gas production, and about one third of total world reserves. With a reserves/production ratio of 56, and relatively low domestic consumption, the USSR will continue to have a large export potential. However, the rate at which this potential will be exploited may depend on the import of Japanese or US technology, and may be limited by the reluctance of Western countries to become dependent on USSR supplies.

PROSPECTS FOR COAL AND LIGNITE

23. Increased oil prices have now placed coal in a favourable economic light, reversing the declining trend in its use which had been evident in the Western world since World War II. The total OECD demand for coal is expected to increase about 50% by 1985, largely due to the increasingly important role assigned to coal in the USA. Exploitable reserves exist to satisfy larger demand, but exploitation requires a lead time of years, and may not be undertaken until advances are made in converting coal to liquid or gaseous form for use in transportation and in liquid-fuelled industries. As is true for shales and tar sands, government Research and Development support or price guarantees are important to the advancement of coal technology, because OPEC can still break the market at any time by reducing oil prices.

24. The OECD in general has adequate reserves of coal, with 60% of the world's total recoverable reserves and a reserves-to-production ratio exceeding 100 years. Once again, however, the important exception is Japan who, with insignificant domestic supply and a large steel industry, must remain fully dependent on imports mainly from other OECD countries.

25. The USSR and China contain abundant deposits of coal, and have no foreseeable supply problems.

PROSPECTS FOR NUCLEAR ENERGY

26. Although nuclear energy now provides only about 1% of global energy requirements, it is the only alternative to conventional hydrocarbons which has significant short-term potential. Nuclear power generation may provide 10-15% of total demand in the industrialized world by 1985, and could provide up to 25% of total world demand by the year 2000.

Since there is little prospect of any contribution from fusion power even by that time, our remarks are confined to energy produced by nuclear fission or thermal reactors which require either natural or enriched uranium.

27. Light Water Reactors (LWRs), which use enriched uranium, will be the primary source of nuclear energy in the expanded programs forecast for the immediate future. Heavy Water Reactors (HWRs) such as CANDU, which use natural uranium for fuel, are not expected to dominate the market for a few years, if ever. Advanced reactors such as HTRs (High Temperature Reactors) and SGHWRs (Steam Generating Heavy Water Reactors) may attain commercial importance within the next few years. Fast Breeder Reactors will not be commercially important by 1985, but they have already found an important place in the debate over environmental and security hazards.

28. Soaring prices for natural uranium since 1972 have prompted charges of price-fixing by a cartel of major producers (Canada, Australia, France, South Africa). Whatever the merit of these charges, an OPEC-like denial of access to developed supplies is unlikely, since 87% of the non-Communist world's reasonably assured resources are located in the aforementioned countries plus Sweden. Nevertheless, the still uncertain future market could lead to serious supply problems, and the expansion of nuclear power capacity will also be attended by other problems.

29. Because of the dominant position of reactors which require enriched fuel, the rate of growth of nuclear power will be governed by enrichment capacity as well as by uranium supply. In the absence of better coordinated government and industry policies, shortages may occur in both these factors by the early 1980s. Other factors which are already slowing the projected growth of nuclear power are shortages of capital

or of professional and skilled manpower, and the debates over the environment and nuclear proliferation hazards implicit in nuclear technology. Furthermore, as regards application in areas of low demand, there is also an economically imposed lower limit on the size of the consumption infra-structure, because of a technically imposed lower limit on reactor size. Hence, nuclear power is not a panacea for global energy problems, and rapid growth of nuclear power capacity in the developed countries is certainly not assured. For example, the 1975 OECD forecast of 513 GW installed capacity by 1985 has already been reduced to 325 GW.

HYDROELECTRIC POWER PROSPECTS

30. It is unfortunately true that in the industrialized nations, particularly in Europe and the USA, the potential of hydroelectric power has been almost fully developed. An exception is Norway, which has per capita the highest hydro power potential in the world -- some ten times greater than Canada. As indicated by the Table below, most of the undeveloped potential is in Africa and South America, where it is not likely to be developed quickly. The environmental effects of large scale hydro developments are a cause for concern, as in Egypt and Canada, and major improvements in long-distance transmission technology are unlikely in the near term. Hence on the world scale, hydroelectric power generation will not add significantly to energy production before 1985.

TABLE IX

HYDROELECTRIC POWER POTENTIAL

Region	Percent of Total Potential
Africa	28
South America	20
USSR and China	17
Southeast Asia	16
North America	11
Western Europe	6
Australia	1
Far East	1
Middle East	negligible

Source: Reference 18.

