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THE POTENTIAL DISPLACEMENT OF PETROLEUM IMPORTS BY SOLAR ENERGY TECHNOLOGIES

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FOREWORD

One reputed benefit of solar energy is that its utilization could relieve the United States of our nation's dependence on foreign—i.e., insecure—sources of petroleum. This would not only be beneficial to the U.S. economy (specifically, its deficit balance of trade) but could also have other social and political benefits. This report attempts to define precisely the costs and benefits of our present reliance on foreign sources of petroleum and offers one estimate of the potential displacement of these sources by solar energy. As such, it should be of particular interest to the policy and analysis divisions of the U. S. Department of Energy as well as to other agencies of the federal government concerned with international trade.

The authors would like to express their appreciation to former and present SERI staff whose ideas, comments and suggested revisions did much to improve the study. These include: John Ashworth, Dennis Costello, James Doane, Donald Hertzmark, Jean Neuendorffer, Dennis Schiffel, Melvin Simmons, and Robert Witholder.

Robert McNown is an associate professor in the Department of Economics at the University of Colorado, Boulder, on leave for the academic year. Gary Mahrenholz, a Ph.D. candidate in the Department of Economics, University of Colorado, Boulder, is presently an analyst with the Congressional Budget Office.

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SUMMARY

Recent analyses of the U.S. energy crisis show that, although a declared policy goal is reduced reliance on imported petroleum, the United States is becoming more and more dependent upon it. This report addresses two aspects of this contradiction. First, what are the costs of our dependence on foreign petroleum? That is, what are the social, economic, and political costs ascribable to purchasing foreign oil? Second, if these costs are significant, how can they be reduced? This report specifically examines the capabilities of solar energy technologies to reduce our current use of petroleum as an energy resource and, concomitantly, the amount of petroleum imported. Given estimated levels of market penetration by solar energy as projected by computer simulation models, what amount of the petroleum presently imported could be displaced by renewable resources?

In 1977, oil imports were the single largest import item by dollar value; the United States paid out over $45 billion that year for foreign oil. That figure was reduced to $42 billion in 1978 but rose to an estimated $58 billion in 1979. As such, oil constituted the largest negative entry on the U.S. balance of payments accounts and contributed greatly to the trade deficit.

Traditional means for alleviating balance of payments deficits (e.g., increasing exports, encouraging investment, or allowing currencies to "float" relative to one another) have not been particularly effective in this case because oil producers can exercise monopolistic powers. Therefore, to reduce the balance of payments deficit caused by American dependency on foreign petroleum, there is no alternative but to simply reduce the amount of oil imported. This can be done in one of two ways: by reducing the amount of energy consumed or by developing alternative, renewable energy sources to displace current uses of petroleum. Solar energy technologies can be one means of advancing the second option.

Before estimating the amount of petroleum that solar energy technologies might replace by the year 2000, we present a number of social, political, and economic "costs" and "risks" that can be ascribed to U.S. oil dependency to allow a more complete accounting of the "real" costs of relying on foreign oil. These include the strategic risk of depending on exogenous sources of oil, the effect of international oil prices on the domestic rate of inflation, the costs of foreign investments ("petrodollars") in the domestic economy, the restrictions that foreign dependencies might place on U.S. foreign policy, and, in general, the opportunity costs foregone by purchasing large amounts of petroleum from foreign sources. Combined, these social, political, and economic costs suggest that the "price" of imported oil is significantly higher than the strict market clearing price. This serves as a partial rationale for developing solar energy technologies as a means to alleviate the costs and risks incurred by American dependence on foreign oil.

The principal device for estimating the amount of oil that might be displaced by solar energy technologies by the year 2000 is a computer simulation model developed by the MITRE Corporation, the System for Projecting Utilization of Renewable Resources (SPURR). The SPURR model compares the probable range of costs for both conventional and solar technologies based upon market penetration curves, in four primary energy markets: heating and cooling of residential and commercial buildings; agricultural and industrial process heat; the utility sector, covering the generation of electricity; and a synthetic fuels and product market. The analysis of each primary energy market by geographic region generates a mix of conventional, solar, and synthetic fuel technologies to meet new and replacement demand for energy.

The SPURR model has a number of methodological limitations that caution against the complete acceptance of its projections of market penetration levels and subsequent oil displacements. For example, the slope and inflection points of market penetration curves for solar technologies are, at best, only estimates. The response to government programs (either positive or negative) is assumed. And the data, both current and projected, are suspect. Still, SPURR can provide rough first-approximation guidelines for bounding the magnitude of oil-displacement levels.

Simulations with the SPURR model under the conditions stipulated by the Administration's National Energy Plan (NEP) indicate that solar energy will displace a small but significant amount of oil from domestic energy consumption. The aggregate amount of oil displaced by various solar energy technologies will reach 0.65 quad per year, or 320,000 barrels per day, by the year 2000. With respect to the U.S. balance of payments problem, the impact can be considerably magnified. Oil imports by the year 2000 are projected to be no greater than 8.6 million barrels per day, or 17.4 quads per year, assuming that the United States can live within the import quota established by President Carter. Therefore, if one can assume that all the oil displaced by solar energy is imported, solar energy market penetration levels as estimated by the SPURR model will result in a 3.7% reduction in oil imports by the year 2000. In dollars, the impact on the balance of payments would be close to $3 billion, assuming that oil would be selling for a conservative $25 a barrel (1978 dollars) by the year 2000. In terms of the $16 billion deficit in the 1978 balance of payments, this represents an 18% reduction in the trade deficit.

The diffusion of solar energy technologies will also displace large amounts of coal and nuclear energy in domestic energy consumption, perhaps as much as 3.0 quads by the year 2000. Combined with the reduction in oil consumption, these replacements should also produce a significant decrease in the level of environmental pollution caused by consumption of fossil and nuclear fuels.

Potential oil displacements by passive solar technologies were not included as part of the SPURR model simulations. Based on results generated by a computer simulation model still under development at the Los Alamos Scientific Laboratories, we estimate that passive solar designs for new houses could displace 0.024 quad of oil by the year 2000. This estimate would be significantly higher if residential and commercial retrofit markets were included.

Finally, we estimate the oil displacement levels if the nation were to employ gasohol as an energy resource. Based on a U.S. Department of Energy (DOE) report, we project that close to 3.0 quads of oil per year could be displaced in the transportation sector. This is almost 17% of the 8.6 million barrels of oil per day currently imported.

The following table summarizes these estimates:

POTENTIAL OIL DISPLACEMENT BY SOLAR ENERGY BY THE YEAR 2000

User Sector	Petroleum Displacement per Year — Million of Barrels	Petroleum Displacement per Year — Quads
Utilities	48.5	0.27
Residential Heating and Cooling	48.58	0.27
Agricultural and Industrial Process Heat	19.79	0.11
Passive Solar Applications	4.3	0.024
Transportation (Gasohol)	525.6	2.92
TOTALS	646.77	3.59

Certain reservations qualify these estimates. First, the bases for reaching the various estimates were quite different: they relied on different methodologies, assumptions, and data. Second, petroleum is an extremely fungible commodity. Solar energy technologies may indeed replace millions of barrels of oil now used daily to produce electricity, heat homes, or drive automobiles. However, this displacement might not result in reduction of oil imports because the displaced oil would be transferred to meet other domestic energy requirements, such as maintaining low gasoline prices. Third, more than 80% of the estimated oil displaced is in the transportation sector. This figure is based on our current best judgment of the amounts of ethanol and methanol American industry can produce and, even more directly, the amounts of gasohol the consumer will purchase. Further uncertainties are introduced in calculating Btu equivalents for gasohol as opposed to gasoline. Many of these values have not been empirically validated or demonstrated over long periods of time. Therefore, the transportation section estimates, particularly, must remain open to revision.

Despite these caveats, even conservative estimates of how much petroleum solar energy technologies can displace by the year 2000 could have a substantial effect on correcting the U.S. balance of payments deficits if policies can be established to guarantee that the oil displaced is, in fact, imported. This could raise the price of oil in some parts of the country because of increased transportation costs. However, if one can add a "national security" component to the economic cost of imported oil, reduced dependence (or increased American energy independence) could be considered adequate compensation for the higher price.

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SECTION 1.0

INTRODUCTION

A recent, well-publicized analysis of the energy situation in the United States emphasized the following contradiction:

> While the declared aim of American policy is to reduce the use of imported oil, the United States is in fact becoming more and more dependent upon it. Between 1973 and early 1979, U.S. oil imports almost doubled, and had begun to provide half of the nation's oil. But current trends in the U.S. will be even more dependent on imported oil in the 1980's. (Stobaugh and Yergin 1979, p. 4)

Two questions stem from this observation: First, does it matter? Second, if it does matter, how can the problem be resolved?

As to the first question, some economists would argue from a free-trade perspective that the growing American dependence on foreign petroleum should be of no more concern than New England's reliance upon Kansas wheat. That is, in a world characterized by the free exchange of commodities, commerce among nations should be based strictly on comparative advantage. If petroleum is cheaper to purchase from Saudi Arabia, the United States should buy Arabian oil and let U.S. exports to that country and the free-floating value of currency react to correct whatever trade imbalances might occur. However theoretically comforting this approach might be, in the political world of energy supplies and international trade it simply is not feasible. As Russett (1979, p. 194) notes:

> In a free market with all the conditions assumed by the Ricardian comparative advantage argument, economic rationality might be indifferent between importation and domestic production. But in a world of producer cartels and otherwise less than freely competitive markets, dependence on foreign suppliers may bring special costs. Energy shortage, moreover, is likely to entail political sensitivity beyond that attributable to purely economic considerations.

Energy resources are much too critical to the economic well-being of the nation to merely assume that they will always be available for a price. Foreign suppliers have already shown a willingness and ability to interrupt petroleum supply for political reasons. Similarly, the economic dislocations caused by oil price increases can have severe effects on the domestic economy well beyond strictly economic ramifications. Furthermore, there is the cost of risks incurred by a reliance on foreign energy resources (e.g., the risk of having fuel shortages imposed for political reasons, as in 1973-74). Thus, sociopolitical costs and risks are attached to the availability of oil that add to the purely economic calculation, even if the "social costs imposed by all these risks cannot be quantified very satisfactorily . . . " (Schurr et al. 1979, p. 429). These costs need to be estimated and included in assessing the total cost of U.S. dependence on foreign oil. As Stobaugh and Yergin (1979, p. 8) ask, "What are the total costs and benefits involved in any decision, who profits, and who pays? We believe that some attempt, however rough, has to be made to assess the total 'social costs' embedded in the problem." President Carter's recently announced decision to limit foreign petroleum imports to their 1977 ceiling argues strongly that these concerns are much more than academic; that, in fact, dependence on foreign oil is a concern of national importance.

Much of the debate as to why it matters and how much it matters has been devoted either to strictly economic costs (direct or indirect) or to political posturing. The analyses to date generally have been restricted to a specific issue, such as effects on unemployment (Black 1978) or nonproliferation (Nye 1978). Even in economic analyses, basic uncertainties in supply and demand projections and the problematic relationships between energy supplies and other economic indicators (e.g., rates of inflation, GNP, and unemployment) reduce precise estimates to little better than qualitative judgments. For example, Stobaugh and Yergin (1979, p. 5) assert that:

> A large, sudden increase in oil prices would have serious indirect effects [on the domestic economy]. It would exacerbate inflation, place further strains on the international monetary system, and sharply contract the demands for goods and services, further reducing national income. In short, the economic consequences would likely be a major recession, or possibly even a depression.

There is a clear need for analysis with a broader perspective than just the economic consequences, but political evaluations are even more prone to rhetoric and supposition than economic analyses. Still, it should be obvious that political and social criteria are important elements that somehow must be blended into a socioeconomic cost-benefit analysis to achieve full appreciation of the total "cost" of the present and growing U.S. reliance on imported petroleum.

Assuming that there are pressing political and economic reasons for reducing or eliminating U.S. dependence on foreign oil supplies, how might this best be done? One proposal has been the use of solar energy technologies. Barry Commoner (1979, p. 61) claims that by using solar energy technologies and natural gas, "it would be possible to eliminate all oil imports over the first twenty-five year period . . . without increasing the present rate of producing domestic oil, coal, and nuclear power." The Federal Energy Agency's (FEA) Project Independence was commissioned by President Nixon to find ways to eliminate U.S. oil imports; Project Independence's analysis of the potential for solar energy contributions suggested that solar energy could be saving the United States from 16 to 44 million barrels of fuel oil per day by the year 2000, (depending on whether solar energy technologies were instituted on a "business as usual" or an "accelerated" basis, respectively). This level of solar penetration would eliminate all petroleum imports. However, more recent analysis has shown the estimates to be highly unrealistic. The FEA report admits that these estimates were meant to be upper bounds for oil displacements (FEA 1974).

This study delineates a number of economic and political reasons why U.S. policy makers should at least stabilize, or better, minimize the amount of imported petroleum. Using these rationales as a basis, the report estimates quantitatively how much foreign petroleum different solar technologies might displace by the year 2000. These estimates are broken down by end use (e.g., utility power generation, industrial process heat) whereas the Project Independence study was broken out by solar technology. The estimates presented here were also disaggregated by geographic region because different parts of the country have different solar characteristics (i.e., the Southeast has greater solar insolation than the national average, while the Northern Plains have greater wind system potential than the West Coast), and, concomitantly, some regions are more dependent upon foreign oil imports than others.*

This report then, serves two purposes. First, it includes an economic and political analysis of the oil import question to motivate the requirement for reducing oil imports. Second, it offers one estimate of the amount of imported petroleum that could be displaced by solar technologies. The socioeconomic analysis is presented in Sections 2.0 and 3.0; Section 2.0 frames the analysis from perspectives of macroeconomics and international trade theory while Section 3.0 is much more issue-specific. Section 4.0 presents the actual oil displacement figures that might be expected by the year 2000, given certain economic growth scenarios and levels of solar technology market penetration; these are largely based on a computer simulation model. Finally, Section 5.0 summarizes the analysis and findings in a policy context. Appendix A discusses in greater detail the computer simulation model used to make the displacement estimates. Appendix B focuses on the National Energy Plan scenario incorporated into the energy computer simulation model.

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*For example, Knight (1979, p. A14) states that New England receives 80% of all its energy from oil, compared with a national average of 49%. Furthermore, 79% of that oil is imported from OPEC sources.

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SECTION 2.0

ECONOMIC THEORY AND BALANCE OF PAYMENTS

2.1 INTRODUCTION

Approximately half of the petroleum presently consumed in the United States is imported. Close to 40% of imported American oil supplies currently originate in the Middle East; almost as much is imported by the United States from continental Africa.* There is no indication that this amount will decline within the near future (Tanner 1978), even given the recent price rises set by the Organization of Petroleum Exporting Countries (OPEC) and the prospects of major oil finds in the western hemisphere (see Metz 1978; Corrigan 1978). Therefore, it is worthwhile to examine the socioeconomic implications that might be ascribed to American dependence on foreign petroleum. In most cases, empirical evidence and relationships are lacking or, where available, are often inconclusive. (Those areas that can be described by empirical estimates are noted.) The following two sections identify possible social, political, and economic issues relating to U.S. dependence on foreign petroleum sources as preliminary to later arguments supporting solar energy alternatives as ways of reducing the balance of payments deficits and relieving American dependence on foreign—especially Middle East and African—petroleum.

This section examines three issues of particular relevance to the U.S. Department of Energy (DOE). First, it offers some evidence to calibrate the assumed but untested "conventional wisdom" that balance-of-payment deficits harm the American economy and body politic. Later, we present a number of specific policy issues in which oil dependence and trade deficits could have a significant, dangerous effect. Where possible, these relationships are empirically supported. Taken in sum, this analysis is a first approximation of the social and economic costs incurred by the United States because of its dependence on foreign sources of petroleum; as such, it represents substantive political and economic underpinnings for proposing and developing new energy technologies and policies to ameliorate that condition. Second, the analysis provides concrete examples describing oil imports in terms of both dollar flow and energy consumption (or quads). Finally, it offers specific issues for later research, thus giving more precise estimates of the magnitude of the problem and the effects of policies designed to resolve it; for example, what would be the effects of a certain number of quads provided by solar energy on the amount of oil imported, the total U.S. balance of trade, and the domestic rate of inflation? This last set of questions serves as preparation for subsequent analysis of the amount of foreign oil that solar energy technologies could be expected to replace and the economic and social ramifications accorded that level of displacement.

The socioeconomic cost-benefit analysis is presented in two parts. The first part (Section 2.0) examines the general issue of balance of payments deficits from the perspective of economic theory, specifically, from macroeconomics and international economics. This discussion introduces the general accounting and theoretical concepts as they structure the analysis of trade deficits and as they affect the domestic and interna-

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*According to the DOE Energy Information Agency, in 1977, 37.9% and 37.7% of the petroleum imported by the United States came from the Middle East and Africa, respectively; by a wide margin, the two largest suppliers were Saudi Arabia (499.8 million barrels) and Nigeria (409.8 million barrels).

tional economic system. Although the arguments are valid for any commodity or asset exchanged across national borders, the emphasis and examples here deal with petroleum. The second part (Section 3.0) is much more issue-oriented. It details specific policy situations and issues that might result from a growing national balance of payments deficit or a dependence upon a limited number of suppliers of a strategic material. It examines possible political and social implications as well as the economic costs of oil dependency.

2.2 ECONOMIC PRINCIPLES

As a point of departure, the costs of petroleum imports are examined using a balance of payments framework. From this perspective, it is clear that a large volume of oil imports imposes economic costs in the form of reduced levels of other imports, increased U.S. exports of goods and services, and/or reduced net capital flows from the United States (i.e., reduced investments by U.S. nationals and corporations in the rest of the world or increased foreign investment in the United States). Balance of payments deficits also can lead to depreciation of the dollar, a greater reliance on restrictions of capital flows and international trade, and the elevation of balance of payments considerations over domestic economic conditions in economic stabilization policy.

