STRATEGIC AND ESSENTIAL industrial MATERIALS FROM PLANTS THESIS AND UNCERTAINTIES

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Strategic and Essential Industrial Materials

The United States depends on other nations for a broad range of materials and manufactured products important to U.S. industry. Among these are agriculturally produced plant substances and mined materials, including petroleum. This paper is concerned with products that are or could be agriculturally produced in the United States and used as industrial materials or as renewable replacements for petroleum as sources of feedstock in the chemicals industry.

Three of these industrial materials are classified by law as “strategic,” meaning critical to our national defense. These are natural rubber, castor oil, and sperm whale oil. The Defense Production Act of 1950 as amended in 1980 (Public Law 81-774) requires that sufficient supplies of these materials be acquired and stored in the United States to meet national defense needs in case of war. The costs of acquisition, storage, and replacement are borne by the Federal Government, which must manage the stocks so they do not interfere with the marketplace for these commodities. Stockpiles are used only for meeting military needs and are not available to meet emergency civilian needs. “Essential” materials are those required by industry to manufacture products depended upon daily. Essential materials include the strategic materials, waxes, resins, oils, gums, newsprint, other items manufactured or extracted from plants, and replacements for petroleum used as feedstock in manufacturing synthetic organic chemicals, plastics, industrial coatings and paints, printing inks, surfactants, and synthetic fibers,

Thesis and Purpose of the Paper

This paper will present and discuss some of the policy issues related to use of U.S. land, capital, and labor to meet the Nation’s long-term needs and to reduce dependence on other nations for strategic and essential industrial materials. The thesis is that the United States can move industrial dependence on a finite resource (petroleum) to renewable ones (agriculturally produced feedstocks).

Available Data

Comprehensive data on imports of agricultural commodities are available from the *Agricultural Statistics* series published annually by the Department of Agriculture (5). The United States International Trade Commission provides comprehensive information on total imports of petroleum and on total domestic production of synthetic organic chemicals. Chemical data on plant extracts are found in publications of the Department of Agriculture, Agricultural Research Service’s Northern Regional Research Laboratory (Center) at Peoria, Ill. The level of confidence in all these sources is high. Examples are shown in table 1.

Other data used in this paper represent estimates rather than “hard,” quantifiable figures. For example, the total amount of plant material and various precursor chemicals imported for use in U.S. industry to produce essential industrial materials is not recorded and must be estimated. Similarly, although the total amount of petroleum imported is known, the amount that might be replaced by renewable sources of feedstock in manufacturing chemical products must be estimated. The best available estimates now are thought to be those made by research chemists in the Department of Agriculture. These are shown in table 2.

Much of the information presented in this paper is synthesized from papers published in refereed scientific journals over a period of 10 or more years, from monographs available from the Agricultural Research Service, and data collected by a task force of USDA’s Science and Education Administration (SEA) personnel established to explore the USDA/SEA role in strategic and essential industrial materials research (7).

Lists of Imports for Which There May Exist Domestic Production Alternatives That Could Be Implemented In Ten Years

Table I.—Agricultural imports-1978

Product		Value of Imports ($ Millions)
Natural Rubber		$665.9
Vegetable Oils and Waxes		$458.0
Cast or	$40.0	
Palm	$74.9	
Palm Kernel	$34.8	
0live	$36.8	
Coconut	$228.9	
Natural Waxes		$9*3
Cocoa Butter		$96.1
Fibers (Other than cotton or jute)		$28.2
Drugs (Agricultural)		$137.1
Essential Oils		$82.1
Oilseed and Products		$508.3
TOTAL		$1,985.0

In addition, the US imported an estimated $35 billion worth of newsprint

SOURCE: Agricultural Statistics 1980; Department of Agriculture, Government Printing Office, Washington, DC., 20402.