ALTERNATIVE ENERGY TECHNOLOGIES

31. A great deal has been written about alternative technologies which promise to provide clean, renewable sources of energy for the future. Many of these technologies may make a major contribution to the world energy mix by the next century, but none is likely to make a significant contribution by 1985; hence they receive only passing mention here.

32. Nuclear fusion was mentioned briefly in the foregoing section. Progress is being made on the containment problem in the USA, the USSR and in Europe, but it will be some time before lasers or magnetic fields will be able to provide sufficient pressures in high temperature plasmas to allow the fusion reaction to take place on a practical scale. It is not likely that feasibility will be demonstrated before the 1980s and significant numbers of fusion reactors will not be in service until well into the 21st century.

33. Solar energy has obvious potential for the heating and cooling of buildings and, in certain circumstances, for the direct generation of electricity. In countries such as the USA, where the weather and latitude are generally favourable, and the energy consumption in the residential/commercial sector is high, solar heating and cooling may make a contribution by the mid-eighties, particularly because this is the technology which has most captured the public's imagination. But large scale power generation by direct conversion of solar energy is not likely until after the year 2000.

34. Geothermal energy, which is derived from water heated or converted to steam by the high temperatures deep below the earth's surface, has been used for many years on a localized basis in a few countries such as Iceland, Italy and New Zealand. There are indications that exploitable geothermal fields may be widespread and capable of making a significant and low cost contribution to the world energy supply, but the full potential of geothermal energy is unknown and certainly will not be realized before 1985.

35. Tidal power is currently being used to generate electricity in France and the Soviet Union, but its potential is severely limited by the scarcity of suitable sites. If all these sites were developed, the total power generated would provide only about 1% of the world's present power needs. Further, tidal power is not economically competitive at oil prices less than $20 per barrel.

36. Wind power has considerable potential and is receiving a substantial amount of R and D attention in a number of countries including Canada. It is most useful in regions of continuous high winds, such as in high latitudes and offshore areas -- areas where population density tends to be low. Like tidal power, it is very capital intensive. Numerous structural

and aerodynamic problems must be solved. Wind power may prove useful for special applications in remote regions in the near future, but it will be many years before it may be expected to contribute significantly to the world's energy needs.

37. Biomass as a source of energy has captured the imagination of many. The term covers the conversion of organic materials into synthetic fuels. For instance, the massive amounts of garbage produced in the USA could be converted to provide oil equivalent to about 2 per cent of present US consumption. Again, arable land could be used to grow organic materials for conversion to synthetic oil; it has been estimated that if all available land were so employed, 10 per cent of present US needs could be met. But the attraction of disposing of wastes in a productive way must be balanced against practical problems: sorting and processing garbage can be very costly, and using large areas of fertile land to grow fuel is in conflict with the food needs of a hungry world. Biomass cannot be expected to be a significant source of energy before 1985, and probably not before the turn of the century.

38. There are other technologies such as the hydrogen economy, magneto-hydrodynamics (MHD), ocean thermal gradients, fuel cells, and improvements in electrical transmission which may hold some promise for the future. But none can be expected to make a significant contribution this century and certainly not before 1985.

SUMMARY

39. On the assumption of continued economic growth in the industrialized countries, energy demand will continue to grow despite conservation efforts. Up to 1985 at least no new technology or energy source can supply a significant portion of world demand. Nor can nuclear energy developments substantially

moderate the demand pressures on traditional hydrocarbon fuels, amongst which oil will retain its crucial importance.

40. Coal reserves are adequate world-wide, and coal production will increase gradually in most areas (substantially in the USA), but the great potential supply of coal cannot be absorbed until large-scale conversion to liquid or gaseous fuels becomes a reality. This is unlikely to occur by 1985. Similarly, synthetic crude from shale or tar sands will provide, at best, only 5% of the North American demand for liquid hydrocarbons by 1985.

41. Natural gas supply will continue to be important for western countries, particularly those of Europe. The USSR has potentially a huge capacity for export of natural gas, but western countries may not be eager to increase their dependence on the USSR for supply.