The examination of the economic costs of oil imports is based on the framework adopted for balance of payments analysis and the interpretation of the data in light of the economic concepts. It is useful, therefore, to define the accounting framework and the determinants of a balance of payments deficit in both the accounting and theoretical senses. Contrary schools of thought are examined in a later section.

2.2.1 Balance of Payments Accounting

Table 2-1 presents the 1977 U.S. balance of payments statement under three major headings: current account, capital account, and official transactions. The economic costs of oil imports are examined using the official reserve transaction concept of the U.S. balance of payments, under which the balance of payments is defined as an accounting of all economic transactions between the United States and the rest of the world. In this concept, the surplus or deficit offset occurs when the sum of private transactions between U.S. nationals and the rest of the world requires official government transactions to offset an imbalance in private transactions. For the purpose of this paper, then, a balance of payments deficit is taken to mean a deficit in official reserve transactions. That is, if Americans purchase from abroad more than they sell, the federal government must make up the difference through its official transactions with foreign governments. The sudden increase in the value of imports that resulted from rising oil prices in 1974 produced such a deficit in U.S. official transactions with the rest of the world.

Entries under the current account include primarily merchandise trade, payments for travel and transportation, and net returns from foreign investment. Oil imports manifest themselves as debits to the U.S. balance of merchandise trade. To the extent that these imports are financed by increased U.S. exports or reduced U.S. imports of other goods, the negative contribution of oil imports to the merchandise trade balance would be neutralized. The balance on current account adds payments for travel and transportation, government and private transfers to and from foreign nationals, net military payments, and the net return from foreign investments abroad. There is presently a large flow of income from these investments into this country. As foreign investment in the United

States grows, it will lead ultimately to a growing flow of income out of the country and an increasing negative entry to the balance on current account.

Table 2-1. U.S. BALANCE OF PAYMENTS, 1977

Payment Category	Amount (billions of dollars)
Current Account	
Exports of merchandise	120.6
Imports of merchandise	-151.6
Merchandise trade balance	-31.1
Travel and transportation (net)	1.7
Net military transfers and sales	1.3
Income on U.S. investments abroad	32.1
Payments on foreign investments in United States	-14.6
Net government and private transfers	-4.7
Balance on Current Account	-15.2
Capital Account	
Statistical discrepancy	-1.0
U.S. investment abroad	-34.4
Foreign investment in United States	13.7
Official Transactions Balance	-36.9
Official Transactions	
Changes in U.S. liabilities to foreign official agencies	36.9
Changes in gold and other reserve assests	0.0

Source: Survey of Current Business, S-3, July 1978.

Any deficit on current account must be offset by some combination of capital flows and official transactions. The capital account summarizes all capital flows into and out of the United States (other than official transactions between governments and international agencies), including direct investments by corporations, transactions in corporate stocks and bonds, purchases and sales of government securities by private firms and individuals, and changes in holdings of bank deposits. Any such investment abroad by an American citizen or firm entails a flow of funds into the country and is a credit to the balance on capital account. For example, when OPEC nations invest their oil revenues in U.S. corporations or assets, this appears under the capital account as a positive entry that offsets the deficit incurred on the current account.

Finally, any cumulative deficit from the current and capital accounts must be financed by official settlements between the U.S. government and foreign governments or international agencies such as the International Monetary Fund. Generally called the official settlements or transaction balance, this entry is a measure of official government actions taken to compensate any imbalance resulting from the current and capital account transactions of private firms and individuals. Deficits are settled with U.S. official reserve assets or debit instruments issued to foreign official agencies. Reserve assets include gold, convertible foreign currencies, reserve position in the International Monetary Fund, and Special Drawing Rights (SDR). Debt instruments include marketable or nonmarketable short- and medium-term securities issued by U.S. government agencies or American banks. Because U.S. reserve assets and the willingness of foreign officials to hold U.S. securities are limited, a deficit leads to pressures for devaluation of the dollar in the foreign exchange market (Kemp 1975).

To the extent that the U.S. government wishes to prevent a balance of payments deficit leading to depreciation of the dollar, it must obtain foreign exchange from other governments or sell gold to purchase the surplus American dollars. In the past, the United States could usually rely on other governments to perform this stabilization because it was in their best interests to avoid a depreciation of the dollar due to its pivotal role in the international economic system. Recent events and policy actions, including President Carter's decisions to issue financial securities denominated in foreign currency and to commit part of American gold stock to the stabilization of the dollar, indicate that the United States will have to rely increasingly on its own resources to stabilize the dollar (Frankel 1979, pp. 303-304). Because such resources are limited, it is clear that the United States cannot simultaneously sustain a balance of payments deficit and avoid further depreciation in the dollar (Mudd and Wood 1978).

2.2.2 Economic Theory and Trade Deficits

The preceding paragraphs delineate the basic accounting conventions in the balance of payments statement, but accounting relations say little about the causes and effects of balance of payments deficits. We need, then, to examine what economic theory tells us about the causal relationship, especially in the context of petroleum transactions. Most current discussions of the U.S. balance of payments problem cite the large volume of oil imports as the key source of the present problems, as evidenced by the simple fact that oil imports account for the single largest import item by dollar value—$45 billion in 1977, over $42 billion in 1978, and an estimated $58 billion in 1979—an amount equal to 30% of all U.S. merchandise imports (Mudd and Wood 1978). Hence, it is not difficult to argue that oil imports have been a principal and growing factor in the continuing U.S. balance of payments deficit, especially as the overall trade deficit declines while the oil export component increases.

Some economists argue that a country's balance of trade or balance of payments position is determined more by natural macroeconomic activity than by changes in particular items on the balance sheet (Frankel and Jacob, eds. 1976; Jai-Hoon 1978). This view questions the relevance of any particular item in the trade accounts, regardless of size, and concentrates instead on other macroeconomic indicators such as the growth in the money supply, size of the government deficit, relative rates of inflation, and relative rates of economic growth as the important determinants of the balance of payments position. For the policy maker, however, this school of thought has two major shortcomings. First, it is valid only if extreme assumptions are made about which economic variables are autonomous and which are dependent. For example, an empirical relationship has been demonstrated between large government deficits and large current account deficits (Jai-Hoon 1978). The issue remains, however, as to which, if either, of these two deficits is causal in relation to the other. Similar objections confront the other macroeconomic variables considered to be the driving factors in the U.S. balance of payments problem.* Different domestic macroeconomic policies and variables will affect the directions and magnitudes of the components of the balance of payments statement. Certainly imports and exports are affected by relative prices of foreign versus domestic goods and by relative rates of growth in aggregate demand in various countries. However, this should not preclude the possibility that exogenous factors can also influence the signs and magnitudes of individual entries; the quadrupling of oil prices in 1974 had an impact on oil imports, and hence the total import bill, which strongly influenced the selection and effects of domestic economic policies.

A second reason for considering individual components in the balance of payments accounts is that some individual items may contribute significantly to the overall balance of payments position in ways not immediately apparent. For example, it is often pointed out that a large fraction of the U.S. oil import bill returns to the United States in various forms of investment by petroleum exporters. From this perspective, the net impact of oil imports on the American balance of payments position is considerably less than the billions paid to the OPEC nations. However, the "petrodollar" method of financing American petroleum imports does entail real economic costs to the United States beyond the net exchange. Valuable domestic resources are sacrificed in the production of U.S. exports; heavy investment in the United States by foreigners will entail large flows of investment income out of the country in the future. This argument is not meant to suggest a policy of no trade between nations. Oil imports clearly provide significant benefits to the U.S. economy. Rather, the main point here emphasizes that the trade deficits partially created by oil imports, but currently offset by foreign investments in the U.S. domestic economy, can impose significant costs in terms of future U.S. balance of payments that do not appear in the current balance of payments accounting.

Theories of automatic adjustment to equilibrium or flexible exchange rates in balance of payments accounting similarly deny the importance of particular items. Under flexible exchange rates, payment surpluses or deficits will automatically be corrected through currency appreciation or depreciation (Friedman 1953). Such adjustments are hardly costless, however, for currency depreciation can fuel domestic price inflation to the extent that an economy is open (Dornbusch and Krugman 1976; McNown 1975). In correcting the initial trade deficit, currency depreciation will necessarily lead to an increase in exports and a reduction in other imports, thereby imposing real domestic economic costs. To the extent that U.S. oil imports are financed by a reduction in other imports, this entails a reduced availability of goods consumed by Americans. Likewise, if the oil imports are paid for by increased U.S. exports of goods and services, these commodities would be less available for domestic consumption (Economic Report of the President 1978).

Fixed exchange rate policies of balance of payments adjustment likewise involve important adjustment costs (Mundell 1963). Any movement from an initial position of trade deficit to a balance of payments equilibrium must entail corrective movements of capital or other trade items. In the case of adjustments in other trade items, the costs are the same as under flexible exchange rate regimes. If a trade deficit is compensated through reduced U.S. investment abroad and/or increased foreign investment in the United States, such capital flows will have long-range effects on the current account

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*See, in particular, the literature on the monetary approach, in which domestic rates of inflation and rates of monetary growth become determined by corresponding variables in the rest of the world. This approach also reverses the direction of the effect of changes in real GNP on the balance of payments from that hypothesized by the Keynesian view.

through their effect on net income from foreign investment.* Greater investment by foreigners in the United States will increase the future payments made by American corporations or governments to foreign agents; similarly, reduced U.S. investment abroad will decrease future investment income expected by U.S. firms and individuals. Both changes will cause a reduction in the current account entry, "net income from foreign investment." In recent years, America has relied on a large net inflow from the return on foreign investment to finance other deficit items; in 1977, American investments abroad returned $32.1 billion. If this figure were substantially reduced as an indirect result of heavy oil imports, the future ability of American investors to finance a high level of net imports or foreign investment would be severely weakened.

This discussion does not reject the validity of the macroeconomic view or the automatic adjustment approaches. Rather, it goes beyond these arguments to consider explicitly the costs of adjustment or of allowing domestic macroeconomic policies to be affected by balance of payments considerations. These approaches also attempt to estimate the social cost of oil imports, namely, the summation of the compensating changes in the other balance of payments items and the costs of allowing domestic stabilization policies to become dependent upon balance of payments considerations.

An initial estimate of the social and economic costs of oil imports is simply the dollar value of such imports ($45 billion for 1977). To achieve equilibrium in the balance of payments, this oil import bill must be balanced by $45 billion in compensating changes in other items in the balance of payments. To the extent that oil imports are financed by increased U.S. exports or reduced imports of other products, the economic cost of the oil imports would be the $45 billion in goods and services forgone by American nationals. Likewise, to the degree that the oil import bill is financed through changes in the capital account, investment by foreigners in the United States must increase by $45 billion and/or U.S. investment abroad must decline by $45 billion. The ultimate cost of such changes in the capital account is the reduced net income from foreign investment accruing in the future, a loss which can be discounted to an equivalent present value.

The dollar value of oil imports would be only a first and most conservative approximation of the total economic and social cost of petroleum imports. Recent balance of payments disequilibria indicate that adjustments do not occur easily or without cost. Under fixed exchange rates, balance of payments deficits have led to restrictions in trade and capital flows and to accommodating deflationary macroeconomic policies. In the United States during the late 1960s, a policy was adopted restricting capital flows from the country. This three-pronged program called for annual limits on new direct foreign investment by U.S. corporations, repatriation of a specified fraction of total foreign earnings, and restriction of holdings of short-term foreign securities (Economic Report of the President 1978, p. 173). Americans were urged to buy domestic products and discouraged from foreign travel; the allowance on duty-free goods brought in by U.S. tourists was reduced from $500 to $100 per person. In Great Britain the repeated balance of payments deficit has forced many restrictive economic measures upon British citizens. For instance, the Labour government restricted the number of pounds British tourists were permitted to take out of the country during the 1968 sterling crisis. More importantly, the Labour government devalued the pound sterling to correct the recurring British balance of payments problem.

Even under a system of flexible exchange rates, adjustment has not always been as smooth as economists might have expected. Relatively low, short-run, import and export

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*See Current Account, Table 2-1.

price elasticities can exacerbate the problem of balance of payments adjustment (Dornbusch and Krugman 1976). Some economists argue that recent exchange rate fluctuations have been wider than would be predicted by economic theory and that these fluctuations have contributed significantly to the current worldwide inflation (Witeveen 1975; Whitman 1975; Laffer 1974).

In summary, the balance of payments framework can be used as a starting point in evaluating the cost of oil imports. Within this framework, it has generally been argued that costs of petroleum imports are the value of other imports forgone, of increased U.S. exports, of increased foreign investment in the United States, and of reduced U.S. investment abroad. Compensatory changes for each of these balance of payments entries must take place to finance the oil import bill, but it should be understood that each of these changes imposes its own cost on the U.S. domestic economy. The total cost of all these changes is the total value of the oil import bill which necessitated the offsetting changes. In addition to these basic costs, there are other economic costs in the form of corrective government balance of payments and domestic stabilization policies, as well as adjustment costs incurred because of exchange rate fluctuations. Simply, there are no "costless" means of balancing a national trade deficit. Finally, there are a number of less quantitative, more social costs incurred that fall beyond the ken of economic theory and can be treated as balance of payment politics.

2.3 BALANCE OF PAYMENT POLITICS

Following the Second World War, the economic preeminence of the United States in the international economic arena was unchallenged. Its gold stock, industrial base, and robust currency were reflected in the international reliance placed on the dollar by the Bretton Woods Conference arguments in 1944. The United States experienced a positive balance of payments condition until the mid-1960s, but by 1970, it had a trade deficit of close to $10 billion. American officials were forced to recognize that the national balance of payments was in basic disequilibrium and that the traditional means to protect the dollar—i.e., to purchase surplus dollars with U.S. gold—was ineffective because the nation's gold supply had declined to a point at which it could no longer defend the dollar on the world financial market. The economic resurgence of the other major industrialized nations, combined with U.S. domestic inflation and involvement in the Vietnam conflict, fundamentally undermined the post-war U.S. economic hegemony. European nations were forced to increase their dollar holdings to maintain their currencies at the established exchange rates until, in 1971, the West Germans and the Dutch permitted their currency exchange rates to vary beyond their assigned parities. In August 1971, President Nixon formally suspended the U.S. policy of converting gold into dollars and, later that year, the Smithsonian Agreements called for a basic realignment of national currencies; the U.S. dollar was devalued by nearly 10 percent in relation to the other major industrial nations' currencies in late 1971 and by another 10 percent in February 1973.

In March 1973, the major industrial countries of the western world ceased "tying" or "pegging" the international monetary exchange rate to the U.S. dollar. The fixed exchange rate system was replaced by a flexible system in which the rate of exchange between the U.S. dollar and the currencies of the other major western industrial nations was determined by the international monetary supply and demand. Surpluses and deficits in the U.S. balance of payments would lead to revaluations of the U.S. dollar in terms of the other currencies and the eventual correction of the payments imbalance. In turn, the revaluation of the U.S. dollar would affect the price of U.S.-supplied goods and services and the price of foreign imports. For instance, a devaluation in the U.S. dollar would result in an increase in American exports to the rest of the world and a reduction in imported purchases; these actions would correct the transaction imbalance between the United States and the rest of the world. In the case of a balance of payments surplus, the dollar would increase in value on foreign exchange markets, discouraging exports because of higher U.S. prices while encouraging imports by lowering their relative prices.

The flexible exchange rate system does not surrender the value of the dollar entirely to the machinations of the world foreign exchange markets. The Federal Reserve and the central banks of other major western industrial nations have intervened on behalf of U.S. dollars to reduce short-term variations in exchange rates that were not indicative of fundamental economic conditions. The actions of monetary authorities reflect a belief that erratic variations in exchange rates are not conducive to international trade and the stability of world financial markets. Similarly, economic summit conferences, such as the Tokyo conference in the summer of 1979, and agreements that are reached in these meetings, can affect the exchange-rate mechanism.

The Federal Reserve has several important sources of foreign exchange upon which it can draw to defend the dollar. Foreign currencies can be obtained through the sale of gold and securities to foreigners, currency swaps between the Federal Reserve and the central bank of other countries, and drawing upon the U.S. reserve position with the International Monetary Fund.

Unpegging the U.S. dollar has been beneficial in stabilizing the world exchange markets after the international monetary crises of 1968, 1971, and 1973, which resulted in the collapse of the gold standard and fixed exchange rates; the U.S. dollar was no longer tied to the gold standard. Flexible exchange rates and the devaluation of the American dollar have aided the United States in adjusting its trade imbalances with other western industrial nations, although it has injected increased uncertainty into the international money market (Healy 1979-80). With respect to deficits vis-à-vis the OPEC nations, however, flexible exchange rates have proved to be an ineffective means of adjustment because almost all of the OPEC's international transactions are tied to American dollars. Thus, a devaluation of the dollar in terms of the currencies of the OPEC nations would have no significant effect on the U.S. balance of payments. The OPEC nations are concerned primarily with the dollar value of U.S. goods and services and not their value in their domestic currencies since they are paying in U.S. dollars for U.S. goods and services (Tew 1977, pp. 210-211).

Standard policy measures for bringing about a balance of payments adjustment have been relatively ineffective in dealing with the present situation. A policy designed to encourage U.S. exports or reduce imports from foreign countries would simply shift the burden of deficit to other oil importing countries. In terms of U.S. exports, the economic characteristics of the OPEC nations presently limit their ability to absorb additional U.S. goods and services (Solomon 1974; Levy 1978-79), leaving only other oil importing countries as targets for the export promotion policies. The situation is essentially the same for imports. The United States purchases most of its imports from other oil importing countries. A successful program to improve the U.S. balance of trade by reducing its nonpetroleum imports would be largely at the expense of the other oil importing countries; i.e., it would have little effect on the U.S. balance of payments deficit with the OPEC countries.

The same problem is encountered with policies directed toward improving the capital account balance by, for example, raising domestic interest rates. Increasing domestic interest rates to attract foreign investment would draw funds out of the other oil importing countries. The OPEC nations do not have capital markets of their own capable of absorbing the dollars or other foreign currency received in payment for their petroleum. Funds received by OPEC nations in payment for oil exports have been channeled into the capital markets of the principal oil importers. Policies undertaken by any of these countries to attract OPEC capital will simply shift the deficit from one petroleum-importing nation to another.

