AN OALS/MRI REPORT

A TECHNOLOGY ASSESSMENT OF GUAYULE RUBBER COMMERCIALIZATION

Final Report

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A TECHNOLOGY ASSESSMENT OF GUAYULE RUBBER COMMERCIALIZATION

FINAL REPORT

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES

PREFACE

A technology assessment (TA) has been conducted of the potential commercialization of the desert shrub guayule (Parthenium argentatum) as a domestic source of natural rubber for the United States. This Final Report concludes the Guayule Technology Assessment, and presents the findings of that project. The study has been supported by the National Science Foundation, Grant No. PRA 78-11632 and MRI Project No. 4628-L. Dr. Patrick Johnson, Division of Policy Research and Analysis is the NSF Project Officer.

The core members of the T.A. project team include: Dr. William McGinnies, Director Emeritus; Mr. Jonathan Taylor, Research Specialist; Mrs. Jean Mills, Coordinator Guayule Information Center; under the direction of Dr. Kennith Foster, Associate Director of OALS; and for MRI, Dr. Ralph Wilkinson, Associate Technology Scientist; Mr. Fred Hopkins, Assistant Scientist; Dr. Chris Wyatt, Senior Social Systems Analyst; and Mr. James Maloney, Senior Policy Analyst under the supervision of Dr. Edward Lawless, Head, Technology Assessment Section.

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EXECUTIVE SUMMARY

This summary highlights significant findings of the Guayule Commercialization Technology Assessment.

1. Elastomer supply and demand: At present, natural rubber represents 25 percent of the U.S. elastomer market. It could meet up to 40 percent of the total U.S. elastomer demand (Riedle, 1980). The tire industry consumes approximately 70 percent of the total U.S. elastomer supply. Increasing popularity of radial tires is expected to increase the portion of the elastomer market occupied by natural rubber.

World rubber market forecasters predicted, in 1979, a natural rubber shortfall beginning in 1981 and extending and increasing through the year 2000. But recent recession of the auto industry has reduced elastomer demands in early 1980 to below projected demand levels. Nevertheless, a "low-growth" rubber future can be expected to have a greater overall elastomer shortfall between 1994 and 2000 than a "high-growth" rubber future. This results from slowed synthetic rubber production, due to feedstock price escalation. And it results from a slowed hevea rubber production growth, due to high value crop competition.

2. Guayule technology: Table 1 summarizes the state of development of guayule technology. In general, it indicates that the lower the level of knowledge, or technology, the greater the likelihood of that particular aspect inhibiting the successful commercialization of guayule. Furthermore, those component systems showing lower development levels require not only greater emphases in research, but also a qualitatively different kind of research support. Table 2 shows the relationship between levels of development and the types of support required.

3. Prospects of commercialization: Declining water tables, with rapidly increasing irrigation energy costs, are making farming conventional crops an increasing marginal enterprise in West Texas, Arizona and other areas in the arid U.S. Southwest. Guayule, with a forecast agricultural profit of only $30 per acre, should be able to compete successfully with wheat, barley, sorghum, sugarbeets, hay (in water-short areas), and cotton (in the most critical water-cost areas such as the Trans Pecos region in Texas).

Guayule rubber production is projected to be economically viable when natural rubber prices reach $.65 per pound. Rubber prices have been escalating rapidly. In fact, prices have more than doubled during the five-year period from 1975 to 1980. In early 1980, natural rubber prices temporarily rose to more than $.90 per pound and then fell to a relatively stable position of $.71 per pound.

Factors operating to constrain the commercialization of guayule include the recent recession in the auto and tire industries in the United States. Also, high interest rates on agriculture loans, coupled with a three-to-four-year production cycle, tend to make guayule production less attractive to farmers. And the relatively "unproven" status of guayule as a crop tends to make investors reluctant to support agricultural or processing development. Last, a lack of clear leadership in investment and risk-taking by either the federal government or private industry significantly constrains the commercial development of guayule.

4. Development scenarios: Two development scenarios are extrapolated from a policy continuum relating to governmental involvement in guayule. Present trends continue, Scenario A, depicts a market that is driven by rubber and agricultural forces. It projects that by 1991 guayule rubber production would meet predicted natural rubber shortfall. By then, a projected 1.3 million acres of guayule would be planted. And by 2000, 1.5 million acres of guayule would be planted. Forty-two percent would be planted in California, 32 percent in Texas, 19 percent in Arizona and 6 percent in New Mexico.

Rapid commercialization, Scenario B, depicts a market characterized by strong governmental involvement. It projects a natural rubber shortfall 2.85 times greater than that extrapolated for Scenario A due to an assumed 50 percent cutoff in U.S. natural rubber imports. More important, it also is projected that guayule rubber production could meet this greater shortfall by as early as 1990. Under Scenario B, a projected 1.2 million tons of guayule rubber would be produced by the year 2000, a 113 percent increase over Scenario A production. It is assumed that greater and more rapid governmental support of guayule research would achieve a rubber yield per acre that is 73 percent greater than that under Scenario A. This increase in production would be achieved, significantly, with only a 23 percent increase in processing capacity and a 29 percent increase in total guayule acreage. Average guayule production distribution is calculated to be 41 percent in Texas, 39 percent in California, 15 percent in Arizona and 5 percent in New Mexico.

A cooperative, government-industry guayule corporation is assumed to coordinate the various phases of guayule development under Scenario B.

5. Development impacts: The primary objectives of the TA are to assess probable impacts and policy implications that result from the scenario projections. To assess social impacts of guayule commercialization, two example areas were chosen for detailed analyses of social, economic and demographic characteristics. The two areas represent the range of diverse social characteristics that occur throughout the guayule growth region.

a. Social impacts: The Bakersfield area, Kern County, California, represents an urbanized, fairly densely populated area, with

Table 1. State of Development of Guayule Technology*

				LEVEL OF KNOWLEDGE/TECHNOLOGY					
				KNOWN/OPERATIONAL	NEEDS REFINEMENT	IN DEVELOPMENT	TO BE DEVELOPED	UNKNOWN	
PRODUCTION	TECHNOLOGY	Growth Conditions	Climate	■					
			Soils	■					
			Water		■				
			Pest/Weed Control			■			
			Genetic Variability			■			
			Growth Characteristics		■				
		Agronomy	Propagation			■			
			Seedling Production		■				1
			Alternative Propagation			■			
			Site Selection	■					
			Land Preparation	■					
			Planting		■				
			Cultural Practices		■				
			Irrigation Practices		■				
			Dryland Practices			■			2
			Pre-Harvest Conditioning		■				
			Crop Yield			■			
		Harvesting	Methods-Machinery		■				
			Timing		■				
			Conditioning		■				
			Storage			■			
	ECONOMICS		Fixed Costs		■				
			Variable Costs		■				
			Longterm Return Expectation			■			
PROCESSING	TECHNOLOGY	Primary Products	Identity	■					3
			Procedures		■				
			Machinery		■				
		By-products	Identity		■				
			Procedures			■			
			Machinery			■			
		Secondary Products	Identity	■					
			Procedures	■					
			Machinery	■					
			Energy Requirement		■				
			Materials Balance				■		4
	PRIMARY PRODUCT ECONOMICS		Capital Investment			■			
			Operating Costs			■			
			Unit Product Costs			■			
MARKETING	PRIMARY PRODUCT COMPETITORS		Identity	■					
			Supply	■					
			Demand	■					
			Price and Supply/Demand Relationship	■					
	PRIMARY PRODUCTS		Uses	■					
			Supply			■			
			Demand		■				
			Price and Supply/Demand Relationship		■				
	BYPRODUCTS		Uses			■			
			Supply		■				
			Demand			■			5
			Price and Supply/Demand Relationship				■		
	SECONDARY PRODUCTS		Uses	■					
			Supply	■					
			Demand	■					
			Price and Supply/Demand Relationship	■					

(1) Economics of seedling production needs refinement

(2) Texas dryland farming of guayule needs further research

(3) Agricultural costs need field demonstration

(4) Supply relationships between primary rubber product and byproducts

(5) Bagasse demand as an energy source for processing is resonably well known. Demand for other byproducts needs more research.

* Matrix conceptual design by Mortensen, Foster et al, 1980

Table 1. State of Development of Guayule Technology

TABLE 2

ACTIONS NEEDED AT DIFFERENT LEVELS OF DEVELOPMENT

TO ACHIEVE COMMERCIALIZATION*

Level of Knowledge/Technology	Actions Needed to Achieve Commercialization
Known/Operational	Form Commercialization Linkages, Provide Assurances
Needs Refinement	Support Demonstration/Pilot Projects
In Development	Support Applied Research and Development Projects
To Be Developed	Support Basic Research
Unknown	None Possible

* Source: Foster, et al 1980.

comprehensive areawide planning in place. The population of Kern County is expected to reach 475,000 persons by 2000. Nineteen percent, or 28,000, of persons employed in the County are in the agriculture sector. The 285 farmers (Lacewell, 1979) estimated to maintain the 200,000 acres of guayule projected for the area would represent only 1 percent of the agricultural work force, the majority of whom would be transferred from production of alfalfa, sugarbeets and potatoes. With 100 to 115 persons required to operate a large processing plant (Nivert, 1979), approximately 200 persons are projected as new employment in guayule rubber processing. Indirect service sector and governmental employee increases are projected to be about 300. Thus, the total non-agricultural employment effect would be less than 0.3 percent of the total 1978 Kern County labor force. Therefore, although socioeconomic effects of guayule development in Kern County are anticipated to be positive, the effects are not expected to be significant.

The Fort Stockton area of Pecos County, Texas, has a quite different socioeconomic profile. The area is rural and sparsely populated, with a projected year 2000 population of 22,000. Agriculture has been decreasing dramatically in the area due to rapidly escalating natural gas prices that place the cost of pumping irrigation water beyond the level of marginal return, even for cotton. Of the 5,400 persons employed in Pecos County in 1978, 10 percent were in the agricultural sector. Projecting 140 farmers to grow 100,000 acres of guayule, agricultural employment would increase by 26 percent. The bulk of this development is projected to occur on abandoned cotton land; thus, it would constitute an increase in both agricultural employment and economic activity. Employment for one large processing facility, plus service- government employment increases, is expected to increase area employment by 12 percent. The socioeconomic impact of guayule development in areas such Pecos County, therefore, is expected to be one of rural community stabilization, both positive and significant. Some strain could be expected, initially on community services, but the overall economic return to the community from guayule commercialization is expected to more than offset these costs. However, significant guayule development in rural areas should be expected to impact the status quo of local socioeconomic power structures severely.

b. Environmental impacts: Guayule development is not expected to have significant environmental impact in the Southwest, particularly if guayule is developed according to the more gradual Scenario A schedule. Water acts as the primary constraining factor on most Southwest agriculture, rather than land availability (Foster, et al, 1979). As water tables recede concurrent with rapid increases in irrigation- water pumping costs, the need for alternative, low-water-use crops becomes increasingly critical. Therefore, guayule production is projected to occur, throughout the region, on existing or abandoned farmland rather than on newly developed or marginal lands. The environmental effects of guayule development, thus, become the effects of crop replacement. One major exception to this interpretation is projected in South Texas where as much as 600,000 acres of dryland guayule farming might be developed on what is currently range or brushland.