42. Most western industrial states, unlike China and the USSR, will remain heavily dependent on oil imports, and it is improbable that even the USA will achieve energy independence. Oil is therefore the energy commodity which will most critically influence world strategy up to 1985, and this will be true even in the unlikely event that nuclear energy fulfills its promise of satisfying up to 15% of world demand by that time. The security problems attendant on nuclear energy development, principally waste disposal, the threat of nuclear weapons proliferation, and the misuse of nuclear materials, will also be important factors in world-wide energy strategies.

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Only the references cited as sources in this Annex are listed below. A more complete list is given in the report bibliography.

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IS NUCLEAR POWER SAFE? IS IT NECESSARY?

1. Even if one could ignore the problem of safeguards to prevent deliberate sabotage of nuclear facilities or misuse of nuclear materials, there would be no consensus of expert opinion on whether rapid large scale development of nuclear power is justified.

2. Distinguished proponents of nuclear power argue objectively that the expectation of personal hazard is negligible,[1] and that the scale of any possible disaster would be acceptable.[2] But the adherents of this view often show disdain not only for the fuzzy opposition of the untutored,[3] but also for the misgivings of their peers.[4] They do not remark in their narrowly rational view the parallel to arguments against the need for a "nuclear

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[1] "A typical coal-fired power plant probably kills about 50 people per year with its air pollution whereas a typical nuclear power plant of the same capacity probably kills an average of 0.01 people per year." Bernard L. Cohen, "Perspectives on the Nuclear Debate", Bulletin of the Atomic Scientists, October 1974, p. 35. Similarly, it is incontrovertible that slips and faults of homeowners installing or servicing solar collectors would make solar power vastly more hazardous, statistically, than nuclear power.

[2] "The argument ... is that morale would be shattered by a single accident killing 10,000 people. However, a large airplane loaded with gasoline crashing into a football stadium could kill that many persons. And ... attendance at later football games would probably not be affected." Cohen, p. 36.

[3] "Surely we can't expect the public to follow these arguments. Even if it did, the public doesn't understand the meaning of probability." Cohen, p. 36. It is worth remarking that some expert probabilists consider the statistical inferences of the nuclear experts to be groundless.

[4] "A few years from now our existing investments in nuclear power will be so massive that major changes in design or siting policies will have become virtually impossible." Joel Primack and Frank von Hippell, "Nuclear Reactor Safety", Bulletin of the Atomic Scientists, October 1974, p. 6.

threshold" in warfare. When the parallel is implicitly recognized, the assertion that all alternatives have been exhausted is used to overcome objections. Thus a very distinguished group of scientists headed by Hans Bethe concluded: "We see no reasonable alternative to an increased use of nuclear power to satisfy our energy needs."[5]

3. Other distinguished observers are neither complacent about the hazards of nuclear power nor convinced that alternatives have been exhausted. The recent "Flowers Report"[6] in the U.K. is a good indicator that the "go slow" approach to fission power, particularly to the development of fast-breeder reactors, is no longer confined to environmentalists. This Royal Commission judged that: "There should be no commitment to a large programme of nuclear fission power until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long-lived, highly radioactive waste for the indefinite future."[7] Flowers himself, a physicist long associated with Britain's nuclear power programs, denigrates such environmentalist groups as the Friends of the Earth but, with allowance for hyperbole, the Royal Commission view shows remarkable similarity to one expressed in a Friends of the Earth book by Amory Lovins: "Governments should suspend their nuclear programmes until enough infallible people can be found to operate them for the next few hundred thousand years..".[8]

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[5] "Scientists Speak Out: 'No Alternative to Nuclear Power'", Bulletin of the Atomic Scientists, March 1975, p. 5.

[6] Report of the Royal Commission on Environmental Pollution. Sir Brian Flowers, F.R.S., was Chairman of the Commission.

[7] Quoted from the Royal Commission Report in "A Warning to Britain: Go Slow on Nuclear Power", Bulletin of the Atomic Scientists, December 1976, pp. 22-23.

[8] Amory Lovins, "World Energy Strategies: Facts, Issues and Options", p. 126.

4. By Flowers' account, it was not until 1974 that the standing Royal Commission thought the environmental risks of nuclear power to be a "fitting subject" for investigation.[9] He subsequently found, in regard to waste disposal, that: "The official response ... is to suppose, like Mr. Micawber, that something will turn up."[10] And in regard to the security of materials in the "plutonium economy" associated with breeder reactors, Flowers states that: "As a nation, we have not studied the problem, nor have the government and its various agencies encouraged us to do so."[11] He does not believe it has been proven that all "reasonable alternatives" to nuclear power have been exhausted. Once again it is Lovins who has provided perhaps the most lucid review of alternatives,[12] leading to the conclusion that it might still be possible to renounce nuclear technologies altogether.