Table 2.–Estimates of Nonagricultural imports-1978

Product	Value of Imports ($ Millions)
Synthetic Rubber	$148.9
Plastics	$517 •5
Synthetic Fibers	$238.2
Pharmaceuticals	$292.3
Dyes, Tanning Agents	$170.7
Petro Waxes	$47.5
Coatings and Printing Inks	$40.0
Adhesives	$100.0
Detergents, Surfactants	$483.0
TOTAL	$2,038.1

SOURCE: Data sheets prepared by scientists at the USDNARS Northern Regional Laboratory at Peoria, Ill, for a Science and Education Aministration Task Force on Strategic and Essential Industrial Materials; March 1980, Data sources used varied and included issuances by the US. International Trade Commission and that collectedly scientists from trade publications and firms The study was intended to be illustrative rather than definitive

NOTE Agricultural imports figures for 1979 are 129 times the 1978 figures The estimates of nonagricultural chemicals Imported for 1979 are 1.15 times the 1978 figures

The trend in expenditures for agricultural imports, 1975-79, is mixed —essentials up 43 percent over the 5-year period, cocoa butter up 170 percent, drugs up 72 percent, and natural rubber up 127 percent, while expenditures for vegetable oils and waxes and for oilseeds remained about even Expenditures for fibers other than cotton and jute declined during the period

Discussion is limited to potential agricultural crops for which sufficient research indicates that their domestic production and use in the chemicals industry is chemically feasibile, agronomically possible, and economically viable, This paper, therefore, must be considered illustrative rather than definitive. Significantly more agronomic and economic research must be undertaken before definitive conclusions can be reached. At the same time, however, urgent public policy issues must be addressed promptly if our Nation is to have an assured supply of strategic and essential materials.

Importance to the United States

The United States imported an estimated $22.1 billion worth of agriculturally produced industrial materials and petroleum for feedstock during 1978; the figure for 1979 was slightly over $23 billion. The trend for the period 1975 through 1979 was an average annual increase of about 10 percent according to data in *Agricultural Statistics 1980* and estimates made in 1980 by Department of Agriculture researchers in industrial chemistry. The Nation could spend an additional $1.1 billion or more (1979 dollars) over the next 18 years acquiring and maintaining strategic stockpiles of natural rubber and castor oil (2).

In 1978, U.S. industry manufactured over 84.6 million metric tons (MT) of synthetic organic chemicals valued at about $754 per MT, for a total of about $63.8 billion (9). The manufacture of these chemicals consumed about 470 million barrels of petroleum, valued at about $15.1 billion, as feedstock (6). U.S. industry also purchased nearly $2 billion worth of agricultural imports including natural rubber, seed and vegetable oils and waxes, cocoa butter, fibers other than cotton or jute, drugs, and essential oils. In addition, the United States imported an estimated $3.5 billion worth of newsprint and other paper products and $2.05 billion worth of chemicals extracted from plants (about 50 percent) or made from petroleum (about 50 percent) (7).

Technologically, it is possible to produce domestically nearly all the aforementioned imported agricultural products and materials and to substitute domestically produced agricultural products for the 470 million barrels of imported petroleum feedstock. It is estimated that increased farming operations to produce these agricultural substitutes would consume an additional 200 million barrels of petroleum for fuel and agricultural chemicals; therefore, the net savings would be about 270 million barrels of imported oil per year.

Production of only one-third the annual domestic demand for strategic materials (natural rubber, castor oil, and sperm whale oil) would eliminate the need to stockpile them.

According to the Federal Emergency Management Agency, the national stockpiling requirement for natural rubber is about 800,000 MT. The stockpile contained about 100,000 MT in 1980, leaving a shortfall of about 700,000 MT. World production of natural rubber has been declining slightly and, on an annual basis, is only keeping pace with world demand. The annual demand of the United States, the largest single user of natural rubber, greatly influences the world supply-demand formula each year. Therefore, each time the United States attempts to purchase rubber for the strategic stockpile, the result is a dramatic increase in price. At the 1978-to-1982 average price for natural rubber ($1,287 per MT), acquisition of the rubber needed to meet the 800,000 MT stockpile requirement would cost the Federal Government about $900 million. Storage and management costs for this stockpile would run an estimated $7 million per year. Total costs, at constant 1982 dollars between now and the year 2000, would be slightly over $1 billion. If the United States domestically produced 270,000 MT of natural rubber per year, the need for stockpiling would not exist.