Processing water could become an environmentally constraining factor to guayule development in water-short areas, depending on the processing technology selected (Saltillo-type processing or direct-solvent-extraction) and on the degree of recycling incorporated into the facility design.

Fire in a relatively dry, hydrocarbon-producing crop is a potential environmental problem associated with guayule development. This problem could be exacerbated, particularly in situations of conflict, for example, labor disputes.

c. Safety and health: Occupational safety and health implications of guayule development are under investigation by Rodriguez and Sternberg (1979). These investigators have found some terpenoid sensitization in laboratory animals from F_1 hybrids, but this needs further clarification before general effects can be postulated. Mears and Larson (1979) have suggested that caution must be exercised in interspecific crossing of *Parthenium* spp. Certain species, for example *P. hysterrophorus*, or Indian congress grass, contain oleoresinous materials that can cause severe respiratory and dermatological reactions. Selection of such species for crossing with *P. argentatum*, however, probably can be avoided. Field experiences during the Emergency Rubber Project (ERP), and those associated with the Saltillo processing plant, have shown no evidence of respiratory or dermatological problems arising from handling guayule.

Use of volatile solvents in guayule processing will necessitate tight controls and efficient separation, recovery and reutilization to avoid occupational health hazards, as well as to lower processing materials costs.

Adverse socioeconomic or environmental impacts of guayule development are anticipated to be relatively minor, unless normal precautions are ignored for the expediency of emergency guayule development.

6. Policy implications: The assessment of policy implications of guayule commercialization is founded on the key question, "Should guayule development be viewed as of strategic value for the United States?" Scenario B correlates closely with viewing guayule rubber as a strategic commodity. Under this set of circumstances, development would be stimulated strongly or led by the federal government and the government would be prepared to accept increased adverse effects to ensure development of this strategic commodity. Under Scenario A, guayule rubber probably would not be considered to be a strategic commodity. Under these circumstances, development would be achieved within the private sector with few government incentives. Protective governmental regulations would remain firm. The federal government, however, could adopt a strategic-material viewpoint for guayule, without development of a crisis situation. In this event, development would be primarily within

the private sector, but with strong federal incentives. The government could be expected to accept some trade-offs, although not as many as under Scenario B.

a. National: The focus of the policy discussion is on those areas where significant conflicts could occur, where guayule development policy might be overridden by, or might override, other stated governmental policies.

Conflicts could occur at the federal level regarding resource allocation policies. Allocations of land, water and labor in the marketplace may not relate to governmental social objectives. At present, municipal and industrial demands for water are outstripping agriculture's ability to pay in much of the Southwest. Allocation of water and land for low-water- use crops may not be possible in this situation. Where such allocation is possible, it implies trade-offs of other agricultural commodities that may be equally important from an overall societal point of view.

At present there is a lack of clear leadership in the initiation of guayule development. Both government and private industry seem to be waiting to see how much risk-taking and initial investment the other is going to assume. Although neither group wants to initiate efforts that will be duplicated by the other, the future control of a guayule industry can be expected to rest primarily in the hands of those who take early action. This policy conflict could be mitigated by the formation of a joint governmental-industrial oversight agency with the responsibility to allocate tasks and coordinate development.

The area of interaction between target beneficiaries and the scale of guayule development has serious potential for policy conflict. If guayule is developed by the rubber-products industry, the scale of development can be expected to be governed primarily by economies of scale in processing. In turn, such scales of development may provide little opportunity for the small farmer, the Indian community or the private entrepreneur to enter the guayule production cycle. If the federal government develops guayule, particularly under a crisis situation, target beneficiaries may again be overlooked. It will be incumbent upon the federal government, if it becomes involved in guayule development, to ensure entry into the guayule commercialization structure by the intended beneficiaries of the Native Latex Commercialization Act of 1978. ("Convey substantial economic benefits to peoples living in arid and semiarid regions of the United States.")

Development of guayule as a strategic material has the potential for direct conflict with other federal policies and goals. Environmental protection policy might inhibit guayule development, although this does not appear to be too likely. On the other hand, environmental policies might be set aside to allow strategic guayule development to proceed unhindered.

Agricultural policy in the United States is marked by disagreement even before any anticipated introduction of guayule. Optimum production levels of competing commodities are poorly understood and rarely articulated. Stated federal policies of family farm support often are countered by agricultural programs that tend to favor large landholders. Guayule production can be expected to suffer the same difficulties in priority structure and scale of development as other crops do. If guayule rubber gains a strategic-material status as a non-food crop, it might still find difficulty in gaining priority in agricultural programs. Further, in time, guayule may well have to compete for priority with energy crops in the Southwest.

Attempts to attain a self-reliant position with regard to a strategic commodity within the United States can conflict directly with State Department objectives to increase international cooperation and interdependence. For example, the U.S. State Department recently lent strong support to an international rubber agreement that had been viewed by the U.S. rubber industry as shoring up inefficient hevea rubber producers at the expense of the domestic U.S. rubber industry. Thus, a strategic guayule development policy would have to have State Department support to be effective.

Antitrust policy has the potential for direct conflict with a strategic-material development policy for guayule. In a crisis situation, strategic-materials considerations could well override current governmental policies designed to prevent industrial monopoly. Conversely, prevention of a vertical guayule industry monopoly, without some governmental involvement and support of the industry, could well preclude development of the structure necessary for successful commercialization. Again, this conflict could be mitigated through the creation of a joint government-industry guayule oversight agency that could coordinate development of all phases of guayule commercialization without allowing any single entity to gain a vertical monopoly control of the guayule rubber industry.

One area of potential policy conflict that has been mentioned frequently by various researchers and agency personnel concerned with guayule commercialization is the stability of U.S. -- Mexico international relations. Concerns focus on the potential for a guayule blackmarket (or la Lina Blanca) and on the possibility that guayule development might affect undocumented workers. Undocumented workers are not seen as being significantly affected by U.S. guayule development, neither under strategic nor non-strategic development. U.S. agriculture tends to be capital, rather than labor, intensive when possible, and guayule production lends itself well to mechanized agricultural productions. Guayule, in most areas, is anticipated to serve as replacement agriculture, thus transferring employment from one agricultural commodity to another rather than creating a significant number of new agricultural jobs. Processing facilities will require primarily skilled labor, and should not act as a draw for unskilled labor.

Smuggling has greater potential for becoming a problem, particularly if guayule processing facilities are developed on one side of the U.S.-Mexico border and not the other. Placement of processing plants near the border in Texas could place a harvesting demand on wild stands of Mexican guayule that could be severely disruptive and difficult to control. The necessity for processing the shrub soon after harvest, as well as the difficulty in transporting large quantities of shrub across the border, should tend to keep this problem from growing large. The recent agreements between the United States and Mexico to cooperate in research, particularly the specific agreements on guayule research, should help in achieving concurrent development of guayule in both countries. This would act as the most effective deterrent to problems developing between the United States and Mexico concerning guayule.

b. Local: Many of the areas of potential policy conflict at the federal level have far-reaching local implications. In addition, there are some areas of policy conflict, which operate primarily at the local level, that could profoundly affect, or be affected by, guayule development.

Of primary interest at the local level is the ability to gain access to the emerging technology. Indian communities are becoming disenchanted with straight leasing of their lands, and are becoming interested in gaining the full value inherent in development of their resources. In the case of guayule commercialization, they would want the economic benefits of growing guayule, the jobs and value added from processing guayule, and the benefits of being able to deal on the international rubber market rather than being restricted to selling shrub to a local processing facility. Non-Indian farmers are also concerned about being squeezed out of the developing guayule industry. They express concern that they may be forced out of the farming business by water shortages and high energy costs, while the federal government supports new, low-water-use agricultural development in some other communities, Indian or non-Indian. An action suggested by one Indian community representative that could mitigate this local conflict would be the development of processing facilities owned and operated by combined Indian reservation/non-Indian agricultural cooperatives.

A final area of concern relates to an interaction of policy decisions taken at a federal or industrywide level that would produce extreme adverse impacts at the local level. This is the impact potential of a guayule industry shut-down. Given the development of large-scale processing facilities, with perhaps 100,000 supporting acres of guayule developed and controlled by either the federal government or large rubber products companies, a shut-down decision might be made in Washington, D.C., or in Akron, Ohio, with little awareness of the effects this could have on a local, rural economy. Again, some local involvement in development could help to avoid such a conflict, or at least foresee the problem and attempt to institute some replacement technologies.

I. INTRODUCTION

Rubber is a critical material in modern technological civilization. Each year approximately 10 million metric tons of elastomers, including both natural and synthetic rubber, are consumed throughout the world in a host of uses that demand its elastic, friction or waterproof properties. These uses include tires and tubes for wheeled vehicles, V-belts for machinery, hoses, shock absorbers, seals, bridge supports, conveyor belts and clothing. Rubber was obtained originally from the rubber tree, *Hevea braziliensis*, but synthetic elastomers developed during World War II now supply more than 60 percent of the world elastomer demand.

The U.S. supply of both natural and synthetic rubber is uncertain. The increasing international demand for the limited production of natural rubber and for the petroleum that serves as a raw material for synthetic rubber is one factor. In addition, international politics pose major uncertainties for the Western World; dependable sources of natural rubber and petroleum are not assured.

The most promising alternative source of natural rubber is the guayule plant (*Parthenium argentatum*), a native shrub of semiarid plateaus of the U.S. Southwest and northeastern Mexico. The rubber industry long has known that guayule (pronounced wy-oo-lee) contained a rubber very similar to that of the rubber tree. Development of guayule as a domestic source of rubber is again receiving much attention, spurred by Congressional passage of the Native Latex Commercialization Act of 1978.

No industrial structure for producing guayule rubber exists at this time, although the plant has been cultivated commercially in the past. The commercialization of guayule, as perceived in this Technology Assessment (TA), can occur through the economic forces of supply and demand for developing alternatives to hevea rubber or through strong government involvement as the result of a drastic cutoff in rubber supplies, or through a sudden cartel-type rise in the price of hevea rubber. The development of a guayule industry must occur within some organizational structure and function in a framework similar to that shown in Figure I-1.

Several groups in industry, government and the academic community are actively studying the technological and economic potential of guayule. It is estimated that by the end of this century 1 million to 2 million acres of land in the U.S. Southwest could be planted with guayule and perhaps even more land could in other arid regions around the world.