5. Faced with such differing views from the experts, the layman need have no hesitation in voicing an untutored opinion. Indeed, his guidance to political authorities, based on visceral knowledge, may be the best available. Many protests have been mounted and publicized internationally, but the defeat of recent referenda which sought to severely limit the spread of nuclear power plants in several states of the U.S. seem to provide a better guide to broad-based public attitudes.[13] Still, the effect of one major disaster, if it should occur, remains an unknown which will limit irreversible commitment to nuclear power for some time to come.

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[9] Sir Brian Flowers, "A Watchdog's View", Bulletin of the Atomic Scientists, December 1976, p. 25.

[10] Ibid., p. 26.

[11] Ibid., p. 27. The problem cannot long be ignored, since breeder reactors are already in operation in France and the USSR.

[12] Amory Lovins, "Energy Strategy: The Road Not Taken?", Foreign Affairs, October 1976, pp. 65-96.

[13] This is an ironic counterpoint to Cohen's view, indicating that opposition to nuclear power is centred in that portion of the public which is most likely to understand probability.

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GLOSSARY OF TERMS

ABBREVIATIONS

EEC	-	European Economic Community
EMR	-	Department of Energy, Mines and Resources (Canada)
IAEA	-	International Atomic Energy Agency
IEA	-	International Energy Agency (OECD)
NEB	-	National Energy Board (Canada)
OAPEC	-	Organization of Arab Petroleum Exporting Countries (founded in 1968)
OECD	-	Organization for Economic Co-operation and Development
OPEC	-	Organization of Petroleum Exporting Countries (founded in 1960)
Btu	-	British Thermal Unit
Quad	-	One quadrillion (10^{15}) Btu
Q	-	1000 Quad (10^{18}) Btu

DEFINITIONS

ACTINIDES	-	Heavy elements with an atomic number greater than 89. Includes Uranium (U) and Plutonium (Pu).
BOILING WATER REACTOR (BWR)	-	A nuclear power reactor cooled and moderated by light water.
BREEDER	-	A nuclear reactor that produces more fuel than it consumes.
BRITISH THERMAL UNIT (Btu)	-	The amount of energy necessary to raise the temperature of one pound of water by $1^{o}F$ at $39.2^{o}F$.
CANDU	-	A Canadian developed nuclear power reactor system. The name is derived from CANada Deuterium Uranium, indicating that the moderator is deuterium or heavy water, and that the fuel is natural uranium.

COAL GAS - An artificial gaseous fuel produced by pyrolysis of coal. Use of coal gas stopped when inexpensive natural gas became available.

CRUDE OIL - Petroleum liquids as they came from the ground.

DISTILLATE FUELS - Commonly used to describe diesel oil and the light fuel oils used for residential heating. Could correctly by applied to all liquid petroleum fractions since all are, in fact,distilled.

ENRICHMENT - The process of increasing the concentration of fissionable uranium-235 in uranium from the naturally occurring level to that required to sustain fission in a nuclear reactor. Uranium enrichment requires very very expensive facilities and great quantities of electricity.

FAST BREEDER REACTOR (FBR) - A reactor which operates with neutrons in the "fast" energy range (greater than 0.1 million electron volts), using enriched fuel. The principal reaction envisiged for most FBRs is conversion of non-fissionable U-238 to fissionable Pu-239.

FERTILE MATERIAL- Potential nuclear fuels which can be transformed in a reactor into fissile material by neutron capture. Th-232 converts to U-233, and U-238 to Pu-239.

FISSILE MATERIAL- Nuclear fuels in which the nuclei, when hit by neutrons, split and release energy plus further neutrons which can result in a chain reaction. U-233, U-235 and Pu-239 are examples of significant fissile materials, but only U-235 occurs naturally.

FISSION - The splitting of a heavy nucleus into two parts accompanied by the release of energy and two or more neutrons. It may occur spontaneously or be induced by capture of bombarding particles, particularly neutrons.