These concerns are more than theoretical. Improvements during the past year in the American balance of payments deficits should not necessarily be attributed to Administration programs. A recent Congressional Budget Office (CBO) report argues that the Carter Administration should receive little credit for recent improvements in the American trade and international payments accounts—that these occurred almost in spite of U.S. policy initiatives (Farnsworth 1979). The CBO report claims that improvements in the U.S. balance of payments were due mainly to the success of economic policies of other nations which generated faster economic growth in foreign nations, thereby accelerating their demand for American products. The instability of the U.S. dollar led to its decline, again resulting in an increased American competitiveness. Finally, the OPEC nations did not raise their oil prices last year commensurate with the decline of the dollar's value. Both the CBO and Carter Administration spokespersons suggest that the U.S. balance of payments deficit will be reduced within the next few years, but the CBO analysis claims that the improvement will be the result of the expected economic recession and thereby represent a "significant failure" in Administration policy because of the underutilization of the economy (Neu 1979). In short, traditional economic measures prior to 1980 have not been especially effective in reducing the oil import component of the balance of payments deficit.

The oil-importing nations, especially the United States, are left with only one policy to reduce the large balance of payments deficits resulting from the simultaneous dependence on large amounts of foreign oil and the great increases in oil prices; namely, to reduce the amount of petroleum they import. If any one country attempted to eliminate its oil-related deficit by financial measures other than reducing its oil imports, the deficit would merely be shifted to another oil importing country. This new condition in international trade relations has been recognized—if not corrected—by the western industrialized nations. In the January 1974 Rome Communique, the western economic ministers labelled any trade policy other than the reduction of oil imports as tantamount to a form of "beggar thy neighbors" (Solomon 1977, p. 296) which could result in debilitating trade wars. Thus, the preferred policy option—the reduction of oil imports as opposed to the mechanistic currency adjustments or increasing exports to other nations—motivates the rationale for displacing imported oil with solar energy. Before estimating what these displacement levels might be, we need to move beyond the general economic framework employed above and examine some specific political and economic issues (in terms of socioeconomic costs) ascribed to the U.S. dependence on foreign petroleum supplies.

SECTION 3.0

POSSIBLE IMPLICATIONS OF BALANCE OF PAYMENTS DEFICITS AND OIL DEPENDENCY

The possible domestic and international ramifications of U.S. dependence on foreign petroleum supplies and the resulting balance of payments deficits are presented here as plausible extensions of the present international economic conditions. Although these concerns are not particularly novel (see U.S. Department of Treasury 1975), the energy shortages of 1979 have reinforced their pertinence. The following scenarios are presented as a basis for discussion in terms of policy planning rather than pressing issues for immediate policy decision making. For the sake of convenience, the issues are categorized into four topics—Strategic and Foreign Policy, International Economics, Domestic Economics, and Social and Environmental—although in actuality the different issues are not nearly so distinct.

3.1 STRATEGIC AND FOREIGN POLICY ISSUES

1. American national security could be adversely affected by its dependence on foreign petroleum (Aikens 1973). The argument can be approached in two ways. First, to rely on foreign nations to supply the United States with strategic materials places American national interest and military operations at the caprice of the supplier nation. U.S. Department of Defense (DOD) officials have consistently warned that Middle East oil is particularly susceptible to interdiction (see DOD responses in U.S. Dept. of Treasury 1979). Second, American imperatives to protect its access to strategic materials might force the United States to engage in a conflict it might otherwise wish to avoid (for example, a confrontation with the Soviet Union over control of the Saudi Arabian or Iranian oil fields). Although the United States has sufficient domestic oil supplies to fulfill all its military requirements, displacement of petroleum from the civilian sector would cause severe disruptions in the domestic economy.

2. The international competition for oil has created serious strains within the American system of alliances, especially among the OECD member nations. The intra-alliance tensions among NATO members during the 1973 Middle East crisis manifested this political cost (Simonet 1975) when American planes airlifting supplies to Israel were not permitted to use European airfields for refueling. There is some sentiment in Europe that the U.S. State Department deliberately urged the Arab OPEC members to raise their oil prices because State Department officials reasoned that the American economy would be less affected than other OECD economies, thereby producing an advantage for the United States in international trade competition (Oppenheim 1976-77). The validity of these charges is suspect, but the fact that they are expressed and that U.S. oil import policies are cited as supporting evidence means that they must be considered as a possible cost of U.S. dependence on Middle East oil. Similar perceptions could trigger between the United States and its major trading partners a trade war that would harm the domestic economy and alliance politics in general.

3. The OPEC oil states' influence on U.S. government policy as a result of American dependence on their petroleum could undermine traditional U.S. political and military commitments (for example, to Israel), which would effectively constrain

American freedom of action in conducting its foreign policy. For example, Mexican oil reservoirs could restrict American policy initiatives with respect to illegal aliens. For Middle East diplomacy, such limitations could create major domestic policy debates with repercussions spilling beyond the foreign policy arena; witness the domestic recriminations when President Ford and Secretary of State Kissinger announced their decision to "reassess" the American relationship to Israel. However, as some observers have pointed out, OPEC, and particularly its Arab members, hardly represent a monolithic organization; increasingly its members are facing growing socioeconomic problems of their own (Smithies 1978). They must consider their own internal vulnerabilities and American strengths before attempting to dictate American foreign policy decisions (Levy 1978-79; Campbell 1977; Singer 1978). Another concern would be Africa, with the continuing struggle between the black nations and South Africa setting the stage for possible pressures by the African oil exporting nations upon the United States to terminate all support of the apartheid regime.

4. A dependence on Middle East oil could make it more difficult for the United States to refuse Arab requests to purchase U.S. nuclear power reactors or even reprocessing facilities. The sale of nuclear reactors, especially to regions as volatile as the Middle East or sub-Saharan Africa, would be contradictory to the declared U.S. policy of nuclear nonproliferation and the problems inherent in that issue (Nye 1978; Lovins 1977).

5. The effects of high oil prices on the lesser developed countries (LDCs) could be especially disastrous because they have few exports, monetary reserves, or investment opportunities to make up their growing trade deficit, and they lack the facilities or capabilities for recycling petrodollars (Farmanfarmian 1975; Chenery 1975; Pollack 1974). They are therefore forced to fall back on international organizations and, more often than not the United States, for increased assistance to meet their fuel bills. Under such conditions of growing debt and deprivation in the Third and Fourth Worlds, the U.S. government might find it extremely difficult to ignore requests for foreign aid and be forced to increase its foreign assistance (either in money or commodities, the latter acting to keep domestic prices at a slightly higher level), and commercial banks would be pressured to reschedule LDC debt repayments (Beim 1977). As another possible way to meet higher oil prices, the LDCs might attempt to raise the price of whatever commodities they export; their success, of course, would be situationally dependent and problematic at best. Finally, the high level of LDC loans and their inability to meet repayment schedules could tie up U.S. bank reserves, which could contribute to a loss of liquidity within commercial banking circles and to higher domestic interest rates.

3.2 INTERNATIONAL ECONOMIC ISSUES

6. The unprecedented transfer of such large amounts of money from one group of nations to another could severely distort the operations of the established international monetary system and its component institutions, even given the system of free floating exchange rates (Triffin 1978-79; Anonymous 1979a). The disruption of the international monetary system could reflect on a number of domestic economies and create either inflationary or recessionary pressures. In 1978, for example, when the dollar came under heavy pressure by foreign speculators, the Federal Reserve set aside domestic policy considerations and began raising interest rates by selling some of its U.S. Treasury bills. This action attracted more foreign-held dollars into the

U.S. money market and helped to offset the heavy dollar sales by speculators and the dollar outflow to pay for continuing trade deficit. The domestic effect, of course, was to increase the cost of borrowing money.

The increase in OPEC oil prices in 1973-74 led to an unprecedented transfer of financial assets into the hands of the OPEC nations. Over the five-year period from 1974 to 1978, the net financial assets of the oil-exporting nations increased by $168 billion (deVries 1979). These funds have been invested almost exclusively in western financial markets. Petrodollars have been channeled into the U.S. money markets to purchase securities such as U.S. Treasury bills and into the Eurodollar market. Because Treasury notes and Eurodollars are highly liquid, these holdings represent a source of considerable uncertainty and disruption for the domestic and international financial systems (Healy 1979-80). For instance, the OPEC nations could convulse world financial markets by converting all of their U.S. dollar holdings into other currencies such as Swiss francs or German marks. Heavy conversion of dollars into other currencies would severely distort foreign exchange rates, forcing American monetary authorities to initiate a massive defense of the dollar, which could lead to a reduction in the U.S. reserve position and a crisis in confidence on the world financial markets. The American decision to freeze Iranian assets in late 1979 forcefully reminded OPEC nations of the vulnerability of their investments and encouraged "them to diversify their holdings out of dollars into other currencies" (Lewis 1979), thus potentially weakening the dollar even more.

Nevertheless, it must be recognized that the OPEC nations rely fundamentally on the western financial markets for investing their foreign currency holdings. Furthermore, the OPEC nations are major importers of western industrial goods and services (Levy 1978-79). Therefore, it would not be to their economic advantage to disrupt western financial markets, although a politically motivated assault on the U.S. dollar is hardly inconceivable.

7. American dependence on oil imports at world prices could weaken the U.S. dollar relative to other national currencies. Given the central position of the dollar in the world economy, the value of the dollar could decline to an extent sufficient to cause a world depression. Secretary of State Kissinger warned the U.N. General Assembly (23 September 1974) that "strains on the fabric and institutions of the world economy threaten to engulf us all in a general depression." Although some argue that a world depression of the magnitude experienced in the 1930s is not presently feasible (Cleveland and Brittain 1975) and that the pressures on the world economic system are grossly overrated (Chenery 1975), the specter of world depression brought about by instability of the U.S. dollar and its possible effects on the internal U.S. economy (both due, at least in part, to the high price of oil and the U.S. dependence upon world oil) cannot be dismissed (Kronholz 1979).

3.3 DOMESTIC ECONOMIC ISSUES

8. The fear of oil embargo has resulted in a program to build up a strategic oil reserve that, in the event of another embargo, would supply the American economy with a six months' reserve of petroleum (Tolley and Widman 1977). In the process of stocking this strategic supply, the Federal government keeps the short-term petroleum demand artifically high in a competitive market, thereby maintaining oil prices at a premium that directly affects the consumer in a myriad of ways (e.g., higher cost for fuel oil, gasoline, and agricultural products) (deVries 1979).

9. The increasingly large influx of petrodollars into the U.S. economy could have adverse effects on internal investment patterns or place critical sectors of the U.S. industry and resources into foreign hands. These possibilities are discounted in some quarters (Amuzegar 1973), but the potential is believed to exist (Enders 1975), and investment is a conspicuous example of an area in which perceptions are as important as reality. There are examples in which petrodollars have already had an exogenous impact (one basically beyond the control of American policy makers) upon domestic U.S. interest rates, economic activity, and in some regions, the real estate market. The relatively low interest rates experienced during the business recovery from the 1974 recession are attributable partly to the influx of petrodollars that improved the liquidity of the nation's money markets.

   The recycling of petrodollars into short-term U.S. securities creates another potentially serious problem. OPEC nations have accumulated very large holdings of highly liquid assets. If, for whatever reason, these investors were suddenly to sell their securities in the domestic money market, the result would be a sharp increase in short-term interest rates that could easily disrupt the domestic economy.

10. An increase in energy costs (partially attributable to the high price of imported oil) drives up the cost of production of almost everything. If labor and capital costs are fixed (or are themselves increasing), a decline in real output must occur. There appears to be little opportunity to substitute capital or labor for energy (at least in the short run). Pindyck asserts that the total cost of output is increased almost as much as the percentage increase in the cost of energy multiplied by energy's share in the total costs (Pindyck 1979a; p. 174; and 1979b). For example, he cites econometric projections in which a doubling of the total cost of all energy in the United States would cause a 3% increase in the cost of U.S. manufacturing output.

11. Watt claims that oil imports drive up the price of food to the U.S. consumer because of the need to export food as a means of reducing the balance of payments deficit (Watt 1978). Pindyck agrees, suggesting that the increased demand for exporting wheat and other foodstuffs to offset OPEC price hikes added 1.5 to 2 percentage points to the U.S. rate of inflation in 1974 (Pindyck 1978). Similar logic would apply to any commodities or asset that the United States might export to balance its trade deficit.

12. The United States imports almost one-half of its domestic oil consumption, a policy that clearly contributes to the U.S. balance of payments deficit even with recycled petrodollars (Bach 1978). The balance of payments deficits contribute, in turn, to the general U.S. rate of inflation through the inflationary effects of devaluation. Although a causal relationship between balance of payment deficits and inflation has not been empirically verified, economists have suggested that half the 11% U.S. rate of inflation in 1974 was due to the fourfold increase in foreign oil prices and the U.S. need to import large quantities of that oil (Pindyck 1978; also Bach 1978). Enders attributes one-quarter of the 14% average rate of inflation among OECD nations in 1974 to the same conditions (Enders 1975). The announced 14.5% price increase in OPEC oil costs scheduled for 1979 was projected to add half to three-quarters of a percentage point to the U.S. rate of inflation for that year (Hillery 1979), although slightly lower estimates were projected by the Council of Economic Advisors (Rattner 1978) and other Administration economists (Farnsworth 1978). Administration sources have repeatedly linked the U.S. 13.3% rate of inflation in 1979 to the 100% increase in OPEC petroleum prices for this year. The general effects of domestic inflation are so well documented that they need not be repeated here.

13. In attempting to counter inflation and correct balance of payment deficits, the government may adopt contractionary macroeconomic measures, such as reduced government expenditures and a restricted money supply, which could lead to a domestic recession and higher unemployment than otherwise might be expected (Silk 1978). Pindyck (1978) claims that the government adopted such policies to counter the 1974 inflation, not realizing that they were appropriate for ordinary demand-pull inflation but relatively ineffective against inflationary tendencies generated from outside the United States, thereby contributing to the general recession in 1975. The result, of course, is reduced economic growth (measured in terms of a gross national product), higher unemployment, and loss of certain production opportunities; a range of estimated GNP and employment losses is given in Black (1978).

14. By directly undermining the value of the U.S. dollar on the international money market, the American balance of payments deficit has two adverse effects. First, because of the U.S. dollar's central role in the world economy, its instability seemingly threatens the integrity of the international monetary system (see No. 7 above). This concern was expressed by world leaders during both the 1978 Bonn and the 1979 Tokyo economic summit conferences and resulted in President Carter's pledges to correct the instability of the dollar. Second, the balance of payments gap reduces the value of the U.S. dollar, thereby making imported goods more expensive for U.S. consumers. This condition is generally thought to be inflationary (at least in the short run) because people's purchasing and consuming patterns are notoriously slow to readjust downwards. Short-term efforts to support and stabilize the dollar, such as borrowing foreign currencies (i.e., incurring long-term debts) could lead to a longer-run, much more serious financial crisis should the current economic conditions that led to these measures continue (Samuelson 1978).

15. The inflationary elements referenced in Nos. 12 and 14 only add to the ongoing inflationary spiral. As inflation undermines the value of the U.S. dollar relative to other national currencies, other nations see the real price of their exports to the United States declining because of the inflated dollar and the central position of the U.S. dollar in the world economy (e.g., OPEC oil is priced in terms of U.S. dollars). The OPEC nations also see U.S. inflation diminishing the value of their investments in American financial bonds or Treasury notes (Amuzegar 1978). This condition leads to yet another series of price increases (Triffin 1978-79), especially as the OPEC nations face greater internal demands for western goods and public services.* Thus, the balance of payment deficit and domestic inflation feed upon and fuel one another. [There are, of course, other causes for domestic inflation and balance of payment deficits—e.g., deficit spending and lack of comparative advantage on the world market—which contribute to this cycle. We do not suggest that balance of payment gaps are the fundamental or most important cause of inflation, nor that the oil imports problem is the only commodity driving the U.S. trade deficit (Lawrence 1978)].

3.4 SOCIAL AND ENVIRONMENTAL ISSUES

16. The perceived role of American oil companies in the OPEC negotiations and policies has created controversy and open distrust of these companies in the American

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*Moran (1976-77) suggests that the internal development policies of the OPEC nations will force them to institute an annual price increase of "10 percent to 15 percent per year <u>above</u> the OECD inflation . . . . " (p. 74; emphasis in original). Smithies (1978) argues that by 1985, Saudi Arabia will experience a balance of payments deficit.

public.* Repeated public opinion surveys show that nearly half the American people believe that the energy crisis was contrived for the economic benefit of the oil companies (Roper 1978). Talk of "ill-gained, windfall" profits, "contrived crises," and "uncontrolled multinational corporations" directed against a major U.S. industrial sector and the suspicion these charges engender might result in debilitating regulatory actions, or even nationalization, which could undermine the industry (Sherrill 1979). Thus, this problem could be counted as a social cost of American corporate involvement in Middle East oil production.

This distrust is by no means limited to the petroleum companies. The perceived continued government debate, contradictory evidence, and resulting inaction over energy policy has confounded large segments of the American public and led them to at least question the efficacy of their government. The inability of the Carter Administration to marshal a coherent energy program through the Congress has suggested to many people that (1) the crisis is not real, and the government is being less than straightforward in declaring the "moral equivalency of war" or, (2) if the crisis is real, their government is ineffective in handling it.** Neither position inspires faith in government, its institutions, or its processes. Although this sentiment is obviously impossible to quantify as a sociopolitical "cost," the potential loss in faith in the government's institutions by the American public should be considered an extremely significant cost. Brunner and Vivian (1979) provide evidence in their sample of citizen viewpoints on energy policy that this condition is already prevalent.