The stockpiling target for castor oil is about 9,981 MT. The present stockpile contains about 5,671 MT. Acquiring the 4,310 MT shortfall would cost an estimated $5.2 million. Acquiring and storing the material through the year 2000 would cost about $13.8 million (1979 dollars). Domestic production of one-third the annual U.S. demand (about 10,000 MT) would eliminate the stockpiling need.

Sperm oil is obtained from the sperm whale, an endangered species. Since U.S. law prohibits production or importation of sperm whale oil, the Nation has no stockpile of sperm whale oil. Alternatives are available and can be provided domestically.

Producing 100 percent of the strategic and essential industrial materials or their replacements would reduce U.S. foreign outlays by about $16.5 billion annually at constant 1979 dollars and demand levels. Savings for different levels of domestic production can also be calculated. In addition, domestic production of one-third the U.S. demand for these three strategic materials would save more than $1 billion of public money over the next 18 years (money that otherwise would be spent in acquiring and maintaining strategic stockpiles of natural rubber and castor oil) and would provide replacements for sperm whale oil. Such a program would increase demands for domestic agricultural production, thus transferring expenditures for foreign petroleum, chemical, and agricultural imports into expenditures for domestic agricultural products.

The United States has about 413 million acres of cropland and about 36 million acres of pasture and other land in farms that easily and inexpensively can be converted to crop production. This represents an immediately available crop production base of about 450 million acres (8). In 1979, America's farmers used 348 million acres for crop production: an uneconomically low use rate of about 77 percent. Production of substitutes for one-third to one-half the industrial materials purchased abroad would demand about 60 million acres of cropland, Production of food and fiber at the 1979 rates plus production of these materials would require 408 million acres of cropland: a utilization rate of nearly 91 percent. A problem would be the propensity for opportunists to produce commodities on fragile soils in years when prices are high and to abandon them in years of lower prices, leaving the State, Federal, or local government to pick up the costs of dealing with stream siltation, severe blowing of soils, encroachment of undesirable plant species, and other problems. A mechanism to prevent such practices, but achieve a 91 percent utilization rate of the U.S. cropland base, would have to be found.

The Nation has about 96 million additional acres of land that could be converted to crop production with more difficulty and expense than the 36 million acres cited above. Therefore, the Nation's total cropland base, or that land capable of sustained crop production under intensive cultivation by known methods, is 540 million acres. According to projections made by the Department of Agriculture (4), about 462 million acres of cropland will be needed in the year 2030 to meet domestic and foreign trade demands for food and fiber. This would leave 78 million acres of the cropland base to meet other production needs, assuming that this base is not converted to urban and other nonagricultural uses, Use of 462 million acres for food and fiber production and 60 million acres for industrial materials production would represent a 96.8 percent utilization rate of the Nation's cropland. At that rate of use, it might be possible to eliminate commodity support and subsidization programs for food and fiber,

Chemical Potential

It is technologically possible to provide domestic agricultural substitutes for nearly all the imported agriculturally produced industrial materials and a large share of the petroleum used as feedstock in the chemicals industry. The following table lists some of the potential domestic crops and what they might replace.

In addition to those plants identified in table 3, a number of others might be used to provide replacements for feedstocks in the chemicals industry, For example, research has already established that *Limnanthes, Lunaria, Valeriana, Cuphea,* and *Foeniculum* are potential sources of specific acids, esters, and oils used in industry. In addition, oils from existing agricultural crops such as soybeans, safflower, sunflower, linseed, corn, and other oilseed and vegetable oil crops could be used for certain industrial purposes.