FUEL REPROCESSING	-	The chemical or metallurgical treatment of used fuel from a nuclear reactor for the purpose of recovering and decontaminating fissionable materials. Because of the intense radioactivity of spent fuels, most reprocessing operations must be performed behind massive shielding and by remote control.
FUSION	-	The combination of two atomic nuclei to yield one larger nucleus whose mass is less than the aggregate mass of the original nuclei. The lost mass appears as energy in the same manner as in fission.
GASEOUS DIFFUSION	-	The principal process for enrichment of uranium.
GASIFICATION	-	Commonly refers to the conversion of coal to high-Btu synthetic natural gas (SNG). Can also refer to the conversion of any organic material either to SNG or to low-Btu "power gas" for on-site conversion to electricity.
HEAVY WATER	-	Deuterium oxide; water in which all hydrogen atoms have been replaced by deuterium.
KEROGEN	-	A resinous hydrocarbon material that is the chief organic constituent of oil shale. When heated, kerogen releases vapours that can be converted to shale oil, which in turn can be refined to produce petroleum products.
LIQUEFIED PETROLEUM GAS (LPG)	-	"Bottled gas" consisting mainly of propanes and butanes recovered from natural gas and in the refining of petroleum.
LIQUEFIED NATURAL GAS (LNG)	-	Natural gas which has been cooled to about -160°C for shipment or storage as a liquid. High pressure cryogenic containers must be used.

MAGNETOHYDRO-DYNAMIC (MHD) GENERATOR - An expansion engine in which hot, partially ionized gases are forced through a magnetic field. Movement of the electrically conducting gas through the field generates an electric current that is collected by electrodes lining the expansion chamber. MHD is thus an efficient way to generate electricity from the combustion of fuels without going through an intermediary steam turbine. If exhaust gases from the expansion chamber are used to operate a steam turbine, the efficiency of fuel use is further increased.

MEGAWATT (Mw) - A unit of power equal to 1000 kilowatts or 1 million watts. One Gigawatt (Gw)= 1000 Mw.

MODERATOR - A material such as heavy water or graphite used to slow down fast neutrons produced by fission thereby increasing the likelihood of further fission.

NAPHTHA - A petroleum fraction intermediate between kerosine and gasoline, and containing components of both. It is expected to be used increasingly as a raw material for the production of synthetic natural gas.

NATURAL GAS - A gaseous fossil fuel generally found in association with oil and whose composition varies with its origin. Most unprocessed natural gases contain methane, ethane, propane, and heavier hydrocarbons. Varying quantities of nonhydrocarbon gases are usually also present. Propane and heavier hydrocarbons are usually removed by liquefication and sold as liquefied petroleum gas (natural gas liquids) or separated and sold individually.

OIL SANDS - Sands and other rock materials which contain crude bitumens and other mineral substances in association therewith. Crude bitumen is defined as a mixture mainly of hydrocarbons that in its naturally occurring viscous state is not recoverable at a commercial rate through a well.

OIL SHALE - A fine-grained, laminated sedimentary rock that contains oil-yielding material called kerogen. In the U.S., oil shale is found primarily in Colorado; much larger deposits exist in several other countries.

PETROLEUM - Crude oil and natural gas, although the term is frequently used to refer only to the oil. Petroleum contains a much greater concentration of lower molecular weight hydrocarbons and a higher ratio of hydrogen to carbon than does coal.

PLUTONIUM (Pu) - A heavy radioactive metallic element with an atomic number of 94 whose principal isotope, Pu-239, is a major fissile material. It is produced artificially in reactors through neutron absorption of U-238.

PRESSURE TUBE REACTOR - A power reactor in which the fuel is located inside hundreds of tubes designed to withstand the circulation of the high-pressure coolant. The tubes are assembled in a tank containing the moderator at low pressure. (See CANDU).

PRESSURIZED WATER REACTOR (PWR) - A power reactor cooled and moderated by light water in a pressure vessel surrounding the core. The water is pressurized to prevent boiling in a closed primary loop and is circulated through a heat exchanger which generates steam in a secondary loop connected to the turbine.

PYROLYSIS - In the context of energy, pyrolysis (also called destructive distillation) is the heating of organic materials or solid wastes in the absence of oxygen with provision for recovery of the desired combustible products.

PRIMARY ENERGY - Refers to the amount of energy available to the final consumer (secondary energy) plus conversion losses and waste used by the energy supply industries themselves. Conversion losses refer to losses in processing of refined petroleum products, for example, or the losses due to inefficiencies in the conversion of fossil fuels into electricity.

RESERVE - That portion of an identified resource from which a usable energy commodity can be economically and legally extracted at the time of determination using currently available technologies. Usage varies, but "proven" reserves of petroleum are usually thought of as virtually certain to be recovered under current conditions, while "probable" reserves should have at least a 50% chance of recovery.