17. The decline of purchasing power of the U.S. dollar creates severe hardships for U.S. citizens living abroad who are paid in U.S. currency. The plight of the American soldiers stationed in Europe (especially West Germany) is often cited as an example, particularly those low-ranking soldiers who do not have access to on-base housing (Anonymous 1978a). Automatic cost-of-living escalation factors for American military personnel living abroad could raise the cost of maintaining U.S. installations so high as to warrant a reduction in American overseas commitments. Problems encountered by the American tourist who is, of course, not required to travel abroad are less severe manifestations of the decline in the dollar's purchasing power.

18. Numerous environmental issues would be addressed by a reduced dependence upon oil as a source of energy, such as reduced air pollution and the preservation of scarce and nonrenewable resources [Hayes (1977) and Lovins (1977) are two examples]. This would apply to the reduced use of any fossil fuels, of course, not just foreign sources, so there is no reason to elaborate except to note the relevance of these issues in the overall social cost-benefit calculus of U.S. dependence on foreign oil supplies. As a point of illustration, the burning of fuel oil to heat homes in the northeastern United States degrades air quality regardless of the oil source. One environmental factor particularly pertinent to oil imports is, of course, potential oil spills from supertankers and their effect on the surrounding ecology (Mostert 1974).

19. Even a marginal reduction in the U.S. supply of petroleum could have magnified effects on American society. For example, the 1979 interruption in Iranian oil exports to the United States, which contributed approximately 10% of U.S. oil imports (or less than 5% of total U.S. energy supplies), again raised the specter of gasoline rationing by the spring of 1979 [see Anonymous (1979b) or Halloran (1979b)].

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*The debate is joined by Church (1977) and Chandler (1977).

**See Appendix B for a brief review of the politics affecting the President's National Energy Program and its treatment in Congress.

Although the effect and duration of the Iranian curtailment of oil were limited (Berry 1979; Halloran 1979a), it is clear that the potential impact could seriously affect American society (Smith 1979 or Halloran 1979c). The Iranian shortage revived memories of the long waits and short tempers experienced by American motorists waiting for gasoline in 1974.* Such conditions could adversely affect business and recreational patterns of American citizens.

3.5 CONCLUSION

From both theoretical and policy perspectives, the present and growing American dependence on foreign supplies of petroleum and the resulting imbalance in U.S. trade can adversely affect the domestic and international economies and societies. One possible strategy for ameliorating oil dependence and trade deficit problems is the displacement of oil by solar energy alternatives such as residential space and water heating, industrial process heating, and biomass applications. Given this option as a means of offsetting the potentially adverse effects of oil dependence, the remainder of this report estimates the amount of foreign oil that can be displaced by solar energy applications and the impact of the released oil on American petroleum imports.

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*For different national perspectives on the effect of the Iranian oil cutoff, see Andelmann (1979) and Reuzin (1979).

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SECTION 4.0

OIL DISPLACEMENT

4.1 INTRODUCTION

This section estimates the oil displacement potential of solar energy technologies by the year 2000. The estimates are predicated upon the scenario of President Carter's National Energy Plan (see Appendix B), which explicity assumes active government programs in solar energy technology RD&D and commercialization.

A computer simulation model is the principal instrument for deriving these estimates; a description of the model, called SPURR, is found in Appendix A. The SPURR model excludes two areas where solar technology could displace large amounts of petroleum: passive solar energy (e.g., designs for conservation) and biomass applied to the transportation sector. We were unable to obtain documented estimates for the first factor and therefore have relied upon reports of work in progress at the Los Alamos Scientific Laboratories. Estimates for the second factor were derived from recent DOE studies. Both sets of projections are appended to the simulation estimates, but neither were part of the SPURR model. In addition, the computer simulation model did not provide estimated oil displacement figures that might be obtained through solar industrial cogeneration. Due to these exclusions, the estimates for oil displacement are probably pessimistic, but we cannot determine with any confidence the magnitude of the underestimation.

4.2 THE SPURR COMPUTER SIMULATION MODEL

The computer simulation model selected for measuring the potential level of oil import displacement through the development of solar energy is the System for Projecting Utilization of Renewable Resources (SPURR) (MITRE 1978a). The SPURR computer simulation model was developed by the METREK Division of the MITRE Corporation to assess the potential market penetration of solar energy technologies and to examine alternative strategies for solar energy development. The model and supporting data base can be adjusted to estimate directly the amount of oil displaced, given a scenario describing the pace of solar technological penetration into the various end-user sectors.

The SPURR model describes the probable range of costs for both conventional and solar technologies in four primary energy markets: (1) heating and cooling of residential and commercial buildings; (2) agricultural and industrial process heat; (3) a centralized utility sector covering the generation of electricity; and (4) synthetic fuels and product markets. Each energy market is broken down by geographic region. The analysis of the first energy market is conducted for 16 major cities and their surrounding areas. The remaining three energy-consuming sectors are analyzed on the basis of the nine major U.S. census regions.*

The analysis of each primary energy market by region yields a mix of conventional, solar, and synthetic fuel technologies to fill new and replacement energy demand. SPURR incorporates constraints that ensure that the level of investment in a particular technology

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*Appendix A gives a more complete account of the simulation model's operations.

does not exceed realistic bounds in any given year. These constraints reflect such considerations as the institutional and behavioral resistance to new technologies that characterize new product market development and the practical limits on the pace at which new utility plants can be built (MITRE 1978b; Bennington et al. 1978).

The data base that supports the computer simulation model is designed to match the conditions that would have been in effect under the proposed National Energy Plan (NEP).* Under the NEP scenario, several policy measures were to be used by the Federal government to promote the development and application of solar energy. For example, the NEP calls for a 10% investment tax credit on solar equipment for commercial building use and a 20% tax credit for solar equipment applied to industrial heat. A 40% tax credit would be provided for the first $1,000 invested in residential solar equipment and 25% for the next $6,400, with the residential tax credits declining through to their termination in 1984. Other policy measures proposed in the NEP include restrictions on oil and gas usage and a series of technology demonstration programs. The commercial and the industrial process heat sectors are subject to restrictions on the use of oil and gas; the electric utility sector would eventually be prohibited from using these fuels. The technology demonstration program would spend $100 million over a three-year period to demonstrate solar heating and cooling equipment for residential, commercial, and government buildings.

The data input for the computer simulation model came from several sources. Total energy demand projections were taken from the Energy Research and Development Administration's (ERDA) Forecast 1, which calls for energy demand to increase from 86 quads in 1984 to 115 quads by the year 2000, an annual growth rate of 2% (ERDA 1977). Electrical energy requirements are projected to grow at an annual rate of 5.1% between 1980 and 1983 and then decline to a rate of roughly 2.6% by the year 2000. The inventory of residential and commercial buildings, which represent the primary demand for solar heating and cooling, and their projected rate of increase was taken from the General Electric Phase O study (General Electric 1974). Process heat demand was forecast in ERDA's Market Oriented Program Planning Study (Energy and Environmental Analysis 1977). This demand was projected to grow by 3.5% a year from the present level of 6 quads. Finally, the cost of different solar technologies was estimated by MITRE analysts from many sources. Cost estimates, including the expected price for each year and the likely variance around the estimate, are employed in calculating market penetration levels.

The computer simulation model uses the NEP scenario and the data base to estimate future levels of market penetration by solar technologies. The model's most important operational features are the use of market penetration curves to characterize the diffusion process of a new solar technology into the marketplace and experience curves to capture the cost reductions that normally accompany increased production of new products [see Roessner et al. (1979)]. A market penetration curve (see Fig. 4-1) shows the historical pattern of diffusion for new products. The initial phase of market penetration is characterized by economic and institutional resistance to change and a reluctance to purchase a new product. The middle phase is the "bandwagon" period when the innovation gains wide acceptance in its market. The last phase shows a return to slower market growth as the product reaches saturation levels among consumers. An experience curve for the production of forced warm air furnaces is illustrated in Fig. 4-2. This curve reflects the improvement in production methods resulting from such factors as

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*A description of the background and objectives of the NEP is found in Appendix B.

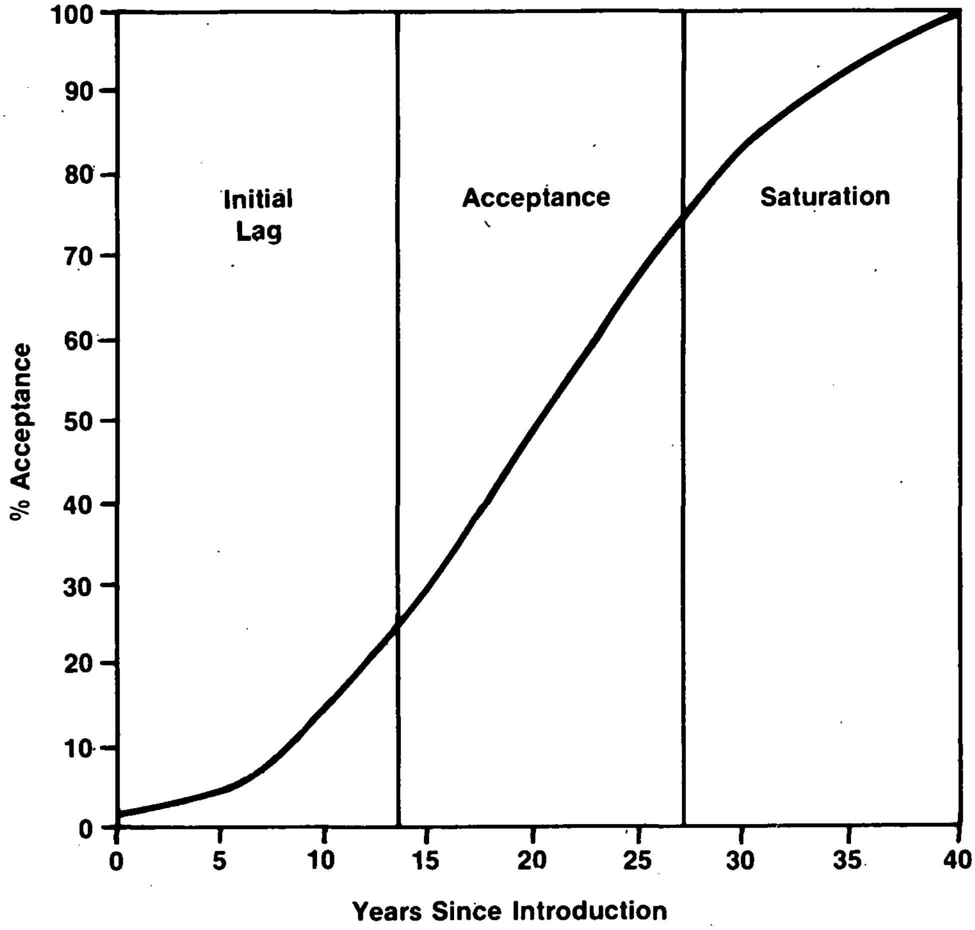

Figure 4-1. Market Penetration Curve For New Technologies (MITRE 1978b, p. 12)

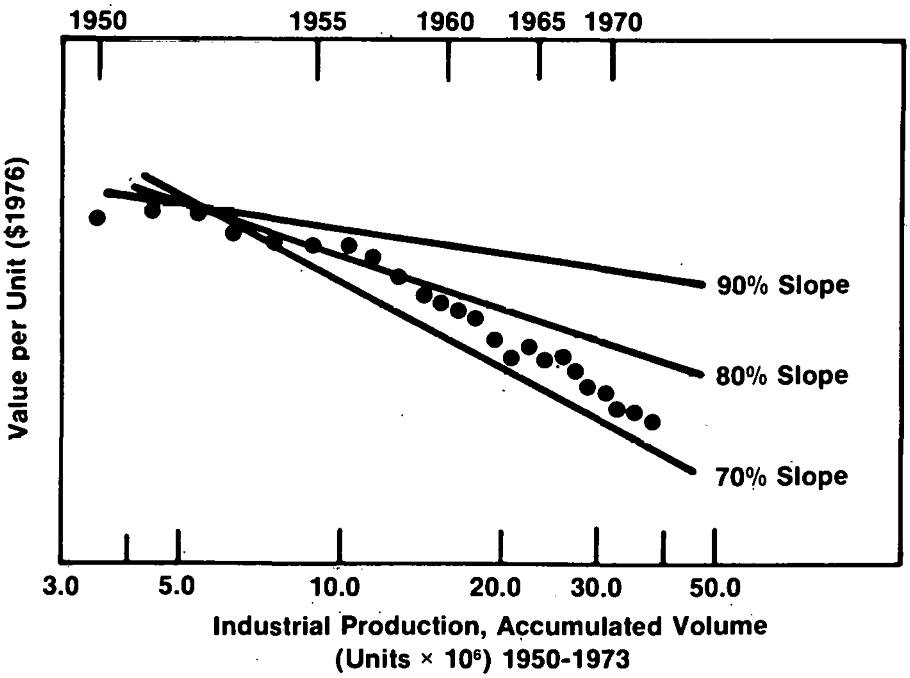

Figure 4-2. Experience Curve: Forced Warm Air Furnaces, Nonelectric 1947-1973 (MITRE 1978b, p. 12)

production experience, employee experience, and improved product design. Experience curves for each solar technology were developed in a MITRE study done prior to the development of the SPURR model (MITRE 1977).

Before looking at the results of the SPURR model simulation, it is important to review the principal assumptions and the methodology underlying the analysis that could result in estimation errors. SPURR is hardly unique among energy econometric or technology models in being susceptible to methodological criticisms [see Koreisha and Stobaugh (1979) and Manne, Richels and Weyant (1979) for two recent reviews of energy models and their methodological shortcomings]. It is convenient to divide the SPURR assumptions into two categories: those that pertain to the level of solar market penetration and a set of more basic assumptions relating to the problems of measuring oil displacement (i.e., of the total amount of energy sources displaced, what percentage is oil?).

The assumptions made in preparing market penetration estimates fall into three areas. The first is the future price of conventional fuels. For each conventional fuel, price estimates were generated for each market region. Within each region, it was assumed that average price levels would be sufficient to analyze the fuel choices that would be made. Beginning with the base year, 1976, conventional fuel prices were projected through the year 2000 using assumed rates of price escalation. For example, electricity prices were projected using a real rate of price increase (excluding the influence of inflation) of 2% per year. If the actual rate of electricity price increase were 1% greater than assumed, the cumulative error in the forecast would exceed 20% by the year 2000. Although a sensitivity analysis has not been performed on the effects of electricity price variations, the differences would be significant because of the importance of relative prices in the SPURR model analysis.[**] More specifically, because the principal market for solar energy between now and the year 2000 is that presently served by electricity, higher or lower electricity prices will have important effects on the competitiveness of solar technologies.

The second general assumption that influenced market penetration levels was that rates of cost reduction in the manufacture of solar devices could be accurately described by experience curves. The experience curves used in SPURR were developed by studying the manufacturing technologies for similar products from an industrial process point of view (MITRE 1977), on the assumption that a constant percentage reduction in manufacturing costs will occur each time the level of production is doubled. Considerable empirical data have been assembled to test this proposition but provide only limited support. These same data show that significant errors can be made using this simple methodology.[¶] The errors could be large enough to create significant variances in the SPURR market penetration estimates.

The third assumption concerns the use of market penetration curves to estimate the pace of solar product market development. New products normally require a fairly long time

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[*] A review of the SPURR methodology is found in Appendix A.

[**] Sensitivity analyses have been performed on capital costs, lifetime, operating and maintenance costs, and biomass fuel costs by Witholder (1979).

[¶] A discussion of the shortcomings of the experience curve methodology can be found in Krawiec and Flaim (1979).

to exploit fully their potential markets. Factors influencing the rate of market penetration range from demonstrable product characteristics to marketing efforts. To identify and quantify all of the factors in determining a product's market penetration rate and to forecast the rate over the expected market development period has generally proved to be too complex a task to be encompassed in computer simulation models. This is particularly true for the behavioral variables. For this reason, the influences of all of the factors that are beyond quantification are aggregated into an S-shaped market penetration curve without accurate knowledge of the individual components. The S-shaped market penetration curve has been observed in the market development of a wide variety of products. Empirical efforts to forecast this curve for new products, however, have met with only limited success because of uncertainties regarding the slope and inflection points of the curve as they apply to specific innovations and markets. The same limitations, of course, apply to the solar technology market penetration forecasts presented here.*

Each of the three methodological assumptions could have a significant effect on the projected level of market penetration by solar technologies, an effect which would, in turn, directly influence the level of oil imports. In terms of the percentage of oil imports displaced, however, the importance of each assumption is not as great. Between now and the year 2000, the forecast market penetration of solar technologies will be mostly in markets now served by electricity. The cost of energy from electricity is considerably greater than that from alternative fuels. Thus, minor changes in the previous three assumptions on the generation of electricity will have only a limited effect on the composition of energy resources displaced by solar energy.

Assumptions underlying the SPURR methodology that might affect the composition of fuels displaced by solar energy can be grouped into two categories: the substitution effects of changing relative prices and the effects of government regulation. The SPURR model simulations assume that there would be no changes in the relative prices of alternative sources of energy resulting from the presence or absence of solar energy development, an assumption that violates basic economic theory. Economic analysis suggests that in some cases the displacement of conventional fuels by solar energy would drive the costs of conventional fuels down as producers attempt to regain the market. This could be important to the measurement of oil displacement by solar energy if the lower price of other conventional fuels led to the substitution for oil of fuels other than solar sources.

There are good reasons for not overemphasizing this deficiency in the SPURR model. One example is the present market situation for coal. On the supply side of the market, coal production by major suppliers is characterized by relatively fixed costs (such as transportation) that may limit price flexibility over time. On the demand side, emission controls on environmental pollutants for coal may severely limit its substitution for other fuels. Technical limits such as a requirement for a rapidly burning fuel may also restrict the substitution of coal for other fuels. Although some substitution may occur, the amount might well be relatively small.** A reasonable estimate of how much substitution would take place would require a much more extensive analysis than is possible here.

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*Problems with the use of market penetration curves to forecast solar development were addressed in a SERI-sponsored workshop. See Schiffel et al. (1978).