Agronomic Potential

Development of the agricultural crops discussed herein could benefit nearly all of the Nation's agricultural areas, Guayule and jojoba, perennial arid-zone plants, can be produced in the arid Southwest. Crambe is a short- season annual crop which might be double-cropped in the major production areas of the Midwest, South, and Southeast. It would provide an alternative to corn or wheat in areas marginal for these crops. Kenaf, a dense-growing annual, is commercially valuable for making newsprint and other paper and fiber products. *Cuphea,* an annual, now is grown experimentally in Germany and the United States. It should adapt well to Northcentral, Northwest, Northeast, and Pacific Northwest United States. *Stokesia* could be produced in the Southeast, and *Vernonia* in the southern tier. Lesquerella could be grown in Central, Southcentral, and Southwestern United States, while *Linmanthes* is adapted to the Pacific Northwest, Both are annuals, *Lunaria* seems to be adapted to northern regions with long days and eventually might provide a crop for Alaska. Some

Table 3.—Potential Domestic Crops and Uses

Guayule	Hevea natural rubber, resins
Crambe	High erucic rape oil and petroleum feedstock
Jojoba	Sperm whale oil and imported waxes
Lesquerella	Castor oil
Vernonia - Stokesia	Epoxy oils
Kenaf	Imported newsprint and paper
Assorted oilseeds	Petrochemicals for coatings and other industrial products

SOURCE: L.H. Princen, Alternate *Industrial Feedstocks From Agriculture* (Peoria, Ill.: Northern Regional Research Center, Agricultural Research Service, U.S. Department of Agriculture, 1980).

Lunaria lines are biennial and some are annual, (The above paragraph is taken from Princen (3).)

Current Research

Current research on the above plants is extremely limited, A little genetics and agronomic work is being done. Less is being done on use of meals and other byproducts, including cellulose, left after extraction of the principal products. Guayule, jojoba, and crambe are being grown on semicommercial scale acreages. Limited plant breeding and agronomic research is under way for these three potential commodities. Some small-scale seed increase and agronomic work is under way with *Lunaria* and *Limnanthes* at universities in Oregon and Alaska. Limited commercialization work on jojoba is being done by the private sector and universities in the Southwest. Federal funding for research is greatest for guayule, a source of natural rubber, because of its importance to the military. However, the total 1981 expenditures committed to guayule research totaled only about $3 million, Research commitments to all other potential substitute commodities discussed herein were considerably less,

Research Needs

Little additional basic chemical research is needed for the commodities discussed in this paper. The next level of research would involve chemical engineering to develop efficient, economical extraction and processing systems, an area of proprietary interest in the private sector. Such research is needed, but if it is to be undertaken at public cost, arrangements will have to be made to sell, franchise, or license the processes for exclusive use by firms. Because of the present lack of risk capital in the private sector, public support of such research probably would be necessary if these plant materials are to be commercialized. However, current administration policy appears not to favor public sector support for agricultural research of this nature. In 1982, the Office of Management and Budget imposed rigid guidelines governing Federal research and directed the Department of Agriculture to terminate any ongoing research commercial in nature (l). Significantly, an article in *The Washington Post* during the week of November 8-12, 1982, noted that a White House report justified continued research on the space shuttle because of its commercial potential. It is interesting to note that the latest flight of the space shuttle, which the news media reported cost the government about $250 million, collected an estimated $38 million from private industry as fees for putting two satellites into orbit. If that is considered the commercial value of the flight, one may conclude that the other $212 million must be charged off to research and development, a subsidy to the private sector. Needed subsidies to develop agricultural materials substitutes would be modest by comparison.