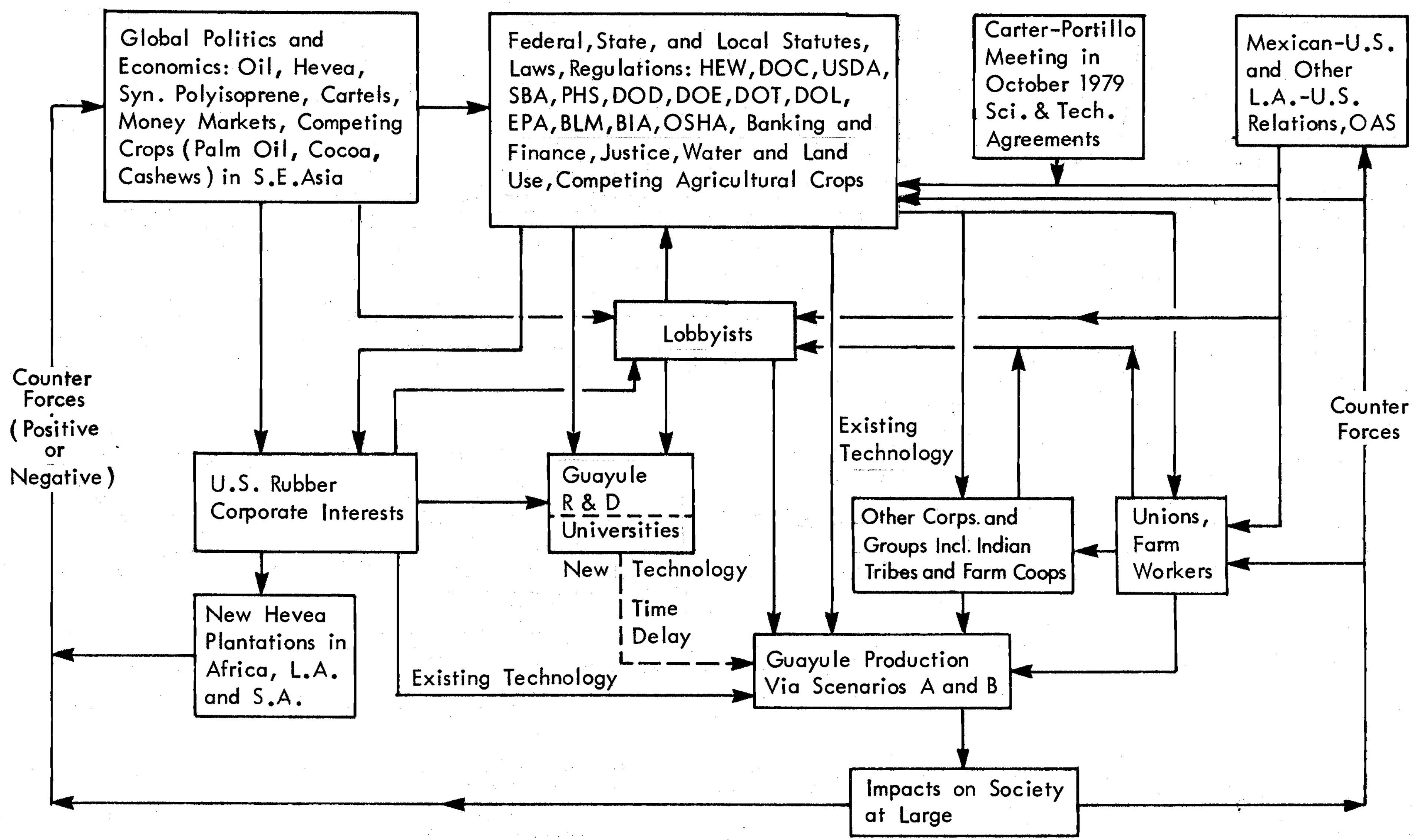

Figure I-1: GENERALIZED INPUTS FOR GUAYULE PRODUCTION

The objective of this study is to perform a comprehensive TA of commercializing the guayule plant as a major domestic source of rubber in the U.S. Southwest. The range of technical, economic, social and national forces that might stimulate the development of this technology is examined. The range of impacts or consequences that this commercialization could generate and the alternative development approaches that would be open to government agencies and private sector groups also are assessed. Finally, the results that might be expected in exercising different policy options are forecast.

The TA project was divided into several work phases. Phase I included a "walk through TA session," chaired by Mr. Joe Coates of the U.S. Congress Office of Technology Assessment, and attended by 22 experts in guayule, the rubber industry and technology assessment. This phase included the brainstorming of potential guayule issues and conflicts, refining the project tasks and developing the first final report outline. The completion of Phase I resulted in publication of Technology Assessment of the Commercialization of Guayule--Domestic Rubber Source of the Future; Orientation Report, in December 1978.

Phase II, the sociotechnical survey of guayule development, consisted of an extensive review of present agricultural-industrial-state-of-the-art aspects of guayule technology. This review involved the examination of the chemical and physical properties of guayule rubber; production history and trends in research and development; prospects for guayule commercialization, including national economic concerns, incentives for guayule production and constraints on guayule production; and alternative technologies that could affect rubber supply or demand. Review material was distributed extensively throughout the scientific and industrial communities and then published as A Sociotechnical Survey of Guayule Rubber Commercialization: A State-of-the-Art Report, in April 1979.

Phase III of the TA involves forecasting technology. Two alternative commercialization scenarios were developed: Scenario A describes a situation wherein present trends continue and guayule development occurs in response to natural rubber demand and to the need for low-water use crops in the arid Southwest. Scenario B depicts the possibility of rapid commercialization, wherein government becomes deeply involved in guayule development in response to perturbations in the international rubber market. These scenarios were reviewed by the scientific community and revised as recommended.

Phase IV, forecasting impacts, is based upon the scenarios developed in Phase III. It is developed from information generated in two public meetings, from extensive interviewing of key government personnel and individuals throughout the potential guayule growth region who could have interest in guayule production, and from detailed sociological and environmental data.

Phase V, assessment of public policy issues, also was developed from the public meetings and from interviews with individuals from the guayule development region, federal government, and the rubber industry.

This guayule technology assessment final report includes synopses of elastomer supply-and demand projections during the next 20 years, the state-of-the-art of guayule technology, and the driving forces and constraints of guayule commercialization. This document includes the first publication of the development scenarios, projected consequences of guayule development, and public policy-issue-analyses. The focus of this report is on the policy implications of alternative means of guayule commercialization.

This TA should be of use to:

(a) Federal agencies including the Departments of Energy, Agriculture, Defense, Labor, Commerce and the Interior (including the Bureau of Indian Affairs); the Small Business Administration; the Environmental Protection Agency;

(b) State and local government agencies and Indian tribes, particularly in California, Arizona, New Mexico and Texas; and

(c) Private sector parties, including citizen participation groups, guayule growers, rubber-producing companies and industries that depend critically on rubber products.

II. ELASTOMER SUPPLY AND DEMAND

To place guayule commercialization in a context for comparison, this chapter includes a discussion of historic and recent developments in the synthetic and natural rubber industries. Trends in world and U.S. elastomer supply and demand are discussed and extrapolated to the year 2000. Alternative elastomer supplies also are discussed.

A. Synthetic and Natural Rubber Developments

Historic and recent developments in the synthetic and natural rubber industries are discussed in this section.

1. Background Developments: Although approximately 2,000 species of plants are known to contain some kind of rubber, few have been sources of significant supplies. Only two, the rubber tree (Hevea brasiliensis) and the guayule shrub (Parthenium argentatum), have been commercial sources of natural rubber The rubber products industry was founded on Hevea production. Hevea rubber was an important factor in developing the many industries that now rely on rubber components.

Since 1900, rapid growth of production and demand has occurred for natural and, since the 1940s, synthetic rubber and rubber products. In 1970, the estimated world annual production of hevea rubber was 3 million tons. Malaysia, the major supplier of natural rubber, produced more than 1.1 million tons on 4.2 million acres of plantations. The United States, the major consumer of natural rubber, accounted for 20 percent of world consumption. In addition a large rubber chemicals industry was producing new vulcanizing agents, accelerators, rubber stabilizers, antioxidants, fillers, softeners, hardening agents, blowing agents and other additives that modern rubber products require. By 1970, nearly 150,000 short tons of these rubber chemicals, worth about $200 million, were produced annually. The total value of all rubber products amounted to billions of dollars. The goods and services that relied on these products were major components of the national economy, defense and the quality of life.

The critical role of rubber in the U.S. economy and national defense became apparent during World War II when 90 percent of the U.S. supply of natural rubber from Southeast Asia was cut by the Japanese. To meet this cutback, an enormous research and engineering effort was initiated in the United States to develop synthetic rubber, and a substantial effort was initiated to develop new sources of natural rubber.

U.S. efforts to develop synthetic elastomers were built on research studies dating to 1910, on German efforts during World War I, on German and Russian developments in the 1920s and 1930s, and on the development of neoprene rubber in the United States in 1932. By 1945, U.S. chemists and chemical engineers had developed production processes for several types of synthetic rubber. U.S. industry was producing 0.7 million tons annually. The Germans also developed a synthetic rubber during World War II.

The Emergency Rubber Project (ERP) was begun when the U.S. Congress passed legislation during World War II to develop a new source of natural rubber. The Guayule Act authorized planting of guayule on 75,000 acres, purchasing the Intercontinental Rubber Company's properties for no more than $2 million, leasing land for 10 years to grow guayule, constructing and operating guayule mills and conducting research. On March 12, 1942, Department of Agriculture Secretary Wickard issued a memorandum that made the Forest Service responsible for administering the Act.

During the ERP 32,000 acres of guayule were planted and approximately 3 million pounds of rubber were milled, including 900,000 pounds from Intercontinental Rubber Company plantations and 500,000 pounds from native shrub harvests in Texas. The ERP guayule project was halted before its planned goal was achieved because of the rapid development of synthetic rubber production and the need for using the land, labor and equipment for the nation's food production program immediately following World War II.

Liquidation of ERP plantations began in January 1946. In some cases, arrangements were made for landowners to repossess their land and destroy the shrub; in others, ERP destroyed the shrub; in still others, ERP destroyed the shrub and reconditioned the land for return to its owners. Except for a few experimental areas, all land was released by June 30, 1946. All remaining property was disposed of by surplus property agencies.

When the Secretary of Agriculture appointed the Forest Service to administer the program authorized by the Guayule Act, he suggested that the Bureau of Plant Industry* and the Forest Service undertake necessary research under a joint plan to be arranged by the two agencies. The Forest Service was authorized to call on any other Department of Agriculture agencies for essential technical services and other assistance of any kind.

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*The identity of this unit has undergone several changes. It has been included in the Agricultural Research Service and more recently in Science and Education Administration.

The work of the Bureau of Plant Industry was limited primarily to botanical and cultural research. Milling-process research was later assigned to the Bureau of Agricultural and Industrial Chemistry (BAIC). The Bureau of Entomology and Plant Quarantine conducted insect-control surveys and research.

Experiment stations and extension services in guayule-producing states supplied much information on the suitability of land for guayule production, as did the state departments of agriculture in Texas and California. State government agencies were helpful also in getting shrub shipments through quarantine.

The California Institute of Technology, The University of California, Leland Stanford University, The University of California at Los Angeles, Texas A&M, The University of Arizona and New Mexico State College all assisted in guayule research.