**All of these points could, of course, be negated by the development of new technologies for the production and utilization of coal, such as the fluidized combustion processes.

Another type of substitution not considered in the SPURR model is the replacement of energy resources with labor and/or capital. In response to changing energy prices resulting from solar energy development, it may become profitable to substitute labor or capital for energy in production. Business firms may switch to more capital- or labor-intensive means of production as compared to more energy-intensive methods. These kinds of substitutions will occur in a competitive economy in which business firms seek the means of production with the lowest cost.

There is still another category of energy resource substitutions, "indirect substitutions," which SPURR cannot estimate. Indirect substitution is a situation in which one energy source replaces a second, which then replaces a third. In effect, the first source has indirectly replaced the third. For example, a solar technology might displace a certain amount of oil used for a utility's electricity generation capacity in a given section of the country; the now-released oil might, in turn, displace some nuclear-generated electricity capacity. Thus, the electricity derived from solar technology has been indirectly substituted for nuclear energy via oil. Thus, though oil might have been directly displaced by solar energy, the substitution did not reduce the net amount of petroleum used because the oil subsequently displaced another energy source. Another illustrative substitution series could be solar for coal for oil, in which case solar energy would indirectly displace oil. In the level of detail found in the SPURR model, it is impossible to estimate the magnitude or direction of this potential bias. For the moment, we can do little except identify the indirect substitution condition as a caveat.

From the perspective of regulatory policy, the SPURR-generated oil displacement estimates should be viewed as an upper bound. More specifically, the level of oil imports in the year 2000 could be independent of the rate of solar energy development because oil import levels may be determined by government policy that limits the level of imports or the use of oil. President Carter has already limited oil imports,* and some concern has been expressed over the nation's ability to live within these limits. Thus, the impact of solar energy on oil imports may be limited primarily to providing an alternative path for making the transition from oil to other energy sources.

Another possible regulatory influence on solar energy is that the development of solar energy technologies might lead to a relaxation in regulations that relate to energy and particularly to oil conservation. The American public may wish to reallocate any oil savings to fuel larger cars or to maintain low gasoline prices rather than to reduce the level of oil imports. Conversely, some of the oil import savings might be absorbed by increasingly more stringent air quality regulations. For example, present technologies for reducing exhaust emission levels from internal combustion engines (such as catalytic converters) have decreased their efficiency and fuel economy. Stricter ambient air quality standards could exacerbate this condition.

A final problem with the SPURR model is the quality of the data, a problem shared by all energy econometric simulation models that project well into the future. The accuracy of current energy data is often problematic; in some cases, disreputable (Mayer 1977). The problem is heightened by forecasts 15 to 20 years in the future and is even greater for the various solar technologies addressed in this study. Unlike the conventional energy technologies now used to generate electricity, heat homes, or provide industrial process heat, most solar energy technologies are in the early stages of engineering development;

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*The Congress has been asked by the President to set a quota on American oil imports that would limit the quantity in any given year to the 1977 level; see Donnelly (1979).

projections of their future costs, mechanical reliabilities, and performance are much more subject to error than the conventional systems against which the SPURR comparisons are made. Thus, estimated market penetration levels are necessarily based on questionable data, a fact that is reflected in cost uncertainties and affects comparative market penetration and oil displacement levels, which are largely functions of relative costs.

In summary, a broad range of operational assumptions is required to obtain a simulation analysis of the oil import displacement potential of solar technologies. If any of these assumptions were significantly violated, the oil import displacement projections developed by SPURR would be similarly distorted. In terms of the level of solar market penetration, the level of solar energy development could easily range from a few percentage points to around 20%, depending on both the government's willingness to promote solar energy development and the price of oil. In terms of the fraction of energy resources displaced that represents oil, however, the accuracy of the SPURR model analysis is likely to be considerably greater, because, as mentioned, solar energy will compete most effectively with electricity, which, in turn, largely establishes the composition of fuels displaced. Due to the high cost of solar energy technologies, it is not expected that they will be able to compete successfully with conventional energy sources other than electricity except in limited applications. Government policy, of course, could change this situation. Thus, at best, the SPURR simulations should be viewed as rough guidelines or boundaries to be modified as developments occur in energy technology and energy policy.

4.3 RESULTS OF SPURR MODEL SIMULATION

Simulations with the SPURR model under the conditions stipulated by the NEP indicate that solar energy will displace a small but significant amount of oil from domestic energy consumption. The aggregate amount of oil displaced by various solar energy technologies will reach 0.65 quad per year, or 320,000 barrels per day, by the year 2000. For the U.S. balance of payments problem, the impact can be magnified considerably . Oil imports by the year 2000 are projected to be 8.6 million barrels per day or 17.4 quads per year, assuming that the United States can live within the import quota established by President Carter. Therefore, if it can be assumed that all the oil displaced by solar energy is imported, solar energy market penetration levels as estimated by the SPURR model will result in a 3.7% reduction in oil imports by the year 2000. In dollars, the impact on the balance of payments would be close to three billion dollars, assuming that oil would be selling for a conservative $25 a barrel in 1978 dollars by the year 2000. In terms of the $16 billion deficit in the 1978 balance of payments, this represents an 18% reduction in the trade deficit.

The diffusion of solar energy technologies will also displace large amounts of coal and nuclear energy in domestic energy consumption, perhaps as much as 3 quads by the year 2000. Combined with the reduction in oil consumption, these replacements should result in a significant decrease in environmental pollution caused by consumption of fossil and nuclear fuels.

4.3.1 National Impacts

Figure 4-3 shows the projected levels of solar energy dissemination and oil displacement under the conditions of the NEP. The figure demonstrates that the SPURR model projects relatively low levels of aggregate energy market penetration until near the end of the century. The levels of market penetration achieved by the year 2000 are the result of a strong government program of solar technology development and commercialization through the year 2000. The accelerating pace of market penetration projected by the SPURR model can be explained by relative costs of alternative energy sources and explicit government encouragement of solar energy technologies. Solar energy is projected by the NEP and SPURR to become increasingly cost-competitive with conventional energy sources as the combined result of rising real costs for conventional fuels and decreased costs of solar equipment. Technical innovations and decreased manufacturing costs due to experience and improved production methods are projected to motivate significant cost reductions in solar equipment.

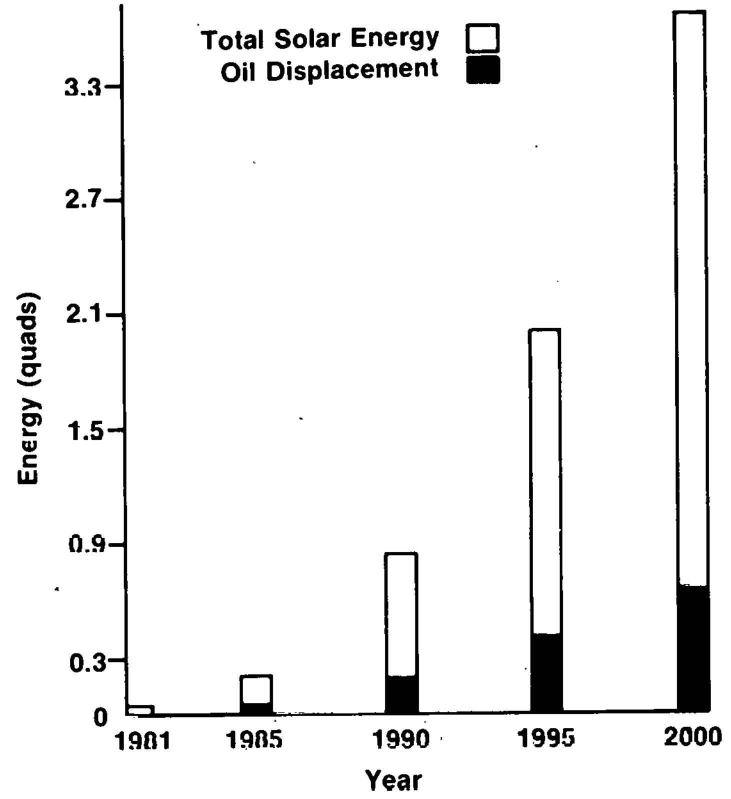

Figure 4-3. Solar Development and Oil Displacement

Figure 4-3 also shows that oil is approximately one-sixth of the total energy that will be displaced by solar technologies as projected by the SPURR model. The mixture of fuels displaced by solar energy technology is a function of the level of solar penetration into various economic sectors. As shown in Table 4-1, solar energy will have its largest impact on the electric utility sector and in the solar heating and cooling of buildings (SHACOB); both will displace 0.27 quad of oil. For SHACOB the ultimate effect of solar energy is on the utility sector, because SHACOB will replace primarily electricity used to heat and cool buildings. This sector largely accounts for the high levels of displacement of coal and nuclear fuel.

Table 4-1. TOTAL ENERGY DISPLACEMENT IN PRIMARY ECONOMIC SECTORS (quads)

Year	Utility	SHACOB[a]	A/IPH[b]
1981	0.001	0.034	0.000
1985	0.001	0.209	0.003
1990	0.183	0.607	0.052
1995	0.680	1.034	0.296
2000	1.444	1.387	0.823

[a] SHACOB — Solar Heating and Cooling of Buildings

[b] A/IPH — Agricultural and Industrial Process Heat

The other sector in which SPURR predicts significant levels of market penetration is the agricultural and industrial process heat (A/IPH) market. The penetration of the process heat sector, however, is forecast to occur at a slower rate than the electric utility sector through the year 2000. In the electric utility sector, where levels of energy conversion efficiency are low, solar technologies can compete directly on a cost per delivered energy unit base with conventional fuels. In the process heat market, conventional fuels are considerably more efficient in generating the final product, heat. For this reason, SPURR forecasts that market penetration levels of solar technologies will be concentrated in the electric utility sector at least through the year 2000.

4.3.2 Regional Impacts

The wide-scale diffusion and application of solar energy technologies will in many respects be spread relatively evenly across the country and accrue to the nation's overall benefit. The regional physical impact, as measured by the percentage of energy supplied by solar energy, however, is projected to vary widely across the country. Table 4-2 lists market penetration levels in the electric utility and process heat markets by the nine U.S. census regions shown in Fig. 4-4. The SPURR model projects higher penetration for solar energy in the Southwest, Pacific, and Mountain regions and lower penetration levels in the Northeast, with the different projection levels accounted for by market factors, cost effectiveness, or regional climatic characteristics. The Southwest, Pacific, and Mountain regions generally enjoy greater amounts of solar energy; high insolation levels are fairly common and good wind resources are available at many locations. Accordingly, solar equipment can be operated more efficiently in these regions than, for example, in the Northeast. It should be noted that costs of conventional fuels also vary significantly on a regional basis.

Key to Regions

Abbreviation	Region
1. NE	Northeast
2. MATL	Mid-Atlantic
3. SATL	South Atlantic
4. ENCL	East North Central
5. ESCL	East South Central
6. WNCL	West North Central
7. WSCL	West South Central
8. MT	Mountain
9. PACE	Pacific

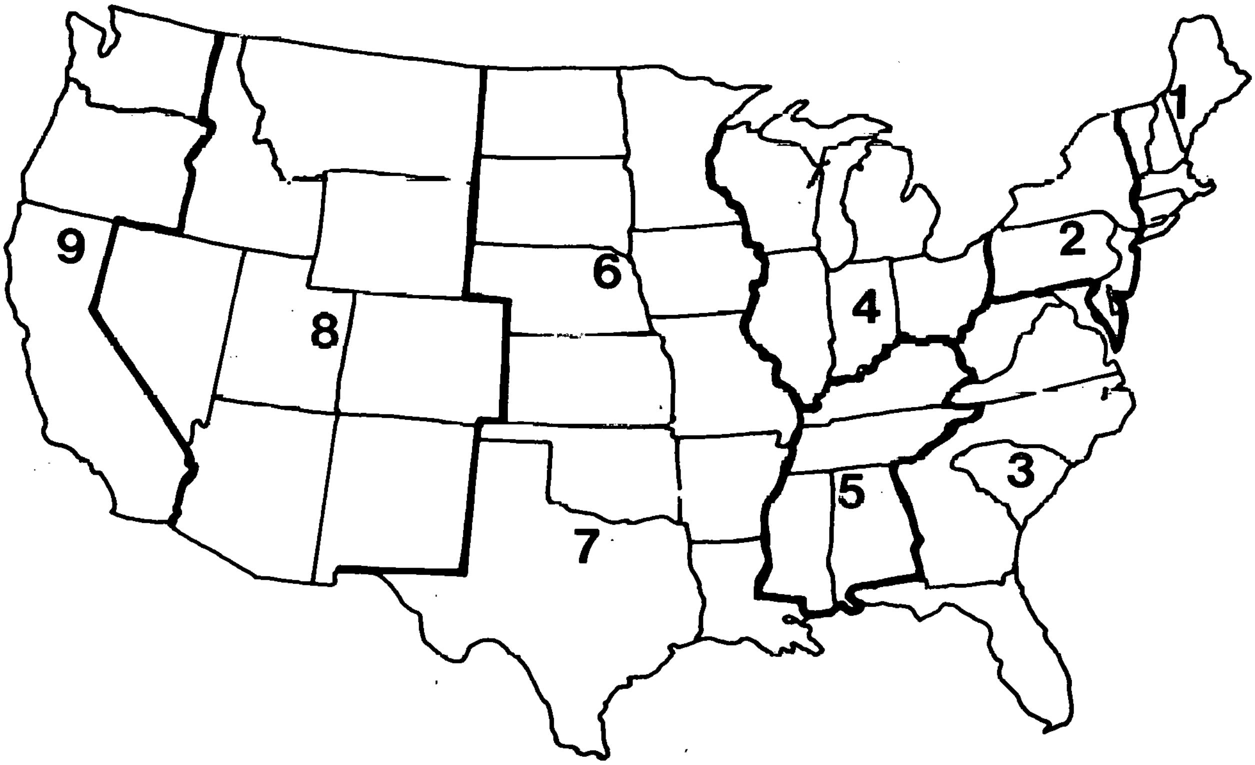

Figure 4-4. U.S. Census Regions

Table 4-2. **ENERGY DEMAND AND SOLAR CONTRIBUTION IN UTILITY SECTOR AND PROCESS HEAT MARKET (A/IPH) IN THE YEAR 2000**
(quads)

	Electric Utility			Agricultural and Industrial Process Heat		
Region	Total Electricity Demand	Solar Contribution	Percentage Solar	Total Process Heat Demand	Solar Contribution	Percentage Solar
USA	9.422	0.638	6.8	13.398	0.823	6.1
NE	0.377	0.025	6.5	0.389	0.021	5.4
MATL	1.460	0.048	3.3	1.916	0.093	4.8
SATL	1.715	0.148	8.6	1.527	0.108	7.1
ENCL	1.734	0.037	2.1	3.068	0.140	4.6
ESCL	0.895	0.072	8.1	1.152	0.062	5.4
WNCL	0.688	0.046	6.7	0.764	0.047	6.1
WSCL	0.999	0.094	9.4	3.068	0.224	7.3
MT	0.471	0.054	11.5	0.389	0.032	8.3
PACE	1.083	0.107	9.8	1.125	0.097	8.6

Geographical differences were also quite pronounced in solar energy penetration of the building heating and cooling market. The South dominated with 54% of the solar energy market. This region has only 30% of the nation's population, as of 1977.* However, the population in the South is projected to be growing faster than in the nation as a whole, and the South has higher insolation values. The West was second with 20% of the projected solar energy market in the year 2000. This is slightly higher than its 18% share of the nation's population in 1977. The West is expected to experience higher than average population growth, and insolation values in the southern part of the region are particularly high; it also has greater potential for wind systems. Conversely, penetration levels were much lower in the Northeast and North Central regions. Solar penetration of the building heating and cooling market in the North Central region was 16% despite the region's 27% share of the 1977 population. The solar energy market penetration level was 11% in the Northeast (which has 25% of the 1977 population), although the Northeast did use wood-burning residential heating systems to a greater extent than the national average.

Oil displacement attributable to the solar heating and cooling of buildings is almost as large as that displaced directly in the electric utility industry, roughly 0.27 quad in the year 2000. Combined, these two end uses represent over 80% of the projected oil displacement. Oil displacement traceable to agricultural and industrial process heat sector runs a distant third at 0.11 quad.

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*Population estimates taken from Anonymous (1978b).

4.4 PASSIVE SOLAR ENERGY

Potential oil displacements by passive solar technologies were not included in the SPURR model simulations. Passive solar energy, as defined here, principally encompasses the design of new buildings and the modification of existing structures to take advantage of the sun's energy; it does not include active systems, such as solar panels, which use mechanical pumps.

The major obstacle to measuring the energy saved through passive solar design of buildings is the great diversity of building types and the determination of the net savings of different passive design elements. Extension of eaves, the number of windows on the south side of the building, and the orientation of the structure on the property all are elements of passive solar design. Work is under way to quantify these elements for both new and retrofit buildings, but only tentative results are currently available for new buildings* and even less empirical evidence is available for retrofit designs.

Between now and the year 2000, it is estimated that a financial incentives program would result in 2.6 million new single-family homes utilizing passive solar design and technology.** This includes 800,000 oil-heated homes, 210,000 natural gas-heated homes, and 1.6 million electrically heated homes. Assuming that the average annual savings per gas- and oil-heated home is 15 million Btu and that for electric homes is 3.5 million Btu, the total oil displacement by passive solar applications would be 0.019 quad. This estimate would increase greatly if the retrofit market were included.

4.5 TRANSPORTATION

As noted in the introduction to this section, the SPURR simulation model does not include oil displacements that might be derived from solar energy technologies applied to transportation. To estimate the displacement effect of ethanol and methanol, we have drawn upon the figures provided by the Department of Energy's Report on the Alcohol Fuels Policy Review (DOE 1979). By 1985, the report projects that ethanol could displace as much as 40,000 barrels a day, or close to 0.5% of the petroleum currently imported. This is equivalent to 0.065 quad of oil (assuming that ethanol has an energy content approximately equal to 70% of the energy content of gasoline on a volume basis). After 1985, large amounts of methanol would begin to become available on a commercial basis. Combined, they could contribute significant amounts to the U.S. petroleum demand currently satisfied by oil imports.