The most needed research on these potential commodities in the immediate future is in the areas of plant breeding and agronomy. Byproduct use research also will be needed. It is not difficult to calculate the price at which plant oil extracts must be sold to compete with petroleum feedstocks in the chemicals industry, but the value of the meal and other byproducts are unknown because information on their possible uses is limited. This knowledge is vital to assessing commercialization potential. For instance, the late 1982 price of soybean oil was about 17.2 cents per pound, and the value of the meal was about 8.8 cents per pound. Total value of the processed commodity was about 26 cents per pound, At a price of $6 per bushel, soybeans sell for about 10 cents per pound off the farm. If there were no value in the meal, the farm price would have to be less to make processing the oil profitable. Such information is needed to assess the economic feasibility of commercialization, Enough work has been done on byproducts of commodities discussed in this paper to suggest that they may have values similar to those of byproducts from soybeans and other conventional oil crops.

Most of these new crop materials now being grown in research projects are from wild or nearly wild plants. Genetic improvements are needed to increase seed and oil yields and predictability of the plant under cultivation, In the absence of such genetic improvements in corn, average U.S. annual yields from unimproved stocks might be *8* to 10 bushels per acre, rather than the 109 obtained for 1979 from improved hybrids. While tenfold increases in crambe production are unrealistic, twofold increases are feasible. A threefold increase in seed yield and a 10-percent increase in oil yield, calculated from the average of present yields in different States, would produce 5,400 pounds of seeds, 2,700 pounds of oil, and 2,700 pounds of meals and other products per acre, Research is needed on how to cultivate the plant to obtain optimum yields of both seed and oil,

Little agronomic research has been done for potential new commodities other than crambe and guayule. Yield data from test plots reflect only initial efforts to cultivate plants using strains of seed that have not been genetically improved.

Economic Potential

Several factors must be integrated to estimate the economic benefits of using domestic production to replace agricultural imports and to substitute renewable agricultural materials for petroleum as feedstock in the chemicals industry.

Paramount is the question of the relative costs of substitutes and current sources of these materials. Next in importance is the degree of profitability in producing new agricultural raw material. The third major factor is the level of subsidization required by the agricultural industry to meet national strategic and essential materials needs.

The National Science Foundation and the Midwest Research Institute, in cooperation with universities in the Southwest and rubber companies, completed an exhaustive study of the commercial feasibility of establishing a domestic natural rubber industry based on guayule. According to that study, the price of imported rubber is expected to rise in the foreseeable future, particularly if world supplies continue to dwindle. The study estimates that the price for imported rubber and the costs of domestic production will converge in the late 1980's, making it equally as attractive economically to produce domestically as to import the material. The advantage of not having to import a strategic commodity over distant sea lanes in times of emergency is, of course, great.

Sperm whale oil is not legally available in the United States, and U.S. policy discourages foreign production; therefore, a substitute for this high-quality lubricant must be provided. Jojoba is an ideal substitute. Jojoba can also be a substitute for castor oil. Castor oil currently costs about 54.5 cents per pound. While castor oil has been produced in the United States, the bean contains toxic and allergenic properties that pose hazards for people and animals and problems for waste disposal. Its domestic production has, therefore, been discontinued. *Lesquerella* is another substitute for castor oil. Its cultivation poses no health hazard, and the meal can be processed for animal feed.

The primary economic consideration in substituting agricultural commodities for petroleum as feedstock in the chemicals industry is the price of petroleum. Currently, petroleum is imported at a price of about 10.6 cents per pound. In industrial uses, seed oils could sell at a higher price per pound than petroleum without increasing the price for the final chemicals produced. These plants yield chemicals in relatively pure form so that they can be used with little processing. Extraction of the same chemicals from petroleum is complex and expensive. The only true comparison of costs and feedstock values can be made when the value of the acids, esters, waxes, or other chemicals produced from the two different sources of feedstock are compared. This comparison cannot be made until semicommercial agronomic production is undertaken and engineering processes for extracting these new plant oils, at the prototype scale, are developed and tested. This will allow accounting for the total processing, agronomic production, and other costs to define total costs at the prototype and commercial scales of production.