More than 800 technicians and classified personnel were employed by the Forest Service, and another 130 were employed by various research organizations in support of the ERP. Total funds expended on the project amounted to about $42 million, of which approximately $3.5 million was spent on research. An evaluation of these expenditures must take into account the fact that the ERP was a wartime project that emphasized speed to meet critical rubber needs. Costs of materials were high and operating efficiencies could not be met because of wartime exigencies.

Recognizing that synthetic rubber was not satisfactory for all essential uses, the Department of the Navy, through its Office of Naval Research, provided funds to continue a guayule-research program until appropriations were made by Congress. Stanford Research Institute was the operating agency.

A research program also was organized in 1947 to be conducted jointly by the Bureau of Plant Industry, Soils and Agricultural Engineering and the Bureau of Agricultural and Industrial Chemistry under the title of The Natural Rubber Extraction and Processing Investigations Project. In December 1950, an emergency program of guayule-seed-and-seedling stockpiling was initiated by the Department of Agriculture. The stockpile was to be administered by the Production and Marketing Administration. The Bureau of Plant Industry, Soils and Agricultural Engineering provided technical guidance.

The seedling-stockpiling program in Texas was brought to a close in December 1951, and all land and personnel were released. The seed-stockpiling program in California was concluded in December 1962.

In June 1953, the Natural Rubber Extraction and Processing Investigations Project of the Bureau of Agricultural and Industrial Chemistry was liquidated. The cultural and breeding program conducted by the Natural Rubber Research Project of the former Bureau of Plant

Industry, Soils, and Agricultural Engineering was discontinued on June 30, 1959.

2. Recent Developments: In the early 1970s, the oil embargo and subsequent petroleum price increases were followed by cost increases of petroleum-based products, including synthetic polyisoprene rubber. These circumstances, uncertainties about continued availability of natural-rubber supplies from foreign sources, and growing pressures to find water-efficient uses for land in the U.S. Southwest all contributed to rekindled interest in obtaining natural rubber from guayule.

Mexico began a guayule research and development project in 1973, and later, in the 1970s, five important events occurred to stimulate U.S. and Mexican interest in guayule research.

a. An international guayule conference was held in Tucson, Arizona, in 1975. Technical papers were presented by scientists who had worked on the ERP and other guayule projects. Proceedings of the conference were published. In 1976, a guayule processing pilot plant began operating in Saltillo, Coahuila, Mexico. In 1977, also in Saltillo, an international conference was held to discuss the new processing procedures developed in Mexico, the chemistry of guayule rubber, and the agronomic and ecological implications of recent developments. Proceedings of this conference were published in 1978. The National Academy of Sciences published a guayule review report in 1977.

The Native Latex Commercialization Act of 1978, enacted by the U.S. Congress, authorized a $30 million program for guayule research and development and for guayule rubber production and manufacturing demonstrations. Appropriation of funds has been delayed, but members of the Joint Commission mandated by the Act have been appointed and the Commission has held several meetings and workshops.

b. Germ plasm has been collected from natural guayule stands in Mexico and Texas, plantings have been established for yield tests and seed increases, and some plant breeding studies are underway. Significant research also is being conducted to increase guayule rubber yield by treating the entire plant with bioregulatory agents.

c. Test plots have been established and will be examined to determine appropriate planting and cultivating practices. Recent guayule seedcoating processes and selective herbicide developments are significant. These advances could eliminate the need for nursery or greenhouse propagation and transplanting of seedlings to the field, and could result in considerable production-cost savings.

d. Improved processing methods have been developed at the pilot processing plant in Saltillo, Coahuila, Mexico. Rubber produced there has been analyzed and tested. The Firestone Tire and Rubber Company has developed a solvent-extraction process that may result in modification of processes now used for guayule rubber extraction.

e. Experimental radial tires containing 30 percent to 40 percent guayule rubber have passed U.S. Department of Transportation high-speed and endurance tests in evaluations by the Goodyear Tire and Rubber Company. A Department of Defense project at the Naval Air Rework Facility in San Diego, California, is designed to evaluate guayule rubber as a substitute for hevea rubber in U.S. military applications.

B. Elastomer Production and Consumption

The success or failure of guayule rubber commercialization in the United States hinges, in part, on the future demand for natural rubber. With this fact in mind, past and projected trends in elastomer supply and demand are discussed in this section.

1. World Consumption of Elastomers: Before the 1940s, hevea natural rubber was the only elastomer of worldwide commercial importance. During World War II, synthetic rubber development and use reached the point where its consumption exceeded that of natural rubber. After World War II natural rubber again became available on the world market, but synthetic rubber technology had become established and was successfully meeting increasing demands. With economies of scale, relatively inexpensive petroleum feedstocks, and aggressive research and development, synthetic elastomers commanded a progressively larger fraction of the world rubber market. Beginning circa 1945, natural rubber production could not keep pace with the growing world demand for rubber. The use of synthetic rubber, therefore, was encouraged in applications that traditionally had been dominated by natural rubber.

Natural rubber use increased on a worldwide basis at an annual average of 3.3 percent between 1948 and 1973, while synthetic rubber use increased at an annual average rate of 9.3 percent. (Grilli et al, 1978). As a result of these expansion rates, synthetic rubber claimed more than 50 percent of the total world elastomer market by 1960, and by 1973 it supplied close to 69 percent of the total world demand for elastomers (Grilli et al, 1978; International Rubber Study Group, London IRSG 1979).

Figure II-1 illustrates the growth in world elastomer consumption between 1946 and 1978. During that period there was a significant increase in consumption. Approximately 1.7 million metric tons were consumed in 1946 and 12.1 million metric tons in 1978. The growth of synthetic rubber use during this period was substantially greater than that of natural rubber. Synthetic rubber consumption increased from approximately 1.1 million metric tons in 1946 to 8.5 million metric tons in 1978; natural rubber consumption increased from approximately 600,000 metric tons in 1946 to 3.6 million metric tons in 1978 (Grilli et al, 1978; IRSG).

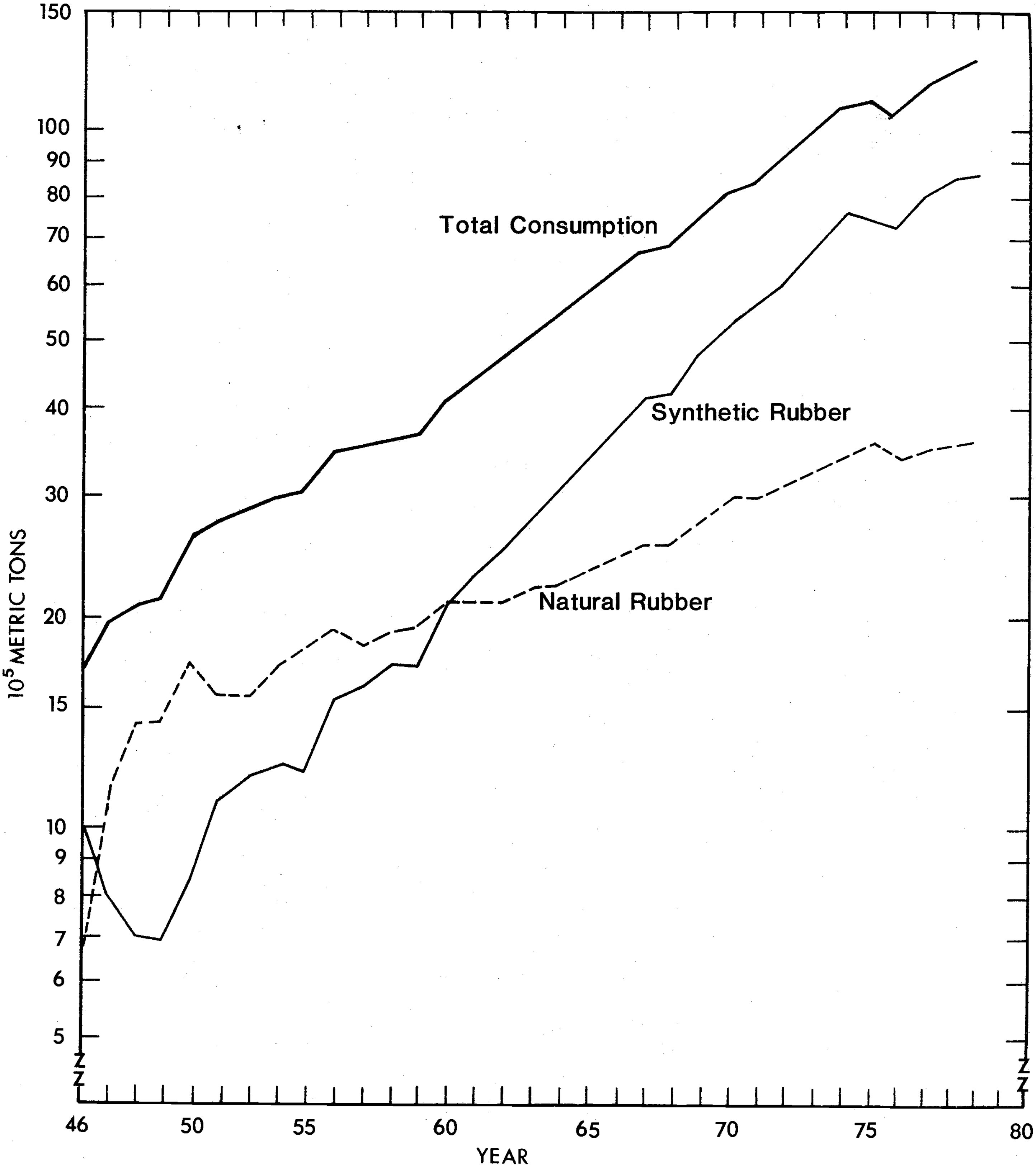

Figure II-1: WORLD ELASTOMER CONSUMPTION, 1946-1978

Source: Adapted from Grilli, et al (1978) and Rubber Statistical Bulletin (1979).

Since the early 1970s, the Arab oil embargo and the increasing world demand for radial tires, have altered the elastomer-consumption growth trends that were established in the 1950s and 1960s. The Organization of Petroleum Exporting Countries' (OPEC) oil embargo caused crude oil prices to triple between 1973 and 1975.* This resulted in a corresponding rise in the price of butadiene, styrene and polyisoprene, the primary feedstocks for synthetic rubber manufacturing. Similarly, the cost of petroleum-derived energy required for processing and transporting synthetic rubber products increased well beyond the existing rate of inflation. Quantitatively, production costs for synthetic rubber rose 70 percent to 100 percent as a direct result of the Arab oil embargo. This estimate does not include increases due to labor and other non-petroleum-related overhead. In contrast, the corresponding direct production-cost increase for natural rubber was approximately 10 percent (Grilli et al, 1978).

Radial tires, which have been reported to require approximately twice as much natural rubber and one-third less synthetic rubber than bias-ply tires, represent an increasing share of the world demand for tires (Anonymous, 1979a). Because production of tires and other automotive products accounts for 65 percent of world elastomer consumption, continued or increased popularity of radial tires is a significant factor in predicting the demand for natural rubber (Grilli et al, 1978).