The DOE Report on Alcohol Fuels does not project a range of ethanol and methanol estimates beyond 1985, nor does it estimate the amount of these products that would be processed into gasohol. It does include a projected maximum alcohol production from U.S.

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*The data and assumptions presented here on the potential energy savings from passive solar new buildings are based on discussions with Fred Roach and Scott Knoll on work done at Los Alamos Scientific Laboratories. Obviously, both should be treated as subject to validation and revision. Additional research is under way at Los Alamos to extend the results to address the retrofit of existing buildings. Future iterations of the SPURR model will explicitly consider passive solar technologies.

**Penetration rates were governed by market diffusion rate considerations similar to those discussed earlier for the SPURR model.

biomass resources by the year 2000 of 12.2 billion gallons per year of ethanol from nonfibrous sources; for methanol, the estimate is 154.7 billion gallons per year (DOE 1979, p. 57). This is roughly equivalent to 800,000 barrels per day of ethanol and 10 million barrels per day of methanol; in terms of gasoline displaced, these estimates (adjusted for Btu differentials) total more than 2.6 billion barrels of oil per year, or 14.6 quads. Combined, they represent more oil than the U.S. presently imports. However, our current best estimate is that only 20% of that total, or approximately 525.6 million gallons per year combined (2.92 quads) is a more realistic projection of the amount of petroleum that would be replaced. This assumption is a result of three factors. First, the maximum estimates, as the DOE report stresses, make no judgment about the total economics of biomass production; in the DOE estimate, all available resources are dedicated to biomass production regardless of the alternative uses and energy sources. For instance, in the case of ethanol, "maximum availability of grain sorghum, corn, and wheat was derived by using all existing cropland available for those crops and assuming no land setaside or diversion" (DOE 1979, p. 55). Second, there is no reason to assume that all the biomass production would be devoted to ethanol and methanol with the purpose of directly displacing oil in the transportation sector (Browne 1979). Significant uses of biomass energy involve indirect substitution for oil as gaseous or solid fuels which are covered by the SPURR simulations. Third, the replacement value of a gallon of ethanol/methanol to a gallon of gasoline at the higher levels of usage (above 25% in gasohol) is thought to be approximately 0.7 rather than the 1:1 ratio usually ascribed to lower levels of alcohol in motor fuel. It is impossible to derive exact displacement estimates given the noted uncertainties, but 1.44 million barrels of oil per day displaced by the year 2000 as a result of ethanol and methanol production appears to be realistic.

SERI

SECTION 5.0

CONCLUSIONS

America's continued reliance on foreign petroleum sources, with its resulting drain of American dollars and negative balance of payment, entails very real economic, political, and social costs to the United States. These costs can be measured in both opportunities foregone (i.e., "opportunity costs") and in additional risks assumed. The traditional policy tools for correcting the U.S. balance of payments deficit are rendered almost completely ineffective in the present situation. A devaluation of American dollars has little impact on U.S. trade relations with the OPEC nations because oil prices are quoted in U.S. dollars; the only assured result of a U.S. devaluation would be a rise in the price of OPEC petroleum. Increasing domestic interest rates to attract additional foreign investment capital would attract funds primarily from the other oil importing nations, thereby shifting the U.S. balance of payment problem to them. This could result in a "beggar thy neighbor" attitude which benefits no nation.

The literature reviewed above suggests that the best means of alleviating the petroleum-induced components of the negative balance of payments are to reduce the domestic consumption of oil or to displace it with domestic sources of energy; in both cases, the key is not to compensate for the cash outflows with increased exports, devaluated dollars, or heightened interest rates, but to reduce the oil imports.

This report has argued that the "costs" of imported petroleum extend well beyond strictly economic costs of the money paid to OPEC for the oil. Even if this cost were reduced or balanced by the influx of petrodollars, significant social and political costs remain. These costs could include the change in the living patterns of American citizens because of a curtailment in oil from the Middle East (witness the gasoline shortages caused by the reductions in Middle East oil during the 1973-74 oil embargo and the Iranian shutdown early in 1979), a restriction in foreign policy options (e.g., an inability to treat the problem of illegal Mexican immigrants because of the need to purchase Mexican petroleum), and potentially debilitating strategic shortages. Although these examples are difficult to translate into dollars, they all must be taken into account when calculating the "cost" of America's current reliance on foreign petroleum sources.

If it is agreed that the broad costs of dependence on foreign petroleum are significant and that the best policy option to reduce the balance of payment deficit is to reduce the amount of imported oil, then we are faced with two general policies: to reduce domestic energy demands or to increase domestic energy supply. (Obviously, the two should not be viewed as mutually exclusive.) One way in which the latter policy could be pursued is by increased use of solar energy technologies in end uses that presently employ petroleum. This national strategy is implicitly advanced in the National Energy Plan.*

Using a computer simulation model designed to predict levels of market penetration, we estimated the amount of solar energy technology penetration that might be expected by the year 2000 in three major end-use sectors—utilities, residential heating and cooling, and agricultural and industrial process heat. From these, we estimated the amount of displaced petroleum. Drawing upon a computer-assisted, market penetration model now being developed at the Los Alamos Scientific Laboratories, we derived estimates for the amount of petroleum that might be displaced by passive solar technologies. Finally,

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*See also President Carter's 20 June 1979 speech on accelerating the diffusion of solar energy technologies.

using a recent DOE study on the potential growth of methanol and ethanol, we estimated the amount of these fuels that might be projected for the transportation sector by the year 2000; this provided a third component for the total amount of petroleum displaced. It must be stressed that these two kinds of market penetration estimations—computer simulation and the DOE study—are very different approaches and should not be equated in methodologies or results. Even the two computer simulations have very different sets of operating parameters and assumptions. However, for the purposes of this report the three estimates can be summed to provide a first approximation of the amounts of imported oil that might be displaced by solar energy technologies by the year 2000. Table 5-1 lists these values.

Table 5-1. POTENTIAL OIL DISPLACEMENT BY SOLAR ENERGY BY 2000

End-Use Sector	Barrels of Petroleum per year (millions)	Quads per year
Utilities	48.5	0.27
Residential Heating and Cooling	48.58	0.27
Agricultural and Industrial Process Heat	19.79	0.11
Passive Solar Applications	4.3	0.024
Transportation (gasohol)	525.6	2.92
TOTALS	646.0	3.59

In terms of total energy, the 3.6 quads presented in Table 5-1 represent almost 3 percent of the 115 total U.S. quad requirements projected for the year 2000 by both the NEP and the Schurr et al. study (1979). In terms of actual oil displaced, the estimate of 646 million barrels of petroleum per year is considerably more conservative than the accelerated solar energy implementation schedule urged by the Harvard Business School study (Stobaugh and Yergin, ed., 1979, p. 232), which predicts a potential solar energy displacement of 1,460 million bbl/yr by the late 1980s. In terms of imported oil displaced, if the U.S. were to adhere to the 8.6-million bbl/day import limits announced by President Carter (see Donnelly 1979), solar energy could displace approximately 21% of the imported petroleum, assuming that all the oil displaced were imported. If this oil were priced at $25 per barrel, this could represent over $16 billion in U.S. dollars not transferred to the OPEC nations, which would be a sizable reduction in the balance of payments debit.

Several reservations must be made explicit. First, as noted, we have summed three very different types of estimations. Each of the three methodologies has its own internal characteristics and potential shortcomings that are reflected in the respective estimates of solar energy displacement. There is no way to determine whether these aggregated internal characteristics are reinforced or balanced by the simple addition of the estimates. Therefore, it is important to note that these totals are presented only as first-level approximations or suggested boundary conditions. It is our judgment that they represent lower order boundaries and that, should the United States attain the President's

20% solar energy goal by 2000, they will be exceeded. Certainly the higher estimates found in other studies, such as that produced by the Harvard Business School, would support this contention.

A second important reservation concerns the fungibility of petroleum products. Solar energy technologies may indeed replace millions of barrels of oil per day currently used to produce electricity, heat homes, or drive automobiles. However, it is certainly plausible that this displacement might result in no reduction in oil imports because the displaced oil could be transferred to meet other domestic energy requirements. For example, imported petroleum released from the utility market may be rechanneled into the transportation sector as a means of maintaining sufficient supplies at low prices. Oil is a very fungible product, and it is somewhat naive to assume that its simple displacement in one sector will result in reduced petroleum imports.

Third, over 80% of the estimated oil displaced is used in the transportation sector. This figure is based upon our current best judgments of the amounts of ethanol and methanol American industry can produce and, even more directly, the amounts of gasohol the American consumer will purchase. Further uncertainties are introduced in calculating Btu equivalents for gasohol versus gasoline, especially when they are weighted for combustion efficiencies. Many of these values have not been empirically validated, nor have they been demonstrated over extended time periods. Therefore, the transportation sector estimates, particularly, must remain open to revision.

Even given these admitted reservations, we submit that the estimated values are feasible and obtainable goals for solar energy displacement of petroleum by the year 2000. The specific means to achieve these goals are beyond the scope of this report, except to note that the SPURR market penetration levels were predicated on a number of proposed government policy initiatives favoring solar energy. Again, it should not be assumed that oil displaced will, ipso facto, be imported oil. Not only are petroleum products extremely fungible, but geographical regions of the nation—typically those that are less suitable for solar energy technologies—presently depend heavily upon foreign petroleum; the most obvious example is, of course, the New England region. To bring solar energy heavily "on line" in the Southwest would replace oil currently used there but would not necessarily relieve New England of its dependence upon OPEC petroleum. Specific government policies must be formulated to ensure that these regional differences are accounted for in estimating reduced petroleum imports.

Even conservative estimates of amounts of petroleum displaced by solar energy technologies by the year 2000 could have a substantial effect on correcting the U.S. balance of payments deficits if policies can somehow be established to guarantee that the oil displaced is, in fact, imported oil. This could raise the price of oil in some sections of the nation because of increased transportation costs. However, if one can add a "national security" component to the economic cost of imported oil, the reduced dependence on foreign supplies could be considered adequate compensation for the higher price.

Obviously, solar energy technologies by themselves cannot solve the balance of payments deficit and its resulting economic, social, and political liabilities; imported oil is only one component of the deficit. They cannot completely ensure American independence from foreign petroleum sources at the estimated 20% displacement level. However, in conjunction with the other putative benefits of solar energy, the capability of these technologies to alleviate balance of payments problems should be considered yet another argument for the continued development and dissemination of solar technologies.

SECTION 6.0

REFERENCES

Aikens, James E. 1973. "The Oil Crisis: This Time the Wolf is Here." Foreign Affairs. Vol. 51 (no. 3): pp. 462-490; April.

Amuzegar, Jahangir. 1973. "The Oil Story: Facts, Fiction, and Fair Play." Foreign Affairs. Vol. 51 (no. 4); July.

Amuzegar, Jahangir. 1978. "OPEC and the Dollar Dilemma." Foreign Affairs. Vol. 56 (no. 4): pp. 740-750; July.

Andelman, David A. 1979. "East Bloc Seeks New Oil Sources: Russians Unable to Help Much in Iranian Cutoff." New York Times. pp. D1, D4; February 20.

Anonymous. 1978a. "Some Reasons to Worry." Time. p. 39; January 16.

Anonymous. 1978b. "The Survey of Buying Power Data Service 1978." Sales Marketing Management Magazine. New York.

Anonymous. 1979a. "OPEC Cash Glut Called Bank Peril." New York Times. p. D1; December 11.

Anonymous. 1979b. "U.S. Mandatory Curb on Oil, Gasoline Use Is Possible by April Due to Strike in Iran." Wall Street Journal. p. 2; February 1.

Bach, Christopher L. 1978. "OPEC Transactions in the U.S. International Accounts." Survey of Current Business. Vol. 58 (no. 4): pp. 21-32; April 1978.

Beim, David O. 1977. "Rescuing the LDCs." Foreign Affairs. Vol. 55 (no. 4): pp. 717-731; July.

Bennington, G.; et al. 1978. Solar Energy: A Comparative Analysis to the Year 2020. MTR-7579. McLean, VA: MITRE Corporation, METREK Division.

Berry, John M. 1979. "Mandatory Fuel Conservation Urged: Iran Impact Seen Limited." Washington Post. pp. A1, A18; February 16.

Black, Robert F. 1978. The Economic Impact of Oil Import Reductions. Washington, D.C.: Government Printing Office for the Congressional Budget Office.

Browne, Malcolm W. 1979. "Plants and Organic Waste Offer Hopes of Filling U.S. Energy Gap." New York Times. pp. A1, D10; December 11.

Brunner, Ronald D.; Vivian, Weston E. 1979. "Citizen Viewpoints on Energy Policy." Ann Arbor, MI: University of Michigan, Institute of Public Policy Studies Discussion Paper No. 140.

Campbell, John C. 1977. "Oil Power in the Middle East." Foreign Affairs. Vol. 56 (no. 1): pp. 89-110; October.

Carter, Jimmy. 1979. "Solar Energy Address." Reprinted in Congressional Quarterly Weekly Report. Vol. 37 (no. 26): pp. 1309-1313; June 30.

Chandler, Geoffrey. 1977. "The Innocence of Oil Companies." Foreign Policy. No. 27: pp. 52-70; Summer.

Chenery, Hollis B. 1975. "Restructuring the World Economy." Foreign Affairs. Vol. 53 (no. 2): pp. 242-263; January.

Church, Frank. 1977. "The Impotence of Oil Companies." Foreign Policy. No. 27: pp. 27-51; Summer.

Cleveland, Harold V.B.; Brittain, W. H. Bruce. 1975. "A World Depression?" Foreign Affairs. Vol. 53 (no. 2): pp. 223-241; January.

Commoner, Barry. 1979. The Politics of Energy. New York: Knopf.

Corrigan, Richard. 1978. "An Optimistic Look at Mexico's Oil, Gas Riches." National Journal. Vol. 10 (no. 51-52): p. 2080; December 30.

deVries, Rimmer. 1979. "Implications of the New Oil Situations." World Financial Market. New York: May.

Donnelly, Harrison H. 1979. "Quotas on Oil Imports Not New to U.S. . . . But Carter Hoping for Difference." Congressional Quarterly Weekly Report. Vol. 37 (no. 29): pp. 1438-1439; July 21.

Dornbusch, Rudiger; Krugman, Paul. 1976. "Flexible Exchange Rates in the Short Run." Brookings Papers on Economic Activity. pp. 537-584.

Enders, Thomas O. 1975. "OPEC and the Industrial Countries: The Next Ten Years." Foreign Affairs. Vol. 53 (no. 4): p. 625-637; July.

Energy and Environmental Analysis. 1977. The EEA MOPPS Industrial Model. Arlington, VA: July 11.

Energy Research and Development Administration. 1977. Analysis of Alternative Energy Futures. Washington, D.C.: February 4.

Farmanfarmaian, Khodadad; et al. 1975. "How can the World Afford OPEC Oil?" Foreign Affairs. Vol. 53 (no. 2): pp. 201-222; January.

Farnsworth, Clyde H. 1978. "U.S. Conceding Inflation in '79 Will Exceed 7%." New York Times. pp. A1, D14; December 20.

Farnsworth, Clyde H. 1979. "Trade Study Discounts U.S. Policy." New York Times. pp. D1, D2. November 23.

Frenkel, Jacob A.; Johnson, Harry G. (eds.). 1976. The Monetary Approach to the Balance of Payments. London: George Allen & Unwin, Ltd.

Friedman, Milton. 1953. "The Case for Flexible Exchange Rates." Essays in Positive Economics. Chicago: University of Chicago; pp. 157-203.

General Electric. 1974. Solar Heating and Cooling of Buildings: Phase O Feasibility and Planning Study Final Report. Vol. 3: Book 3. Document No. T5D4219. Valley Forge, PA: General Electric (Space Division).

Goldstein, Walter. 1978. "The Politics of U.S. Energy Policy." Energy Policy. Vol. 6 (no. 3): pp. 180-95; September.

Halloran, Richard. 1979a. "Iranians Said to Hint Oil Resumption in '79." New York Times. p. D16; February 15.

Halloran, Richard. 1979b. "Oil Curb Ruling Set for April 1: Iran Cutoff Cited by Schlesinger." New York Times. pp. D1, D2; February 1.

Halloran, Richard. 1979c. "Schlesinger Issues Renewed Warning on Iran's Oil Flow." New York Times. pp. A1, D2; February 14.

Hayes, Denis. 1977. Rays of Hope. New York: Norton.

Healy, Denis. 1979-80. "Oil, Money, and Recession." Foreign Affairs. Vol. 58 (no. 2): pp. 217-30; Winter.

Hillery, Victor J. 1978. "Stocks Staggered by Shock of OPEC Oil-Price Boost; Industrials Tumble 17.84 to 787.51 in Heavy Trading." Wall Street Journal. p. 2; December 19.

Kemp, Donald S. 1975. "Balance of Payment Concepts - What Do They Really Mean." Federal Reserve Bank of St. Louis Review. Vol. 57: pp. 14-23; July.

Knight, Michael. 1979. "Thousands in New England Try to Discover Energy Substitutes." New York Times. p. A14. August 4.

Koreisha, Sergio; Stobaugh, Robert. 1979. "Limits to Models" in Stobaugh and Yergin, eds., Energy Future. New York: Random House, pp. 234-265.

Krawiec, Frank; Flaim, Theresa. 1979. Solar Cost Reduction Through Technical Improvements: The Concepts of Learning and Experience. Golden, CO: Solar Energy Research Institute; forthcoming.

Krunholz, June. 1979. "Trade Currency Wars Deepen Depression: Could it Happen Again?" Wall Street Journal. pp. 1, 20. October 23.

Laffer, Arthur B. 1974. "The Bitter Fruits of Devaluation." Wall Street Journal. January 10.

Lawrence, Robert Z. 1978. "An Analysis of the 1977 U.S. Trade Deficit." Washington D.C.: The Brookings Institution. Brookings Occasional Papers.