Some cost projections can be made on the basis of available data. For example, initial attempts at production of crambe on semicommercial acreages in western Kentucky yielded 1,800 pounds of seed and 720 pounds of oil per acre. At the current price of petroleum (10.6 cents per pound), the oil from an acre of crambe would be worth $76. If one assumes that this oil is 25 percent more valuable as feedstock than petroleum because it requires less costly processing, its value would rise to $95 per acre. This compares favorably with the economic returns from wheat production of 30 bushels per acre in the same area. With even minimal increases in production, crambe might become an attractive substitute for current crops that are only marginally adapted to certain geographical areas. However, suppose research can triple the seed yield and increase oil content by 10 percent; then the crop would be valued at $286 per acre based on the current competitive price of imported petroleum. In addition, the meal can be fed to beef cattle. With a 25-percent value increase based on lower processing costs than petroleum, the value would rise to $357 per acre. Taking the average yield and mean price for corn in the United States during the past 5 years, corn for grain would be worth about $252 per acre. An assessment based on economics alone then might favor growing crambe over corn in that area.

During recent years, the Federal Government has spent between $7 billion and $14 billion annually to subsidize production of commodities that are already in surplus. If this subsidy were spent instead to encourage the domestic production of imported plant materials or to provide substitutes for petroleum feedstocks in the chemicals industry, the average subsidy on the 60 million acres would fall between $116 and $233 per acre per year.

Some estimates may also be made regarding the effects of a successful program to substitute domestic production for importation and agricultural commodities for petroleum feedstocks. If 60 million acres are used to produce such commodities, onfarm employment would increase by about 155,000 jobs, or about 7 percent over 1979 farm employment. The 60 million acres is equal to 133,333 average-sized farms, each employing 1.618 workers. If the assumption that one job in agriculturally related enterprises (transportation, processing, machinery and equipment, agricultural chemicals, sales, and management) will be created for each new onfarm job, the total job increase would be about 311,000. (In the combined agricultural and food industries, there were about 17 million workers in 1979, but only 2.7 million onfarm. This is a ratio of 6.2 to 1.) At average rates of use, these hypothetical 133,333 "new farms" would need 253,000 tractors; 173,000 trucks; about 120,000 harvesters of various kinds; and related equipment. Thus the benefits would spill over into the manufacturing sector. At average-use rates for all farms, production would consume about 2.9 million tons of fertilizers and about 200 million barrels of petroleum in addition to other products and services. (These figures were calculated from data contained in *Agricultural Statistics 1980.)*

Another consideration must be the impact on world demand and price for OPEC petroleum if the United States reduced its demand by nearly 740,000 barrels per day (270 million barrels per year). Evidence suggests that oil conservation efforts in the United States and other importing countries already have had major dampening effects on world production and pricing. This factor represents approximately 4 to 5 percent of our annual consumption of petroleum. However, should substitution of agricultural commodities drive down the price of oil, there would be incentive to switch back to petroleum as feedstock. Conversely, if the price of oil continued to rise, there would be incentives to switch back to agricultural substitutes.

In the event the world oil price decreased as the United States switched to agricultural alternatives, the United States would have increased leverage with suppliers as long as its option to substitute agricultural commodities were kept open. At this point, the issue would become a political rather than economic one.

Political Considerations

Political considerations underlying this issue revolve around two central questions: 1) what does the United States have to gain and lose in the international community, and 2) whose ox will get gored?

Exporting nations presumably would react unfavorably if the United States chooses to substitute domestic production for imported agricultural materials and petroleum. On the other hand, nations competing with the United States for these resources in the world market would be happy. Those who compete with the United States for marketing their food and fiber also would be happy. The complex effects of such a substitution strategy on any one nation are calculable but beyond the scope of this paper. Given that such effects can be calculated, the decision whether or not to substitute is as much political as it is economic.