The outlook for natural rubber was not seriously affected by the recession that occurred in industrialized countries in 1975. Although world elastomer demand did decline because of this economic downturn, the average price of natural rubber was more competitive than either synthetic cis-polyisoprene or styrene butadiene rubber. Consequently, the share of natural rubber in the total market continued to increase, while synthetic rubber producers bore a larger share of losses caused by the recession (Grilli et al, 1978).

The price of natural rubber climbed above \$.60/lb and approached \$.70/lb on several occasions during 1979. In early 1980, natural rubber prices exceeded \$.80/lb. In addition, international agreements between consumer and producer countries to stabilize natural rubber prices and supplies reached the final stages of negotiation. The popularity of radial tires continued to grow. All of these events suggest a promising future for natural rubber.

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*Between 1973 and 1975 crude oil prices increased from an average of \$3.75 to \$12.00/bbl in Western Europe, \$3.30 to \$11.90/bbl in Japan, and \$4.10 to \$10.40/bbl in the U.S. (Grilli et al, 1978).

At the same time, oil prices are rising much faster than world inflation. Between 1972 and 1979, the contract price per barrel of oil had risen from approximately $3 to $20. The latter figure undoubtedly will increase after this report is published. This rate of growth is equivalent to an average per annum increase of more than 30 percent. The full, long-term impact of this trend on elastomer demand and world economy remains to be seen.

2. U.S. Consumption of Elastomers: The history of the competition between natural rubber and synthetic rubber in the United States has been similar to that in the world market. During the last 30 years, consumption of synthetic rubber has taken a commanding lead. Figure II-2 and Table II-1 illustrate the dominance of synthetic rubber in the U.S. market during the past 18 years. Since 1960, natural rubber use has never accounted for as much as 30 percent of the total annual elastomer consumption, and the actual rate of use tends to remain at, or below, 25 percent per year. Table II-2 shows consumption of natural and synthetic rubber in 1970. It is apparent from the data in this table that in the United States, as elsewhere in the world, tire production accounts for the major portion of elastomer consumption.

Since World War II, the United States has relied on synthetic rubber whenever possible. Dependence on a predictable petroleum supply, rather than on Southeast Asian rubber, was a reasonable approach to satisfy elastomer demands in the postwar era. Manufacturers had experienced a total cutoff of Southeast Asian rubber during the war, and they were continuing to experience shortages of natural rubber because demand was outstripping supply. As a result synthetic rubber production grew steadily and by the early 1950s was supplying more than 50 percent of the U.S. demands for elastomers. (Grilli et al, 1978)

As shown in Figure II-2 and Table II-1, elastomer consumption, particularly of synthetic rubber, increased rapidly in the United States during the 1960s. Between 1968 and 1978, the average-percent-per-annum-consumption growth rates for natural rubber and synthetic rubber were 5.3 percent and 5.6 percent respectively, compared with a more typical 2.9 percent and 8.0 percent respectively for the 1961-1968 period. From 1973 to 1977, the average natural rubber and synthetic rubber percent per annum growth statistics, 4.7 percent and 1.8 percent respectively, show increasing growth in natural rubber consumption, reflecting the impacts of the Arab oil embargo and the resulting rise in feedstock prices, the rapidly increasing popularity of radial tires, and the recession in the developed nations of the world in 1975 (IRSG, Anonymous, 1979, U.S. Department of Commerce, 1975).

The following table shows the relative importance of various elastomers in the U.S. market (estimate based on Allen, et al, 1975).

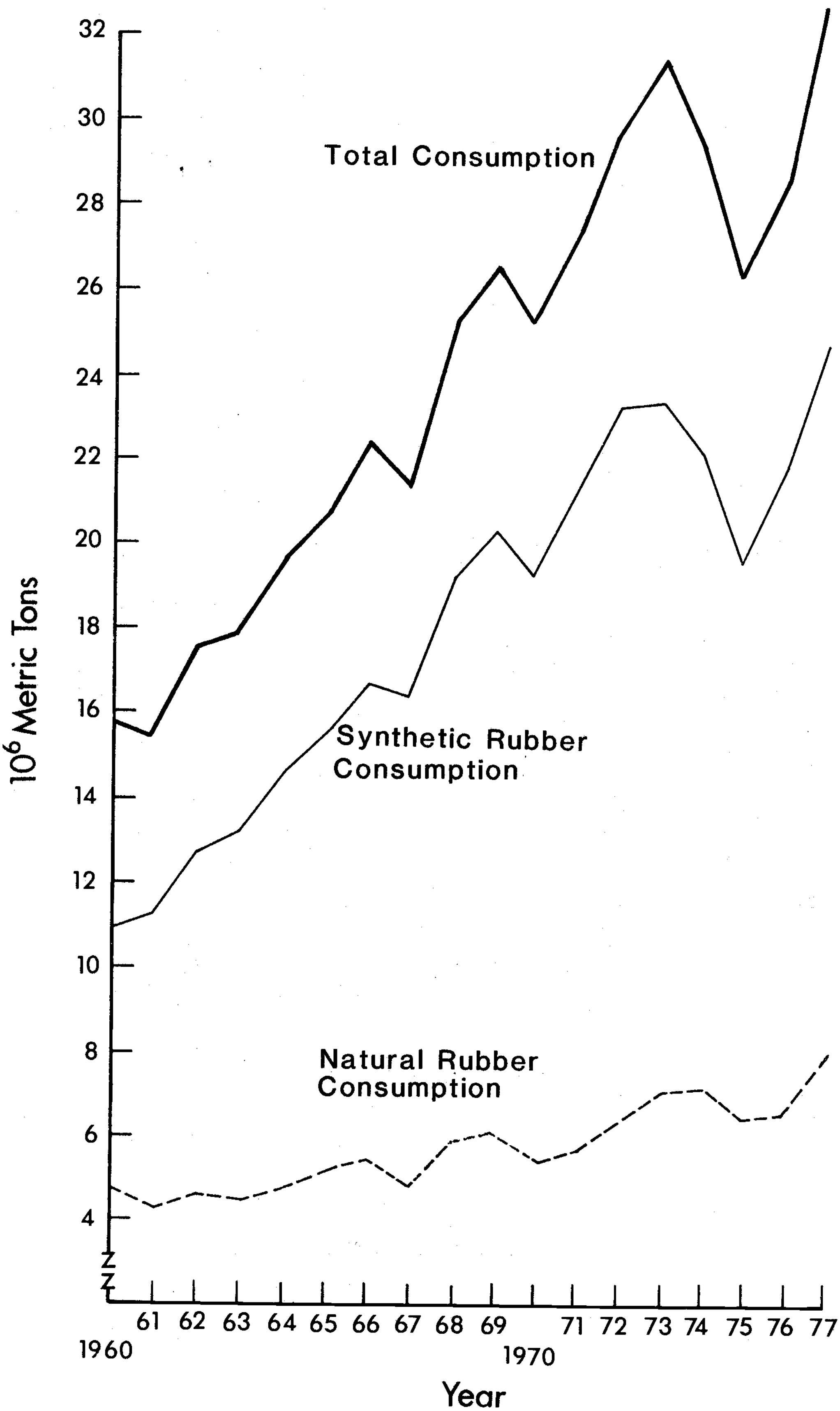

Figure II-2: U. S. ELASTOMER CONSUMPTION, 1960-1977

Sources: Rubber Statistical Bulletin (1979) and Current Industrial Reports (1952-1975).

TABLE II-1

U.S. ELASTOMER CONSUMPTION, 1960-1977

Year	Total Elastomer Consumption 10^3 Mg	Natural Rubber Consumption 10^3 Mg	% NR	Synthetic Rubber Consumption 10^3 Mg	% SR
1960	1,583.2	486.7	30.7	1,096.5	69.3
1961	1,553.9	434.1	27.9	1,119.8	72.1
1962	1,746.2	470.2	26.6	1,276.0	73.4
1963	1,792.2	464.5	25.9	1,327.7	74.1
1964	1,963.9	489.2	24.9	1,474.7	75.1
1965	2,087.6	522.9	25.0	1,564.7	75.0
1966	2,247.2	554.4	24.7	1,692.8	75.3
1967	2,151.0	496.6	23.1	1,654.4	76.9
1968	2,517.7	591.2	23.5	1,926.5	76.5
1969	2,664.4	607.9	22.8	2,056.5	77.2
1970	2,516.8	568.2	22.6	1,948.6	77.4
1971	2,725.6	587.0	21.5	2,138.6	78.5
1972	2,983.6	650.8	21.8	2,332.8	78.2
1973	3,152.0	711.9	22.6	2,440.1	77.4
1974	2,948.3	738.3	25.0	2,210.0	75.0
1975	2,629.5	665.9	25.3	1,963.6	74.7
1976	2,858.8	686.7	24.0	2,172.1	76.0
1977	3,284.4	803.5	24.5	2,480.9	75.5

Source: Rubber Statistical Bulletin (1979) and Current Industrial Reports (1952-1975).

TABLE II-2

ELASTOMER CONSUMPTION BY MAJOR END-USES IN THE UNITED STATES DURING 1970

	Consumption by End-use (%)	Natural Rubber (%)	Synthetic Rubber (%)	Tonnage Consumed (10^3 Mg)
Tire Uses				
Passenger Car	21.8	14.5	85.5	885.2
Truck/Bus	39.1	50.0	50.0	444.0
Tractor/Industrial	5.3	30.0	70.0	100.0
Aircraft	1.4	90.0	10.0	8.9
Retreading	2.3	10.0	90.0	130.0
Inner Tubes	0.03	5.0	95.0	40.0
Other	0.02	5.0	95.5	20.0
Total	70.4	24.9	75.1	1,598.1
Non-tire Uses				
Latex Products	11.8	33.0	67.0	203.0
Belting and Hoses	2.1	15.0	85.0	80.0
Footwear	3.9	25.0	75.0	88.0
Wire and Cable	0.01	3.0	97.0	3.3
Other	11.6	13.0	87.0	507.7
Total	29.6	19.0	81.0	882.0
Total Consumption	100.0	22.6	77.4	2,480.1*

Source: Reference Grilli et al, 1978.

*There is a difference of approximately 1 percent between this U.S. total consumption figure and that given in Table II-1 due to the different sources.

Elastomer Type	Estimated U.S. Market Share in 1975 (%)
Natural polyisoprene	25
Synthetic polyisoprene	Negligible
Styrene-butadiene and polybutadiene	58
All others, including polychloroprene, ethylene-propylene co- and ter-polymers, butyl and speciality varieties	17
	100

The primary use of these materials is for tire treads, sidewalls and inner tubes. Other uses include automotive, industrial and appliance components.

Seventy-two percent of all natural rubber imported to the United States is consumed in making tires. The remaining 28 percent is used to make various rubber products, including rubber bands, shoe soles, carpet backing, adhesive bandages, baby-bottle nipples, garden hoses, windshield wipers, door gaskets, brake diaphragms, and bumper moldings (Anonymous, 1978).