Levy, Walter J. 1978-79. "The Years that the Locust Hath Eaten: Oil Policy and OPEC Development Prospects." Foreign Affairs. Vol. 57 (no. 2): pp. 287-305; Winter.

Lewis, Paul A. 1979. "Iran Crisis Is Speeding Returns." New York Times. pp. D-1, D-3; December 11.

Lovins, Amory. 1977. Soft Energy Paths: Towards a Durable Peace. chap. 11. Cambridge, MA.: Ballinger for Friends of the Earth.

Manne, Alan S.; Richels, Richard G.; Weyant, John P. 1979. "Energy Policy Modeling: A Survey." Operations Research. Vol. 27 (no. 1): pp. 1-36; January-February.

Mayer, Lawrence S. 1977. "The Value of the Econometric Approach to Forecasting Our Energy Future." Princeton, NJ: Center for Enviromental Studies, Princeton University.

McNown, Robert F. 1975. "The Impact of Currency Depreciation and International Markets on U.S. Inflation." Quarterly Review of Economics and Business. Vol. 15: pp. 7-14; Winter.

Metz, William D. 1978. "Mexico: The Premier Oil Discovery in the Western Hemisphere." Science. Vol. 207 (no. 4374): pp. 1261-1265; December 22.

MITRE Corporation, METREK Division. 1978a. SPURR Agricultural and Industrial Process Heat Component—Program Methodology and Documentation. McLean, VA: MITRE Corporation, METREK Division; March.

MITRE Corporation, METREK Division. 1978b. SPURR Utility Component Program Methodology and Documentation. McLean, VA: MITRE Corporation, METREK Division; May.

MITRE Corporation. 1977. Systems Description and Engineering Costs for Solar Related Technologies. MTR-7485. Vol. I-IX. McLean, VA: MITRE Corporation.

Moran, Thomas H. 1976-77. "Why Oil Prices Go Up: The Future: OPEC Wants Them." Foreign Policy. No. 25: pp. 58-77; Winter.

Mostert, Noel. 1974. Supership. New York: Alfred Knopf.

Mudd, Douglas R.; Wood, Geoffrey E. 1978. "Oil Imports and the Fall of the Dollar." Federal Reserve Bank of St. Louis Review. Vol. 60: pp. 2-6; August.

Mundell, Robert A. 1963. "Capital Mobility and Stabilization Policy Under Fixed and Flexible Exchange Rates." Canadian Journal of Economics and Political Science. Vol. 29: pp. 475-485; November.

Neu, C.R. 1979. The U.S. Balance of International Payments and the U.S. Economy Developments in 1978 and Early 1979. Washington, D.C.: Government Printing Office for the Congressional Budget Office. November.

Nye, Joseph S. 1978. "Nonproliferation: A Long-Term Strategy." Foreign Affairs. Vol. 56 (no.3): pp. 601-623; April.

Oppenheim, V. H. 1976-77. "Why Oil Prices Go Up: The Past: We Pushed Them Up." Foreign Policy. No. 25: pp. 24-57; Winter.

Pindyck, Robert S. 1978. "OPEC's Threat to the West." Foreign Policy. No. 30: pp. 36-52; Spring.

Pindyck, Robert S. 1979a. "Interfuel Substitution and the Industrial Demand for Energy: An International Comparison." Review of Economics & Statistics. Vol. 61 (no. 2): pp. 169-179; May.

Pindyck, Robert S. 1979b. The Structure of the World Energy Demand. Cambridge, MA: The MIT Press.

Pollack, Gerald A. 1974. "The Economic Consequences of the Energy Crisis." Foreign Affairs. Vol. 52 (no. 3): pp. 452-471; April.

Rattner, Steven. 1978. "Fight on Inflation: Outlook is Bleaker." New York Times. p. D3; December 21.

Revzin, Philip. 1979. "Western Europe Frets About Iranian Oil Cutoff But Shows No Panic." Wall Street Journal. pp. 1, 35; February 20.

Roessner, J. David; et al. 1979. Application of Diiffusion Research to Solar Energy Policy Issues. SERI-TR-51-194. Golden, CO: Solar Energy Research Institute.

Roper Reports 78-10 Section D.

Russett, Bruce. 1979. "World Energy Demand and World Security." Policy Sciences. Vol. 11 (no. 2): pp. 187-202; November.

Samuelson, Robert J. 1978. "The Turning Point." National Journal. Vol. 10 (no. 45): p. 1829; November 11.

Schiffel, Dennis; Costello, Dennis; Posner, David; Witholder, Robert. 1978. The Market Penetration of Solar Energy: A Model Review Workshop Summary. SERI/16. Golden, CO: Solar Energy Research Institute; January.

Schurr, Sam H.;et al. 1979. Energy in America's Future: The Choices Before Us. Baltimore, MD: The Johns Hopkins University Press for Resources for the Future.

Sherrill, Robert. 1979. "The Case Against the Oil Companies." The New York Times Magazine. Section 6, pp. 32, 34, 101-105, 114-123; October 14.

Silk, Leonard. 1978. "Economic Scene: Can U.S. Cope with Oil Rise?" New York Times. p. 2; December 20.

Simonet, Henri. 1975. "Energy and the Future of Europe." Foreign Affairs. Vol. 53 (no. 3): pp. 450-463; April.

Singer, S. Fred. 1978. "Limits to Arab Oil Power." Foreign Policy. No. 30: pp. 53-67; Spring.

Smith, J. P. 1979. "Mandatory Fuel Conservation Urged: Schlesinger Spurs Debate." Washington Post. pp. A1, A18; February 16.

Smithies, Arthur. 1978. The Economic Potential of the Arab Countries. R-2250-NA. Santa Monica, CA: The Rand Corporation. November.

Solomon, Robert. 1974. "The Allocation of Oil Deficits." New York: Board of

Governors of the Federal Reserve System.

Solomon, Robert. 1977. The International Monetary System, 1945-1976: An Insider's View. New York: Harper and Row.

Stobaugh, Robert; Yergin, David, eds. 1979. Energy Future. New York: Random House.

Tanner, James. 1978. "Barreling In: Oil Imports are Rising after First Half Drop; Record '79 Total Likely." Wall Street Journal. p. 1; August 9.

Tew, Brian. 1977. The Evolution of the International Monetary System, 1945-1977. New York: John Wiley.

Tolley, George S.; Wilman, John D. 1977. "The Foreign Dependence Question." Journal of Political Economy. Vol. 85 (no. 2): April.

Triffin, Robert. 1978-79. "The International Role and Fate of the Dollar." Foreign Affairs. Vol. 57 (no. 2): pp. 269-286; Winter.

U.S. Department of Energy. 1979. The Report of the Alcohol Fuels Policy Review. Washington, D.C.: Government Printing Office.

U.S. Department of Treasury. 1975. Report on the Investigation on the Effects of Petroleum Products on the National Security Pursuant to Section 232 of the Trade Expansion Act in Federal Register. Washington, D.C.: Government Printing Office, Vol. 40.

U.S. Department of Treasury. 1979. "Report of Investigation Under Section 232 of the Trade Expansion Act, 19 U.S.C. 1862." Federal Register. Washington D.C.: Government Printing Office. Vol. 44, (no. 62); pp. 18818-18853.

U.S. Executive Office of the President. 1978. The Economic Report of the President. Washington, D.C.: Government Printing Office.

Watt, Kenneth E. F. 1978. "Why Energy Prices Should be Deregulated." House of Representatives Subcommittee on Energy and Power, Committee on Interstate and Foreign Commerce. Washington, D.C.: U.S. Government Printing Office.

Whitman, Marina v. N. 1975. "The Payments Adjustment Process and the Exchange Rate Regime: What Have We Learned?" American Economic Review. Vol. 65: pp. 115-146; May.

Witeveen, H. Johannes. 1975. "Inflation and the International Monetary Situation." American Economic Review. Vol. 65: pp. 108-114; May.

Witholder, Robert. 1979. SPURR Sensitivity Analysis. Golden, CO: Solar Energy Research Institute; forthcoming.

Yang, Jai-Hoom. 1978. "Budget Deficits and Trade Deficits: Is there a Link?" Federal Reserve Bank of St. Louis Review. Vol. 60: pp. 9-15; October.

APPENDIX A
SPURR METHODOLOGY

The System for Projecting the Use of Renewable Resources (SPURR) computer simulation model was chosen to estimate the amount of imported petroleum that could be displaced by solar energy technologies for the years 1985 and 2000.

SPURR consists of a computer simulation model and an energy data base composed of engineering costs and two possible economic scenarios, the National Energy Plan (NEP) and the Recent Trends Scenario (RTS). The economic forecast chosen as most plausible for this study was the NEP. This scenario encompasses President Carter's recent energy plan, which emphasizes coal as a substitute energy source for oil and gas in the utility and industrial sectors of the economy (see Appendix B).

Basically, SPURR divides the economy into four major markets: (1) the heating and cooling of buildings, (2) agricultural and industrial process heat, (3) a centralized utility sector covering the generation of electricity, and (4) a synthetic fuels and products market. Each market is subdivided by geographic region and other characteristics specific to that sector. For example, the utility sector is divided into nine census regions with further partitioning of each region into four demand types.

SPURR combines the techno-economic base with the scenario assumptions of the NEP to simulate the market penetration achieved by solar energy technologies in each submarket of the model. The techno-economic data base and the NEP scenario are important assumptions and factors influencing this market penetration. The NEP scenario projects specific levels and types of energy demand for 1985 and 2000 together with projections for fuel cost and escalation rates. The NEP calls for government demonstration and incentive programs and supplies other pertinent economic information. The data base contains engineering information for solar and conventional technologies. Also included are data on climatic and regional factors and experience curves, explained more fully below.

THE NEP SCENARIO

SPURR incorporates a number of assumptions derived from the proposed NEP. First, the NEP scenario incorporates a 10% investment tax credit on solar equipment for commercial building use and a 20% investment tax credit for solar equipment used in process heating. A tax credit is provided for the purchase of residential solar equipment. In 1977, a 40% federal credit commenced for $1,000 toward the purchase of solar equipment together with a 25% credit for the next $6,400. This tax credit declines over time with a reduction in 1984 to 25% for the first $1,000 and 15% for the next $6,400. After 1984, federal tax credits as an incentive to purchase solar equipment are terminated.

Starting in 1978, the NEP scenario provides $100 million for a solar heating and cooling demonstration program spanning three years. Taxes and other restrictions will be placed on gas and oil in the commercial sector to encourage increased use of electricity for hot water and space heating. Natural gas also will be provided to residential users at a reasonable price, thereby encouraging a moderate use of electricity for space heating and hot water in this sector.

The NEP calls for a prohibition on the use of gas and oil in the utility sector and restriction on their use in the process heat sector. The NEP also projects taxes on oil and gas to increase the price of domestic oil to that of the world market by 1980 and the price of gas to a level slightly less than the world price by 1985. Reflecting President Carter's reluctance to develop breeder reactors and nuclear fuel reprocessing technologies, the NEP scenario does not develop new sources of nuclear energy. In its stead is a light water reactor (LWR) which utilizes no fuel reprocessing. The Canadian deuterium-uranium reactor is forecast to be commercialized by 1990 as a more fuel efficient reactor than the LWR.

It is important to examine what conventional fuels are displaced by the solar technologies in different end use applications. In the process heating sector, solar technologies compete with coal, oil, and electricity. Since electricity cost is projected to rise to $16/MBtu by 2000 (electricity is by far the most expensive of the three conventional energy sources) electricity should experience the greatest percentage reduction in use as an energy source in the process heat sector. The NEP proposal of taxes on gas and oil, together with projected escalations in the price of coal, also encourages the penetration of solar into the sector. Coal prices are expected to rise because of the capacity constraints of coal mining as demand increases.

Variations of the NEP were conducted by MITRE to identify the factors to which the process heat sector was most sensitive. These studies showed that the rate of solar market penetration would increase much more rapidly if this sector were forced to utilize electricity, the most expensive alternative to solar energy. If coal costs were to increase at a smaller rate than projected under the NEP, solar market penetration would not be greatly hindered.

In the building sector, solar energy competes with electricity in the heating and cooling of buildings and in water heating. Early market acceptance is expected because these solar systems are already at, or fast approaching, the commercialization stage. The NEP calls for taxes on oil and gas in the commercial building sector, thereby stimulating demand for electricity there and encouraging a shift to natural gas in the residential building sector. The residential subsector has unrestricted use of natural gas in this scenario. This switch to natural gas undoubtedly inhibits the penetration of solar technologies in the residential sector because natural gas is a less costly substitute for oil than is solar energy.

For the utility sector, the NEP projects a prohibition on the use of oil and gas for new facilities, thereby forcing utilities to shift to coal for electricity generation. The response to the increased demand for coal can be an increase in the price and/or quantity of coal; the projected result is a combination of the two. The price of coal rises due to capacity constraints on coal mining. MITRE's sensitivity analysis suggests the use of a 20% investment tax credit for solar electric technologies and the use of a hybrid solar system (which uses small quantities of oil). These two actions, combined with a large-scale commercialization program, would significantly increase the percentage of total U.S. electric energy supplied by solar energy by the year 2000 because hybrids are closest to commercialization and initially provide more rapid solar penetration.

Wind energy conversion systems (WECS) have the largest impact of the solar technologies in the utility sector, mainly as fuel savers. The decision to purchase a fuel saver depends on the net life-cycle savings. Since WECS cannot be relied upon all of the time, they are granted only a 10% capacity credit (i.e., they can be counted on to deliver only 10% of the total electric demand at any one time). Again, the WECS most likely to be introduced first into the utility sector is a hybrid one that utilizes a gas turbine backup system.

THE SPURR SIMULATION MODEL

To describe more completely how SPURR functions, one needs to examine the methods used in describing the four major markets of the model: the building, agricultural and industrial process heat, utility, and synthetic fuel components.

The Building Component

The building market sector is subdivided into 9 building types, new and retrofit solar systems, 16 climatic regions, and at least 3 conventional hot water, heating, and/or cooling systems.

For each market subdivision, a solar system, equipped with storage and auxiliary backup and possessing a collector area minimizing life-cycle costs with respect to other relevant solar systems, is chosen to compete with conventional system(s) within that subdivision. Once this minimum life-cycle cost has been calculated, a figure of merit (FOM) is determined that expresses the ratio of life-cycle costs for each conventional system to the optimum solar system for each market subdivision. The FOM represents the relative competitiveness of the new technology and determines the shape of the market share function for the solar technology.

The market share function reflects the initial market inertia and other institutional factors impeding the market penetration of a solar technology. The function is typically S-shaped, reflecting the fact that a new technology initially will capture only a small share of the market, will then capture a larger share at an increasing rate, and eventually approaches an equilibrium market share. The equilibrium share will be 50% if the FOM is equal to one (both the conventional and solar system are valued equally); the speed with which this share is reached depends on the time constant (or replacement time) utilized. An FOM of greater than one means the solar system is valued more than the conventional system and will eventually capture the entire market (again depending on the time constant utilized). If the FOM is less than unity, the conventional system is valued more than the solar system and the latter's market share will eventually reach zero. The fact that a new technology with an FOM less than unity actually captures any share of the market is due to the assumed "boom-or-bust" phenomenon, in which consumers experiment by purchasing an unproven technology.

Many crucial elements incorporated in the SPURR methodology and data base motivate solar market penetration. Foremost is the FOM, which provides a ratio of life-cycle conventional to solar energy costs for the relevant market. This, coupled with the time since the new technology was introduced on the market, determines the level of solar market penetration. Next are the learning effects assumed to be operative for solar technologies. Learning effects are a function of cumulative production. Once the solar market share is determined, cumulative production necessarily increases and learning effects prevail, thereby diminishing production costs for the next time period. To determine the market share then requires calculating a new FOM that incorporates a lower life-cycle cost for the solar technology and (except, possibly, for nuclear systems) a higher life-cycle cost for conventional technologies due to the escalation in fuel prices. This generally biases the FOM in favor of solar technologies and hence increases the solar technology's market penetration level. Thus solar market penetration is enhanced as the FOM shifts in favor of the new technologies until some level of market equilibrium is attained.

The Agricultural and Process Heat Component

The agricultural and industrial process heat market (A/IPH) is divided into nine census regions, six conventional systems, and eight temperature applications. The six fuels with which solar technologies compete are: (1) direct electricity, (2) electric heat pump, (3) natural gas, (4) coal, (5) oil, and (6) synfuels and waste residues.

To determine the market penetration of a solar technology, an FOM is computed comparing the annualized life-cycle cost for a solar system with that of a conventional system appropriate to the region and temperature application. The cost of the solar system includes the initial cost of the system plus a factor allowing for economies of scale due to cumulative production. An adjustment also is made to determine whether a particular market is suitable for a given solar technology. This factor improves over time in the SPURR model.

The cost of the conventional fuel system is calculated by considering a regional fuel cost factor, capital investment, an operating and maintenance variable, a fuel escalation factor, and a fuel adjustment variable that takes into account other external effects possibly omitted by the fuel escalation factor (e.g., environmental costs and government taxes or subsidies). Once these competing cost figures are calculated, an FOM is computed and market penetration percentage is calculated using the market share function. The shape of the market share is determined by the FOM, and the location of the particular technology on the curve is dependent on the time elapsed since the technology was introduced on the market.

The Utility and Synthetic Fuels Component

The utility and synthetic fuels sectors are combined in this discussion because both sectors have the same methods for determining costs and market penetration. The markets are subdivided by the nine census regions and further by four demand types for the utility sector and four synthetic fuels for the synfuels sector. For fuel savers, a ninth demand type, costs are calculated differently, as discussed following the methods for determining costs and market penetration of the other eight demand types.

In the utility sector, the four demand types for each of the nine regions are satisfied by three basic systems: (1) expensive, highly fuel efficient, capital-intensive coal and nuclear plants to satisfy base-load demand, (2) older base-load plants and oil steam plants satisfying intermediate and semipeak load, (3) cheaper (e.g., low fixed costs, hence less capital intensive) but less efficient (e.g., higher fuel costs) combustion turbines to meet peak load demand.