On the domestic front, the key short-run issue for farmers, agricultural firms, and the Federal Government will be whether to subsidize production of new agricultural commodities instead of continuing to subsidize surplus production or support agreements to take land in surplus commodities out of production. As for defense, the issues are: 1) how much should we invest in stockpiling materials as opposed to encouraging domestic production of strategic materials to avoid stockpiling needs, and 2) what is it worth to have domestic control of strategic materials supplies?

Public policy discussion will be strongly affected by private sector concerns. Domestic production of these commodities will not be in the short-run interest of vertically integrated firms now producing chemicals from petroleum feedstock, or of those firms now importing and supplying such agricultural materials. However, the negative interest of these firms in the issue might be offset by the positive interest of industrial users of such intermediate chemicals and other products. For instance, the news publishers could be highly interested in shifting from imported newsprint and other paper to domestically produced paper, since current data suggest it can be produced domestically for less than the cost of importing it. It is possible that users of intermediate chemicals or finished products (coatings, paints, and printing inks) may encourage substitution if a superior or less costly product can be obtained in the long run, if the rate of price fluctuation is decreased, or if assurances of continued supply are increased. Consumers of the final products might be expected to support substitution if assurance of supply is increased, the rate of price fluctuation is decreased, and the general economy is benefited. This includes anyone who owns a house, paints an apartment, owns a car or household appliances, uses cosmetics, holds a job, purchases a toothbrush, or wears clothes made totally or partly of synthetic fibers. Military leaders might be expected to support domestic supply of strategic materials,

Policy Shifts Needed

Four domestic policy shifts are needed to facilitate any move toward domestic control and production of strategic and essential industrial materials. The first is from dependence on foreign nations for agriculturally based strategic materials to domestic supply of them. The $1.1 billion that would otherwise be spent acquiring and maintaining these stockpiles should be committed to this end.

The second shift is to a national policy of encouraging agricultural research that has foreseeable commercial application including participation with the private sector in commercialization activities, partly research and partly commercial in nature. Federally supported research should be able to take commercialization through the prototype or pilot scale of activity under conditions that assure private sector partners exclusive rights to use patentable processes or products for a period of time, thus allowing the firm to recapture its investments.

The third domestic policy change needed is to spend federal funds to support production of useful agricultural commodities rather than supporting production of surplus commodities or for paying farmers to discontinue production.

The fourth domestic policy change needed is to look at domestic production of agriculturally produced materials as a way of using our farm production potential rather than depending on foreign trade. The United States, along with most of its allies and friends, is competing for a limited foreign market with surplus commodities,

On the international scene, the government may have to be prepared to limit, initially, the import of petroleum to encourage U.S. firms to substitute domestically produced agricultural commodities. The reduced demand should provide increased leverage in negotiating prices for the remaining imports,

conclusion

On the basis of "best case" assumptions, the chemical technology exists to substitute domestically produced renewable agricultural commodities for about 170 million barrels of petroleum annually and for about $6.3 billion worth of imported agriculturally produced materials. There is a potential to reduce expenditures by about $1.1 billion over the next 18 years for stockpiling natural rubber and castor oil and for providing a substitute for sperm whale oil. The possibility of finding a more constructive use for the dollars spent in maintaining our agricultural production capability also exists,

No further research on the basic chemistry of these materials is needed, What is needed now is research related to the agronomic of producing such commodities, plant breeding to improve seed and oil or fiber yields, and research into byproduct use. In tandem with these efforts, economic feasibility assessments and/or definition of the economic parameters for commercialization are needed.

Research or commercialization activities in partnership with private firms should be undertaken to develop prototype processing or other production facilities, Such commercialization activities must have an educational component. Industrial chemists are trained in the chemistry of using petroleum as feedstock. In the early development of the chemicals industry, plant materials and coal were used as feedstock. Farmers who might become involved in producing the plant materials for use in commercialization research will not know the best cultural practices.

It would not make sense for the United States to jump headlong into a substitution program, but sufficient resources should be committed to the kinds of activities suggested above to use or discard, with just cause, the many development options that exist.

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