Styrene-butadiene is used primarily for tire treads, sidewalls and carcasses. Polybutadiene usually is blended with styrene-butadiene and natural isoprene. In the United States approximately 95 percent of all polybutadiene is used in tires.

Some polychloroprene or neoprene is used in the white sidewalls of tires, but most is used to manufacture automotive and industrial components, wires, cables and adhesives. Ethylene-propylene, co- and ter-polymers, generally are not used in tires but are used in automotive and appliance components, and in cables. Because of its very low permeability to gasses, butyl rubber is used most often for inner tubes.

In 1977 the total U.S. elastomer consumption was 3.28 million metric tons. Elastomer consumption dropped slightly in 1978 to approximately 3.2 million metric tons (IRSG, 1979). U.S. elastomer consumption was expected to decline in 1979 to approximately 3.1 million metric tons (Anonymous, 1979b). This continuing downward trend is due in part to changes in the U.S. economy and a decline in the demand for U.S. automobiles. The latter of these two factors is particularly significant because 28 percent of the tires manufactured in the United States are purchased by U.S. automobile makers (Anderson, 1979).

3. Projected World Elastomer Demand Through 2000: If world demand for natural rubber continues to grow, it is likely that hevea rubber supplies will fall behind increaseing demand in the near future. Data depicted in Figure II-3 and Table II-3 point to the possibility of a natural rubber shortage during the next 20 years. Growth curves in Figure II-3 are postulated on a "high-growth" future for world elastomer supply and demand.

The total elastomer-demand curve, projected in Figure II-3, assumes a starting point of 14.47 million metric tons for 1980. This figure is at the lower end of the range formed by the 1980 projections that have been made by industrial experts, the World Bank and the IRSG. These projections from 14.4 million to 14.8 million metric tons (IRSG, 1979; Ruebensaal, 1978; Agostini, 1977).

The total elastomer-consumption growth curve assumes a per annum growth of 6 percent through the year 2000.* This growth curve represents a resumption of the consumption increase of 6.3 percent per annum that occurred between 1948 and 1973 (Grilli et al, 1978; IRSG, 1979).

The upper limit for world natural rubber demand as plotted in Figure II-3 is 30 percent of the total demand for both natural and synthetic rubber. Due to end-use applications that require natural rubber, world consumption of natural rubber could remain near 30 percent + 5 percent through the year 2000, but division of the demand for "isoprenic rubber" between Hevea, synthetic polyisoprene, guayule or some other elastomer yet to be created by new technology is difficult to forecast. If the natural rubber share of total elastomer consumption falls to 25 percent or below, the decline probably will be due to a shortage of natural rubber. Substitution of more expensive or lower quality synthetic polyisoprene then will become necessary (Allen et al, 1975; Agostini, 1977; Riedl, 1977). The 30 percent figure represents an approximation of potential natural rubber demand, if production can continue to supply the world market with the tonnage desired.

The upper limit of anticipated hevea rubber production was obtained by plotting the FAO projections for Hevea production through 1990 and then assuming a growth of 4 percent per annum to the year 2000 (Agostini, 1977). A 4 percent per annum growth rate represents a return to the average growth rate of the 1960s. This growth rate is slightly higher than the 3.2 percent to 3.7 percent growth rates now occurring and those anticipated through 1990 (IRSG, 1979; Agostini, 1977).

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* This approach yields statistics that closely resemble the consumption projections made by the U.N. Food and Agriculture Organization (FAO) through 1985 (Agostini, 1977).

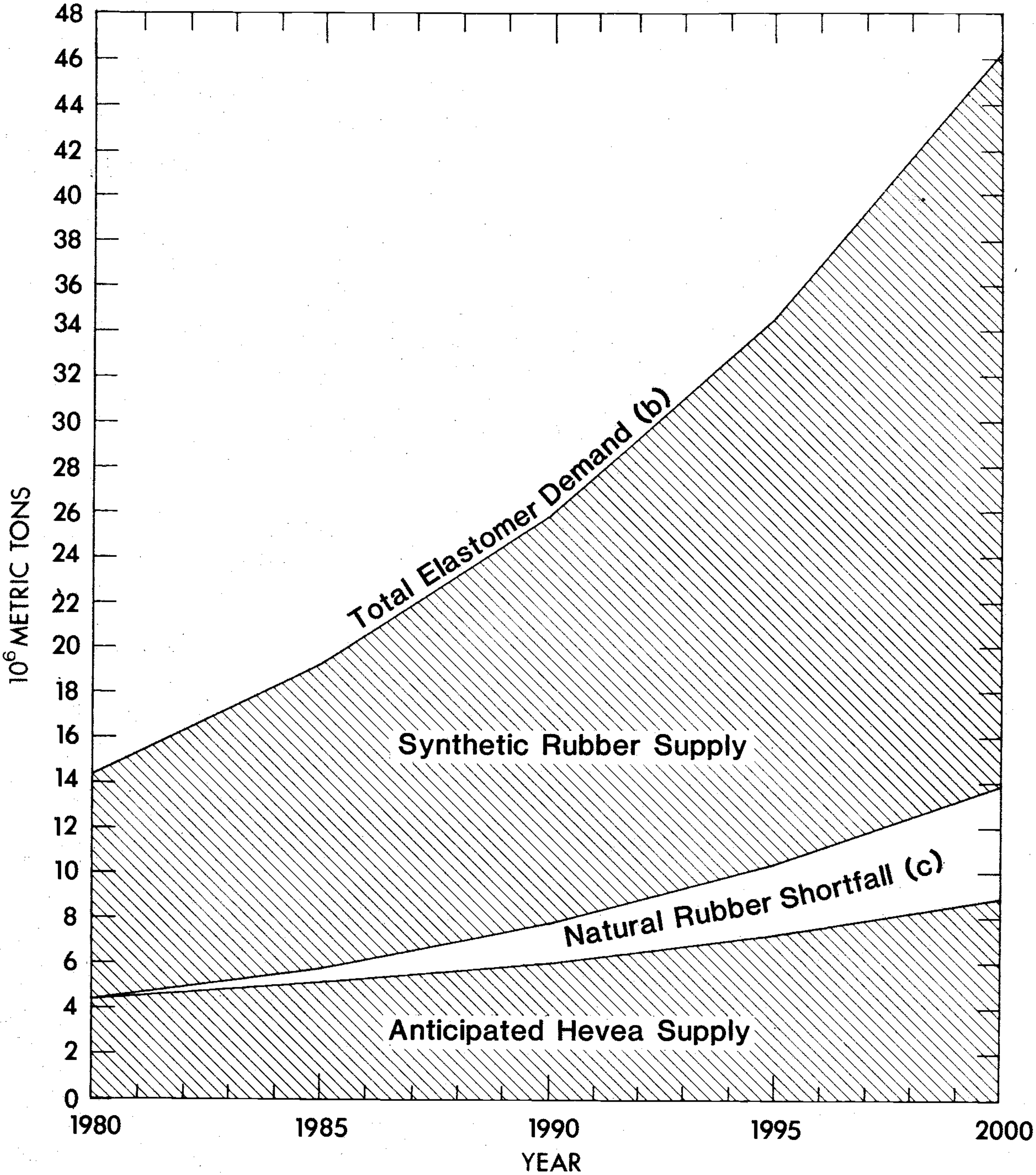


Figure II-3: THE DISPARITY BETWEEN ELASTOMER SUPPLY AND DEMAND ASSUMING A HIGH-GROWTH FUTURE FOR WORLD ELASTOMER SUPPLY AND DEMAND[a]

(a) This figure is a graphic representation of the calculations summarized in table II-3.

(b) The total world elastomer demand assumes a total demand of 14.47×10^6 metric tons in 1980 and increases 6 percent per annum through the year 2000.

(c) The upper limit shown for Natural Rubber demand is 30 percent of the total elastomer demand. The upper limit shown for anticipated hevea supply was obtained by plotting FAO estimates of hevea rubber production through 1990 (3.2 percent to 3.7 percent per annum growth, Agostini, 1977) and then assuming a 4 percent per annum growth in production between 1990 and 2000. The gap between hevea and Synthetic Rubber represents a possible shortfall in the future supply of isoprenic rubber.

TABLE II-3. A HIGH-GROWTH FUTURE FOR WORLD ELASTOMER SUPPLY AND DEMAND

Year	Synthetic-Rubber Production from Petroleum Feedstocks (6% per annum growth) 10^6 Mg	Natural-Rubber Production from Hevea 10^6 Mg	Natural-Rubber Production from Hevea % per annum growth	Total Elastomer Production from Existing Sources 10^6 Mg	Total Elastomer Demand (6% per annum growth) 10^6 Mg	Potential Natural-Rubber Market Share %	Potential Natural-Rubber Demand 10^6 Mg	Natural-Rubber Shortfall 10^6 Mg
1980	10.13	4.34	3.5 ↓	14.47	14.47	~30 ↓	4.34	-
1985	13.55	5.15		18.70	19.36		5.81	0.66
1990	18.14	6.12	4.0 ↓	24.26	25.91		7.77	1.65
1995	24.27	7.43		31.70	34.67		10.40	2.97
2000	32.48	9.04		41.52	46.40		13.92	4.88

A complementary projection that assumes a "low-growth" world elastomer supply-and-demand situation is presented in Table II-4 and Figure II-4. Here, the increase in total elastomer demand is postulated at only 3.5 percent per annum through the year 2000. This departure from past trends and existing projections is considered possible because of the uncertain future of oil supplies and prices.

Other assumptions are listed below.

a. Total elastomer demand will be 14.47 million metric tons in 1980 (the same starting point used in the high-growth projection).

b. Petroleum shortages and/or rapidly rising petroleum prices will slow growth in synthetic rubber production during the late 1980s. Synthetic rubber production will level off during the early 1990s and actually will decline slightly at the turn of the century.

c. Growth in the hevea natural rubber supply will be only 3 percent per annum due to competition from other crops, labor shortages and political disturbances in the Southeast Asian prime growing areas.

d. Successful use of non-petroleum fuel sources will allow tire-rubber demand to maintain a modest rate of growth (3.5 percent per annum) despite petroleum shortages during the 1990s.

e. Both synthetic and natural rubber supplies will fall short of demand during the 1990s. The total elastomer shortfall will grow to 7.87 million metric tons by the year 2000. The natural rubber shortfall will grow to 2.23 million to 3.67 million metric tons by the year 2000, assuming that 35 percent to 40 percent of the total elastomer market is open to natural rubber usage during the 1990s.

Figure II-5 summarizes the data provided by the two contrasting projections of future world elastomer demand. Similarly, Figures II-6 and II-7 illustrate the potential world elastomer shortfall indicated by these projections.