Market penetration is determined in the utility sector by first computing an annualized cost of the output product for each technology competing in a particular submarket—usually cost per kilowatt hour for electricity and per million Btu for synthetic fuels. However, due to uncertainties surrounding future operating and management costs and fuel and capital costs, maximum and minimum cost figures are calculated together with the expected cost figure. Once these costs have been calculated, the competing technologies are ranked based on a triangular probability distribution (assumed for simplicity) of annualized cost of output, the end points of which are the minimum and maximum cost calculations with the peak as the expected annualized cost. (See Figure A-1.) Only the three systems yielding the lowest probability distribution of annualized costs are considered in determining market shares.

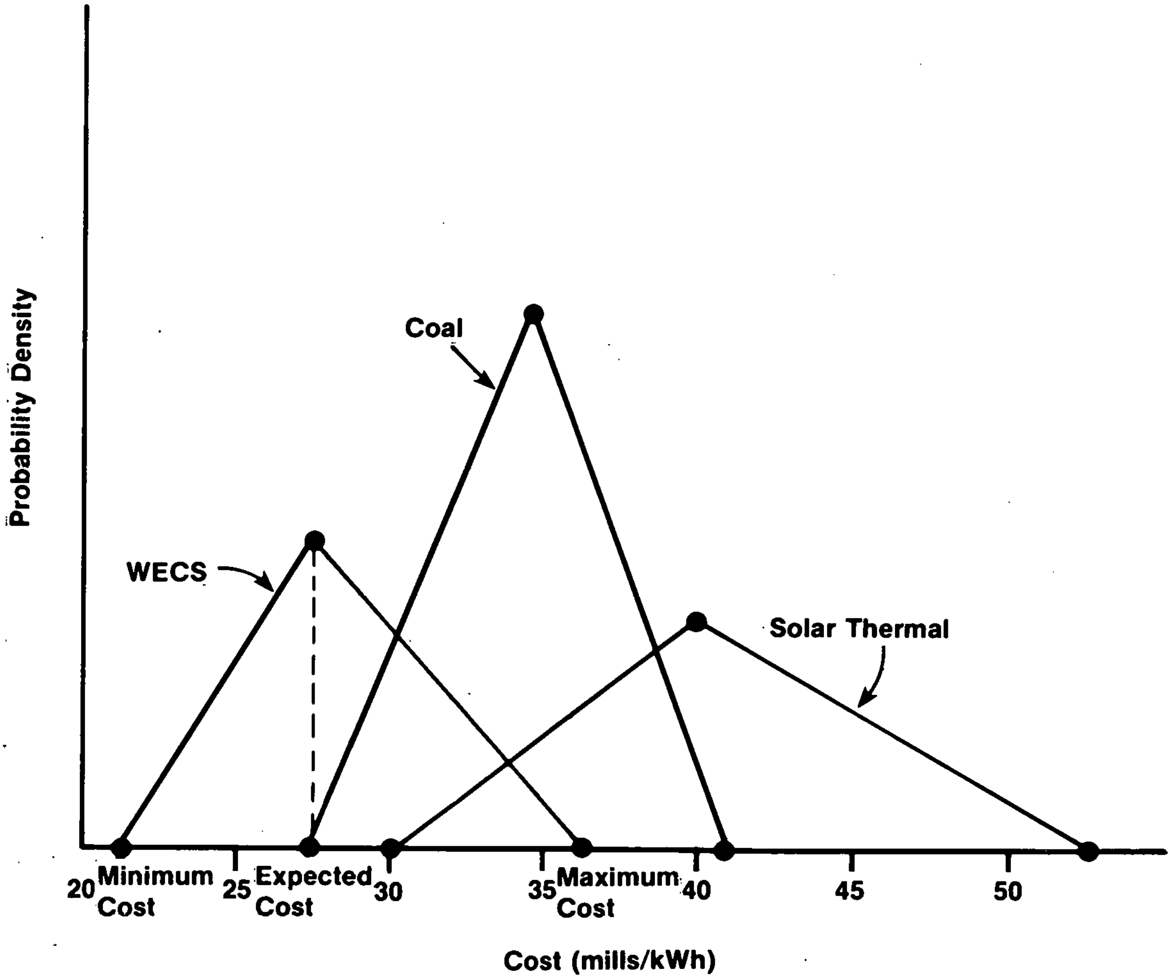

Figure A-1. Example of Probability Distribution for Utility Market Allocation Among Three Competing Technologies

A Monte Carlo simulation is used to compute the probabilities of least cost through a random number generator. In this simulation, a random number is assigned to each of the three competing technologies which, in turn, is translated into a cost figure based on the triangular probability distribution. The technology with the lowest cost is considered best for that particular trial. Repeated trials are conducted; the probability of least cost for a technology is the number of times the technology obtained the lowest cost divided by the number of trials. Trial size varies but must be such that the probability least cost calculations for each technology fall within an acceptable error tolerance range. MITRE modellers argue this stochastic process is more appropriate than a deterministic approach for a least cost calculation because it reflects real world uncertainties in the introduction of untested technologies and uncertain future fuel costs. It also permits market demand to be met by new technologies which are not yet cost competitive with conventional ones.

Once the SPURR simulation determines how the market is to be divided, consideration is given to whether each technology satisfies two essential constraints. The first, the market function constraint (whose shape is determined by the FOM), is used to reflect market inertia and institutional factors inhibiting acceptance of new technologies. The second constraint considers possible resource limitations and other factors, such as site availability for WECS. This constraint applies to both new and conventional technologies. If one or both of these constraints should preclude a technology from meeting the market share assigned to it by the simulation, then the next best (fourth ranked least cost probability) technology enters the picture and a Monte Carlo simulation assigns this unmet portion of demand to the remaining three best technologies.

SPURR considers four synthetic fuels: (1) methanol, (2) ammonia, (3) synthetic crude oil, and (4) synthetic natural gas. These four demand types compete in each of the nine regions, and the methods used in the utility sector are employed to determine least cost probability and market penetration.

A probability least cost estimate is not conducted for solar electric fuel savers. Because fuel savers are those solar systems not equipped with storage or backup, they do not compete in any meaningful sense with other technologies. The decision to purchase a fuel saver requires an examination of the present value of the revenue requirements of the fuel saver (capital, operating and maintenance, and fuel costs inclusive). If this figure is greater than the sum of fuel savings from base, intermediate, semipeaking, and peaking systems plus a specified percentage capacity credit on these same systems, then it is not worthwhile to purchase the fuel saver. If the revenue requirements are less than the sum of the fuel savings, then a decision to purchase the fuel saver will be positive.

The percentage capacity credit granted to a fuel saver varies. For example, due to the uncertainty of the timing and consistency of wind, WECS are granted only a 10% capacity credit in the SPURR simulation. In contrast, solar central receiver systems, another type of fuel saver, are granted a 70% capacity credit because they are located mainly in the Southwest where they can provide electricity during peaking, semipeaking, and intermediate periods. The fuel savings distribution for a particular fuel saver is obtained from data on the proportion of hours in the year during which fuel savings are obtainable from the four demand types (base, intermediate, semipeaking, and peaking periods).

The fuel saver cost formula is:

$$\text{Cost} = (\text{Revenue Requirements}) - (\text{Capacity Credit Savings}) - (\text{Fuel Savings}).$$

If the cost is negative, the decision will be made to purchase a fuel saver; if it is positive, the fuel saver should not be purchased.

APPENDIX B
BACKGROUND TO THE NATIONAL ENERGY PLAN

In discussing the motivation behind the National Energy Plan (NEP), it is appropriate to emphasize the 1973 OPEC oil embargo. Although the embargo lasted only five months, its long-term economic impact has been substantial. This embargo and its accompanying effects on the U.S. energy situation forced the United States to acknowledge its critical vulnerability to interruptions in foreign energy supplies. This vulnerability results from the fact that the infrastructure of the U.S. economy (e.g., machines, buildings, automobiles, factories) has been predicated on low-cost energy supplies. To understand why this has occurred requires an examination of the relative price of energy and policies affecting that price during the period 1950-1970, which saw the relative price of energy fall 13% with respect to all finished goods (Economic Report of the President 1978). Consequently, producers tended to substitute energy and capital for labor during this period while consumers purchased durable goods (i.e., automobiles, appliances, and homes) whose operation required substantial amounts of energy. At the same time, the United States experienced a transition from coal, its primary source of energy during the 1930s and 1940s, to oil and gas. Both oil and gas were cleaner, easier to use, more convenient, and were not threatened by the recurrent possibility of strikes.

Federal Government policies during this period were a major factor in energy's declining relative price. Costs for natural gas transported via interstate pipelines were held below the market value. Depletion allowances for oil producers reduced their tax liability and thereby effectively reduced the cost of producing and consuming energy. In addition, relatively low excise taxes on gasoline coupled with continued government support of highway construction rather than mass transit encouraged gasoline consumption. This is hardly an exhaustive list of factors but rather an illustrative one that helps explain how the U.S. economic infrastructure was centered around low-cost energy.

THE 1973-1977 CONDITIONS

With the 1973 oil embargo by OPEC, American vulnerability to foreign energy vagaries was starkly manifested and efforts to conserve energy began to take shape. Indeed, the ratio of total energy consumption to real GNP was 5% less in mid-1977 than in 1973 (Economic Report of the President 1978, p. 185). This ratio dropped even further as the economy climbed out of the 1973-1975 recession. With increasing economic prosperity in 1976 and 1977 and real GNP on the rise, total energy consumption increased.

Overall, the 1973-1977 period saw domestic oil production decline while oil consumption increased slightly. Natural gas production also declined while demand for natural gas increased. The inability of domestic oil production to meet the increase in oil demand resulted in a substantial increase in oil imports, and the ability of domestic natural gas production to meet increased demand has been largely unsatisfied. Consequently, U.S. oil imports have doubled since 1971, creating a growing balance of payments deficit for the United States (see Sections 2.0 and 3.0).

Although the number of new domestic oil wells increased substantially over this period, their average output declined. Coupled with diminished productivity of existing wells, this resulted in a decline in total domestic oil production. The Alaskan pipeline, opened in September 1977, had its delivery capacity reduced from 1.2 million barrels/day to 0.7 million barrels/day due to a pump house fire and other mechanical difficulties.

Furthermore, without a pipeline to transport Alaskan oil from the West Coast to the Midwest, transportation costs heightened the problem of high fuel costs. To remedy the growing disparity between domestic petroleum demand and supply, oil imports of crude were increased. Between 1972 and 1977, petroleum imports increased 92%. The cost of these imports increased from $5 billion in 1972 to $45 billion in 1977. Although oil consumption as a percentage of real GNP remained relatively constant during this period, oil imports as a percentage of real GNP increased sharply.

The increased demand for natural gas was not satisfied. One reason lies in the difference between the price of interstate and intrastate natural gas. During the 1960s, the price of regulated interstate gas was greater than that of unregulated intrastate gas. In the 1970s this condition was reversed; intrastate gas prices exceeded interstate prices. Consequently, producers committed a large portion of their supply to intrastate pipelines and created shortages for consumers dependent on interstate pipelines, such as those living in the Northeast. Also, the use of "rolled in" prices encouraged increased consumption of natural gas because the consumer paid the average of newer, high priced gas and older, lower priced gas; i.e., the price did not reflect the true marginal cost of new natural gas. Unlike crude oil, the excess demand for natural gas was largely unsatisfied because liquefied natural gas was extremely expensive to import except from Mexico and Canada.

The U.S. reliance on imported oil increased significantly during the 1976-1977 period, as the demand for energy grew due to a disproportionate increase in demand for petroleum products. This growth is attributable to a number of factors. The unusually cold winter of 1977 increased the demand for home heating oil. Also, the 1977 West Coast drought forced many utilities to switch from hydroelectric generation to oil-based generation. Similarly, the shortage of natural gas caused many utilities to rely more on oil-based generation of electricity rather than gas-based generation. In addition, although the rising prices of oil encouraged a switch from oil-based to coal-based electricity generation, the transition was tempered by the strict environmental regulations of the Clean Air Act. All of these factors increased the reliance of the United States on oil as an energy source, an increasing proportion of which was imported from the Middle East and Africa.

INTERNATIONAL COMPARISONS

The increase in oil imports by the United States during the 1967-1976 period stands in sharp contrast to the other western industrialized nations. During this time, each of these countries (with the exception of Japan) managed a greater reduction in energy consumption than the United States. All of them, including Japan, reduced their crude oil imports while the United States increased its crude oil imports by an average annual increase of 22.7%.

One important reason for the difference lies in the use of greater excise taxes on energy consumption by these countries. For example, gasoline excise taxes in Europe range from 32 cents per gallon in the United Kingdom to 65 cents per gallon in France before 1973-1974; in the United States, the average excise tax per gallon was 12 cents per gallon. In 1977, the U.S. average excise tax remained unchanged while all those in Europe increased and ranged from $0.55 in the United Kingdom to $1.48 per gallon in Italy (*Economic Report of the President* 1978, p. 187).

THE NEP

Recognizing the need for policies that make energy prices reflect their true social costs and discourage excessive consumption, President Carter formulated the National Energy Plan (NEP), a comprehensive set of policies designed to set national energy priorities. Seven essential features are included in the NEP.

1. A reduction of oil imports. This was to be accomplished by a well head or a crude oil equalization tax (COET) which would be phased in over three years, such that by 1980 domestic and oil import prices would be equalized. Revenues from the COET were estimated to be between $11 billion and $14 billion by 1980 and were planned to be distributed back to consumers on a per capita basis. To encourage research, development, and exploration, specific types of oil meeting geographic and depth specifications would receive the 1977 world price adjusted for inflation. User taxes, commencing in 1979 for industry and 1983 for utilities, would be imposed for petroleum consumers. They were expected to increase costs of oil by as much as $3 per barrel for industry and $1.50 per barrel for utilities.

2. Conversion to coal. The NEP provided for increases in the price of oil and gas to coal, especially for utilities and industrial consumers. This would encourage more rapid conversion from oil and gas to coal.

3. Reformation of utility rates. The NEP proposed a number of methods whereby utility pricing would more closely reflect the true incremental costs of energy production. For example, utilities could be required to adopt time-of-day pricing, thereby encouraging consumers to reduce their peak load usage patterns.

4. Conservation. By various conservation measures, the NEP envisioned a 16% reduction of the oil presently consumed. Tax incentives were the major legislative means by which this would be accomplished. For instance, a tax on "gas guzzlers" (i.e., those new automobiles with fuel efficiencies below the national car fleet average) would be imposed together with tax incentives and credits for insulation in homes and buildings and for solar heating and cooling equipment.

5. Natural gas regulation. The NEP proposed to extend federal regulation to all natural gas production and to increase pipeline prices by 63% over seven years. For oil, there would be a natural gas user tax for both industry and utilities, with the taxes commencing in 1979 and 1983, respectively. Eventually the price of natural gas would rise to a level equivalent to the price of oil.

6. Oil reserve provision. A Strategic Petroleum Reserve would be created to temper the economic ramifications of an interruption in oil imports like that in 1973. Presently, a 500 million barrel reserve is planned by 1980. This would be enough for the United States to endure a four-month interruption with a usage of four million barrels per day.

7. Establishment of the Department of Energy (DOE). The DOE would be a new Cabinet agency designed to unify, formulate, and implement federal agency programs.

The NEP has made fragmented, sporadic progress through the Congress. The energy plan moved rapidly through the House of Representatives, largely due to the efforts of Speaker O'Neill. However, the Senate drastically altered the NEP. Six parts of the original NEP were finally agreed upon but only with substantial alterations from their original form (see Commoner 1979). Most notable was the insistence by the Senate that financial incentives rather than tax inducements be utilized to accelerate the pace of conversion and conservation. As of the 1979 session, Congress was still debating which method was more appropriate. In addition, two other major components of the NEP reached an impasse in Congress: the extension of natural gas regulation and the well head tax (COET). With regard to natural gas, the impasse is attributable to the opposing interests of producing and consuming states. Producers argue for deregulation so that natural gas prices would rise with world oil prices. Consumers argue against deregulation, claiming it would be regressive, inflationary, and not the most appropriate method for curtailing oil imports and encouraging energy conservation. Debate continues as to the use of the COET revenues. Northern liberals and labor leaders insist that the revenues should go to the unemployed and retired citizens because they would be the most adversely affected by a price increase. Others contend COET revenues should be funneled to the oil companies to encourage exploration and improvement capital equipment. Still others question the need for a COET at all (Goldstein 1978).

In essence, President Carter's NEP has not remained coherently intact in any meaningful sense. Perhaps one reason for the extensive debate in Congress following the NEP's introduction is the fact that world energy supplies became more available during this period. Hence, action on any national energy plan was perceived as being less pressing, and a careful and slow adoption of national energy priorities was seen to be the best course of action. However, with the interruption of U.S. oil supplies in the spring of 1979, due largely to the Iranian Revolution, and the more than 100% increase in the cost of OPEC petroleum in 1979, one may expect to see more rapid enactment and adoption of a national energy program whereby energy prices reflect more fully their true social costs.

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The United States currently imports close to half of its petroleum requirements. This report delineates the economic, social, and political costs of such a foreign oil dependency. These costs are often intangible, but combined they clearly constitute a greater "price" for imported petroleum than the strictly economic cost.

If we can assume that imported oil imposes significant socioeconomic costs upon the American economy and society, one way to reduce these costs is to develop alternative, domestic energy sources--such as solar energy technologies--which can displace foreign petroleum. The second half of this report estimates that by the year 2000, solar energy technologies can displace 3.6 quads of petroleum. This figure includes solar energy applications in utilities, industrial and agricultural process heat, and transportation. The estimate can be treated as a lower bound; if the United States were to achieve the proposed goal of 20 quads by 2000, the amount of displaced oil probably would be greater. Although all the displaced oil would not be imported, the reduction in imported petroleum would relieve many of the conditions that increase the present "cost" of foreign oil to the American consumer.

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