SYNTHETIC NATURAL GAS (SNG) - A manufactured gaseous fuel generally produced from naphtha or coal. It contains 95 to 98 percent methane, and has an energy content about the same as that of natural gas.

THERMAL BREEDER - A breeder reactor that operates with neutrons in the thermal energy range; that is, neutrons with energies less than 1 electron volt. The reaction most often considered for use in thermal breeders is conversion of nonfissionable thorium-232 into fissionable uranium-233.

THORIUM (Th) - A heavy slightly radioactive metallic element with an atomic number of 90 whose naturally occurring isotope Th-232 is fertile and the source, when irradiated in a reactor, of U-233.

TRITIUM - A radioactive isotope of hydrogen with an atomic number of three, it has one proton and two neutrons in its nucleus. It is produced in heavy-water-moderated reactors by neutron capture of deuterium, and is expected to be used as a fuel in fusion power plants.

URANIUM (U) - A heavy slightly radioactive metallic element with an atomic number of 92. As found in nature it is a mixture of the isotopes U-235 (0.7 percent) and U-238 (99.3 percent). The artificially produced U-233 (see Thorium) and the naturally occurring U-235 are fissile. U-238 is fertile.

URANIUM DIOXIDE (UO_2) - Used, with the natural concentration of U-235 unchanged, as the fuel in CANDU power reactors because of its chemical and radiation stability, good gaseous fission product retention, and high melting point.

YELLOWCAKE (U_3O_8)- The form in which uranium leaves the mill-head to be further processed into natural or enriched uranium fuel. Estimated world resources of uranium are classified according to the price per pound of yellowcake.

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CONSULTING AGENCIES

In order to gather maximum objective information on the study, the Study Team established contact with a variety of agencies outside the Department of National Defence. Within the Canadian Federal Government these included:

Department of External Affairs
Department of Energy, Mines and Resources
Department of Industry, Trade and Commerce
Ministry of State for Science and Technology
National Energy Board
Senate Special Committee on Science Policy
Parliamentary Library
Uranium Canada Ltd.
Atomic Energy of Canada Ltd.

Outside the Canadian Federal Government, they included:

Ontario Hydro
International Institute for Strategic Studies (London)
Hudson Institute (New York)
United Nations Secretariat (New York)
United Nations Institute of Training and Research (UNITAR), (New York)
Organization for Economic Cooperation and Development (Paris)
Commission of the European Communities (Brussels)
North Atlantic Treaty Organization (Brussels)
U.S. Atomic Energy Commission (Washington, D.C.)
British Nuclear Energy Society
Central Policy Review Staff (London)
U.K. Parliamentary Select Committee on Science and Technology
Oxford University, U.K.
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British Petroleum (London)
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and several multi-national corporations active in the energy sector.

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"The Impact of Energy on Strategy: World Future Society's Special Forum on Energy 1974: Some Notes, Conclusions and Ideas for Research", written by LCol J.W. Storr, Maj. A. Nellestyn and Dr. K.E. Solem. Directorate of Strategic Analysis, Ottawa, Staff Note No. 74/11, July 1974. (Unclassified).

"The Impact of Energy on Strategy: The Hydrogen Economy and the Transmission of Electricity", written by Maj. A. Nellestyn. Directorate of Strategic Analysis, Ottawa, Staff Note No. 74/12, July 1974. (Unclassified).

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1. Only those references cited in the report are given here, exclusive of Annex B which contains its own list of references. A separate list of ORAE reports on energy topics is presented at Annex E.

2. Comprehensive bibliographies on energy may be found in the January 1, 1977 edition of "Library Journal", and in the annual editions of "The Energy Index" series. Periodicals found most useful in staying abreast of current developments include "The Petroleum Economist","Foreign Policy", "Foreign Affairs", "The Economist", "The Bulletin of the Atomic Scientists", "Science", and the "International Herald Tribune".

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This report deals with the effects of the growing energy shortage on the world strategic picture. Since 1973 both the supply and price aspects of energy have been factors of great importance in political, economic and military affairs. Over the past two years the Directorate of Strategic Analysis has studied future trends and interpreted events related to the energy crisis; the report summarizes this work. The importance of a firm US policy in the energy field is emphasized; however, the implications of the new US policies announced in April 1977 have not yet been fully explored although it is clear that they show some concern for easing international tensions.

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