Table II-5 compares other world-rubber-consumption forecasts with the U.S. high-growth and low-growth projections described earlier in this chapter. The 1990 high-growth projection is about 6 percent higher than a comparable consensus-consumption forecast and 16 percent below a comparable forecast based on a return to the 1962-1976 growth rate for elastomer consumption (Allen, 1978; Hurley, 1979). The 1990 low-growth projection is about 16 percent below the comparable consensus consumption forecast and about 33 percent below the forecast based on past trends. Table II-5 stops at 1990 because sufficient long term projections are not available to provide a consensus forecast against which the internally generated numbers may be compared.

TABLE II-4. A LOW-GROWTH FUTURE FOR WORLD ELASTOMER SUPPLY AND DEMAND

Year	Synthetic-Rubber Production from Petroleum Feedstocks 10^6 Mg	Synthetic-Rubber Production from Petroleum Feedstocks % per annum* change	Natural-Rubber Production from Hevea 3% per annum growth* 10^6 Mg	Total Elastomer Production from Existing Sources 10^6 Mg	Total Elastomer Demand 3.5% per annum growth 10^6 Mg	Total Elastomer Shortfall 10^6 Mg	Potential Natural-Rubber Market Share %	Potential Natural-Rubber Demand 10^6 Mg	Natural-Rubber Shortfall 10^6 Mg
1980	10.13	3.5	4.34	14.47	14.47	-	30-35	4.34 - 5.06	0.00 - 0.72
1985	12.03	3.5	5.03	17.06	17.18	0.12	↓	5.15 - 6.01	0.12 - 0.98
1990	13.59	0	5.83	19.42	20.40	0.98	35-40	7.14 - 8.16	1.31 - 2.33
1995	13.59	0	6.76	20.35	24.22	3.87	↓	8.48 - 9.69	1.72 - 2.93*
2000	13.06	-1	7.84	20.90	28.77	7.87	↓	10.07-11.51	2.23 - 3.67*

*Synthetic rubber shortfalls of 0.94-2.15 and 4.20-5.64 million metric tons (Mg) in 1995 and the year 2000, respectively, are indicated by this low-growth projection.

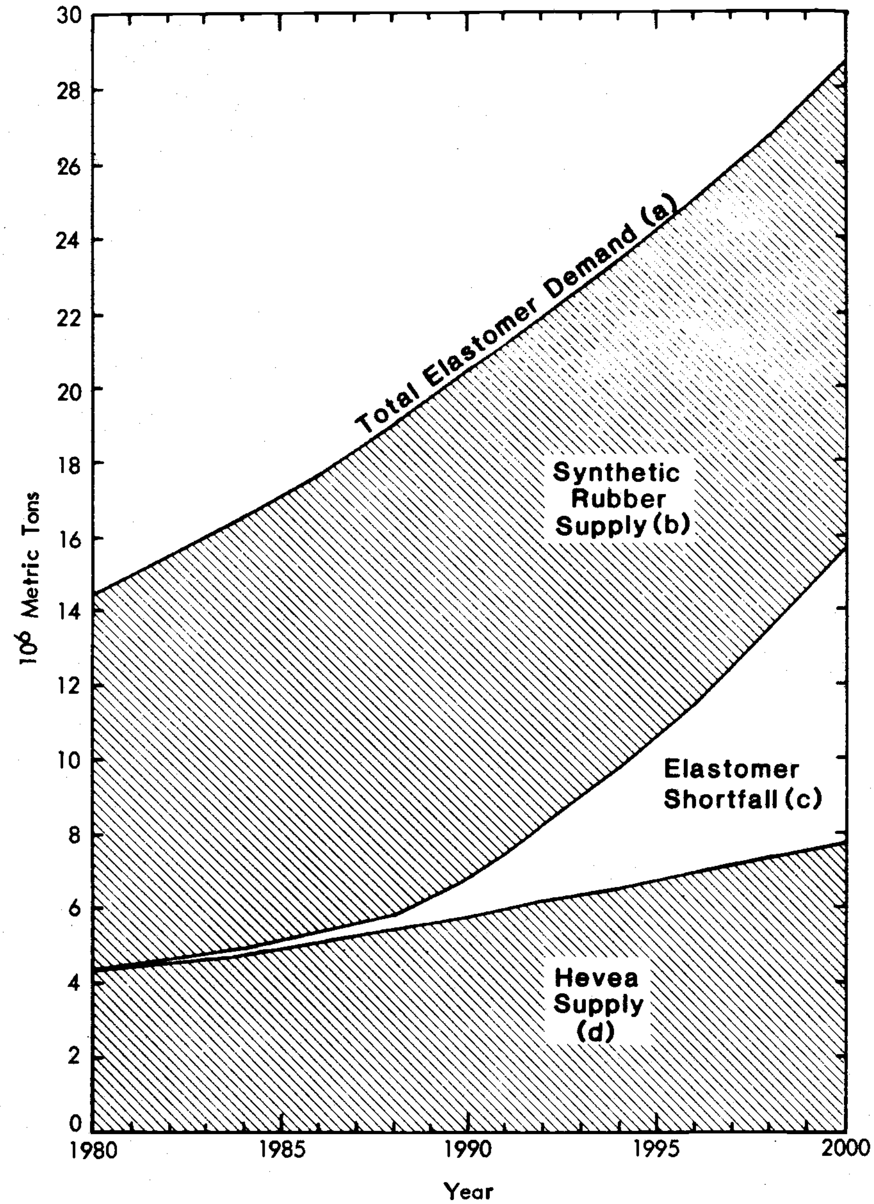


Figure II-4: THE DISPARITY BETWEEN ELASTOMER SUPPLY AND DEMAND ASSUMING A LOW-GROWTH FUTURE FOR WORLD ELASTOMER SUPPLY AND DEMAND[a/]

(a) Total world elastomer demand assumes a total demand of 14.47 x 10^6 metric tons in 1980 and increases 3.5 percent per annum through the year 2000.

(b) The petroleum-based Synthetic Rubber supply is assumed to equal 70 percent of total demand in 1980. The supply gradually falls behind demand in the late 1980's. Synthetic Rubber supplies plateau during the 1990's.

(c) The hevea Natural Rubber supply is assumed to equal 30 percent of total elastomer demand in 1980. The supply increases 3 percent annum from 1980 through the year 2000.

(d) Both Synthetic Rubber and Natural Rubber supplies fall short of demand during the 1990's.

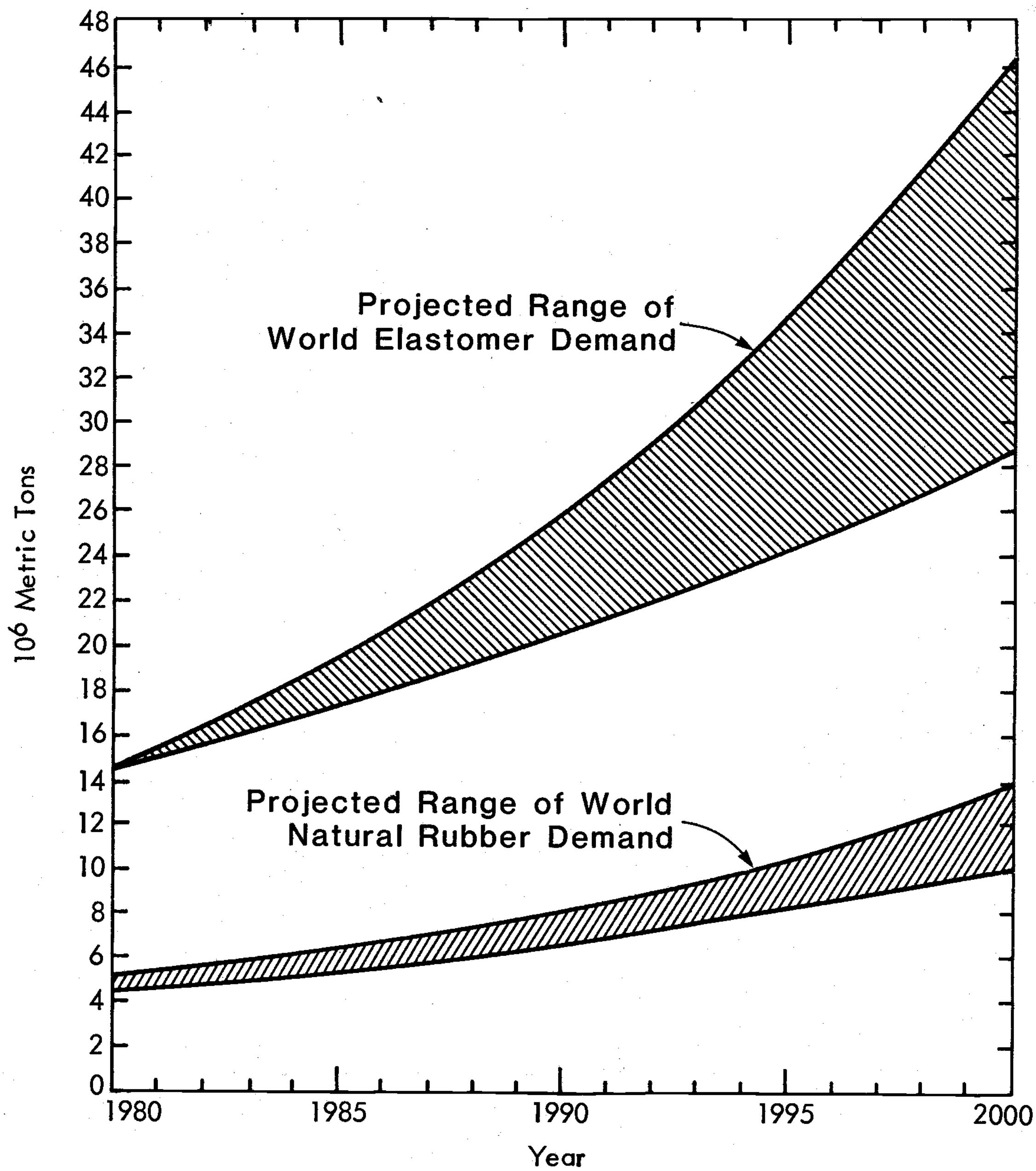


Figure II-5: SUMMARY OF TOTAL WORLD ELASTOMER DEMAND AND WORLD NATURAL RUBBER DEMAND PROJECTIONS

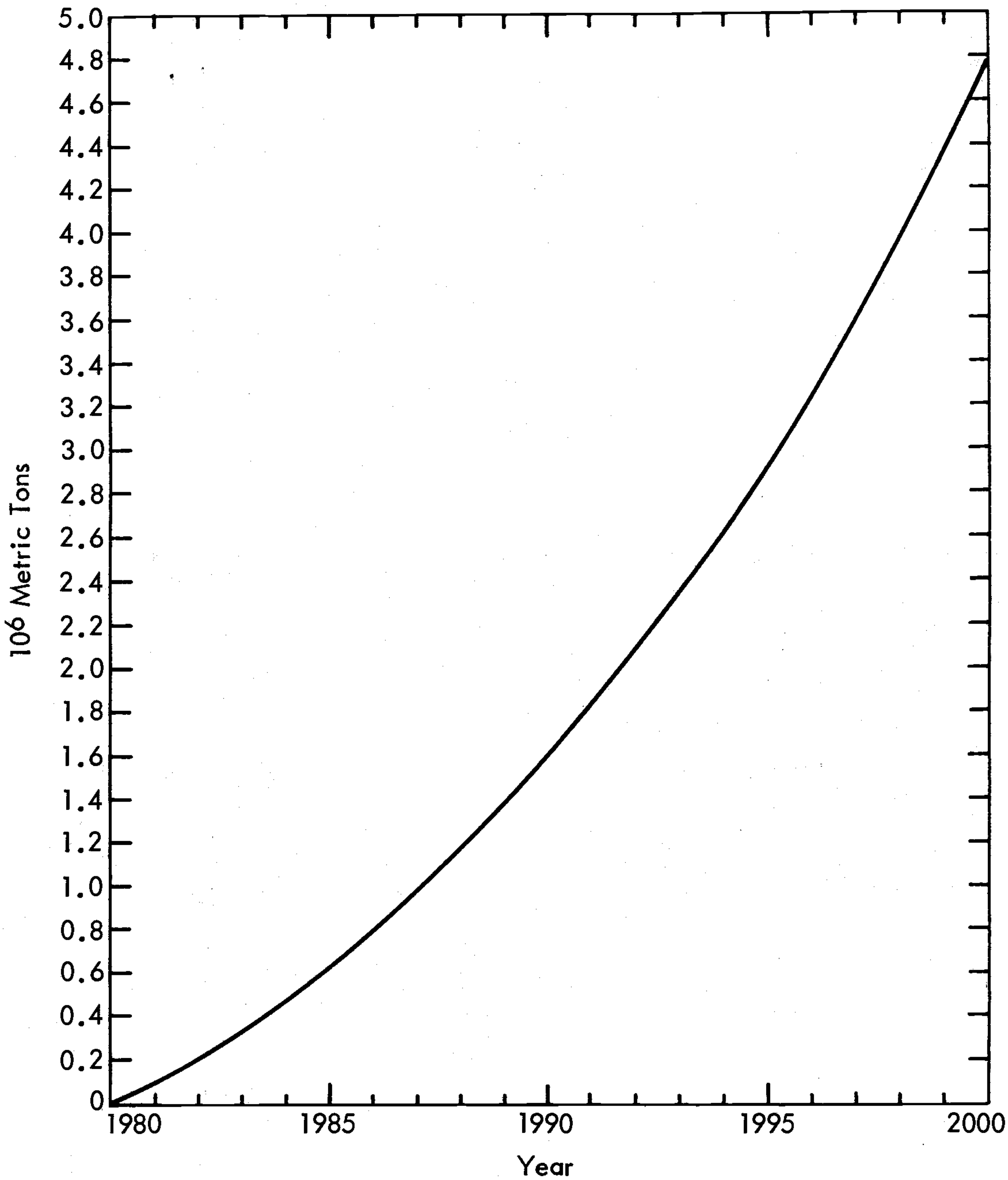
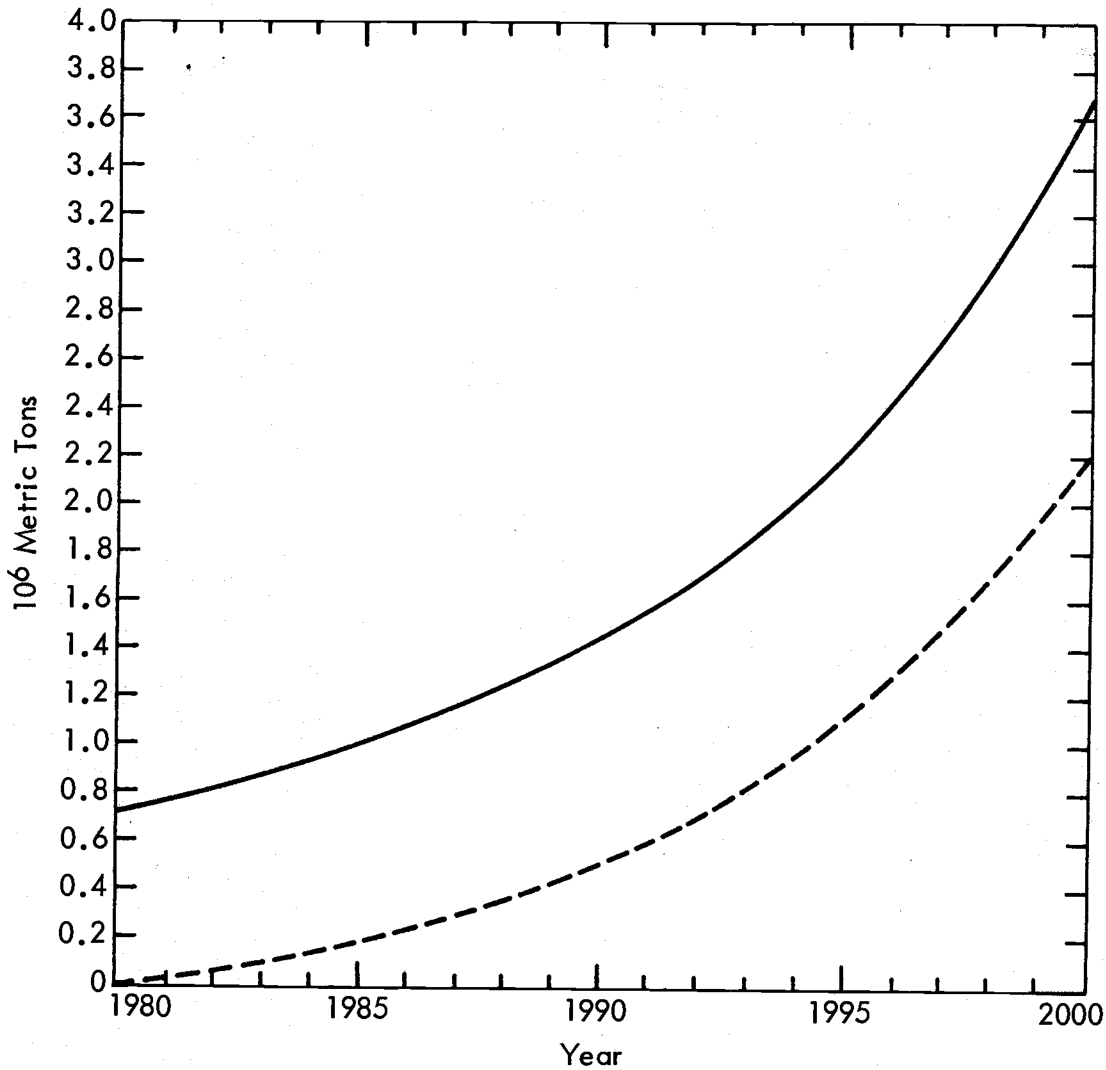


Figure II-6: THE POTENTIAL WORLD NATURAL RUBBER SHORTFALL ACCORDING TO THE HIGH-GROWTH SUPPLY-AND-DEMAND PROJECTION.



*The solid line represents the potential shortfall if natural rubber demand grows from 35% of total elastomer demand in 1980 to 40% of total elastomer demand in 2000. The dashed line represents the shortfall if natural rubber demand grows from 30% of total elastomer demand in 1980 to 35% of total elastomer demand in 2000.

Figure II-7: THE POTENTIAL WORLD NATURAL RUBBER SHORTFALL ACCORDING TO THE LOW-GROWTH SUPPLY-AND-DEMAND PROJECTION*

TABLE II-5. CONSENSUS AND TREND FORECASTS OF WORLD RUBBER CONSUMPTION COMPARED WITH THE RUBBER-DEMAND PROJECTIONS USED IN THIS STUDY[a/]

Year	Consensus Forecast for Rubber Consumption[b/] 10^6 Metric Tons	Low-Growth and High-Growth Rubber-Demand Projections Published by the Authors of this Study[c/] 10^6 Metric Tons	Rubber-Consumption Forecast Based on the 1962-1976 Trend[e/] 10^6 Metric Tons
1980	14.5	14.5[d/]	15.7
1985	18.5	17.2 - 19.4	21.3
1990	23.0	20.4 - 25.9	29.1

a/ Adapted from Allen (1978) and Hurley (1979).

b/ The forecasts consulted in compiling this consensus included projections made by the World Bank, the International Rubber Study Group, the International Institute of Synthetic Rubber Producers, and Predicasts Inc. (Allen, 1978).

c/ The underlined numbers represent the high-growth projections internally generated by the study team. These are the projections along with projections for 1991-2000 that are employed in subsequent assumptions necessary to the technology assessment.

d/ The low-growth and high-growth projections share the same 1980 starting point.

e/ As compiled by Allen (1978).

4. Projected U.S. Elastomer Demands Through 2000: Projecting the future of elastomer demand in the United States is complicated by international petroleum pricing and the energy crisis, the extent to which the U.S. public responds to the need for conservation of natural resources, and the U.S. economy. Nonetheless, an extrapolation to the year 2000 of U.S. elastomer demand based on a continuation of recent trends is presented in Figure II-8.

Several factors were taken into account to determine the starting point and the per annum growth rate for projected growth in U.S. elastomer demand between 1980 and 2000. The data for the 20 years preceding and including 1977 show that the average per annum increase in total elastomer consumption was 4.4 percent (IRSG, 1979; U.S. Department of Commerce, 1975). An annual demand of approximately 3.5 million metric tons can be forecast by extending this trend to 1980. However, a recent publication by the International Institute of Synthetic Rubber Producers, Inc., (IISRP) reports that member companies foresee a definite slowdown of the rubber-consumption increase rate (new rubber consumption) in the United States (Anonymous, 1979d). Pointing to a 1.3 percent decline in consumption in 1978, or total U.S. consumption of 3.24 million metric tons, and anticipating an additional 3 percent decline in 1979, or total U.S. consumption of 3.14 million metric tons, the IISRP suggests that consumption of new rubber in the United States is leveling off. The IISRP 10-year industry forecast through 1989 indicated an annual 2.3 percent gain in total demands for new rubber, with increases of 1.9 percent per annum in the tire sector and 3.1 percent in the non-tire sector.

According to the World Bank, the per annum growth of elastomer consumption in developed countries will average 4 percent between 1976 and 1990 (Grilli, et al, 1978). This projection is based on projections of motor vehicle park* and on automobile production during the 1980s. Because these statistics show that U.S. elastomer demands will be less than those of the other developed areas of the world, a percent-per-annum growth in elastomer demands of less than 4 percent is indicated for the United States.

The IISRP elastomer-demand-growth-rate estimate of 2.3 percent per annum and the World Bank estimate of 4 percent per annum through 1990 both suggest a significant decline from the average-growth rate of approximately 4.4 percent per annum during the last 20 years.

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* Motor vehicle park refers to the number of existing vehicles and is subdivided into two categories: Privately owned automobiles and commercially owned vehicles.

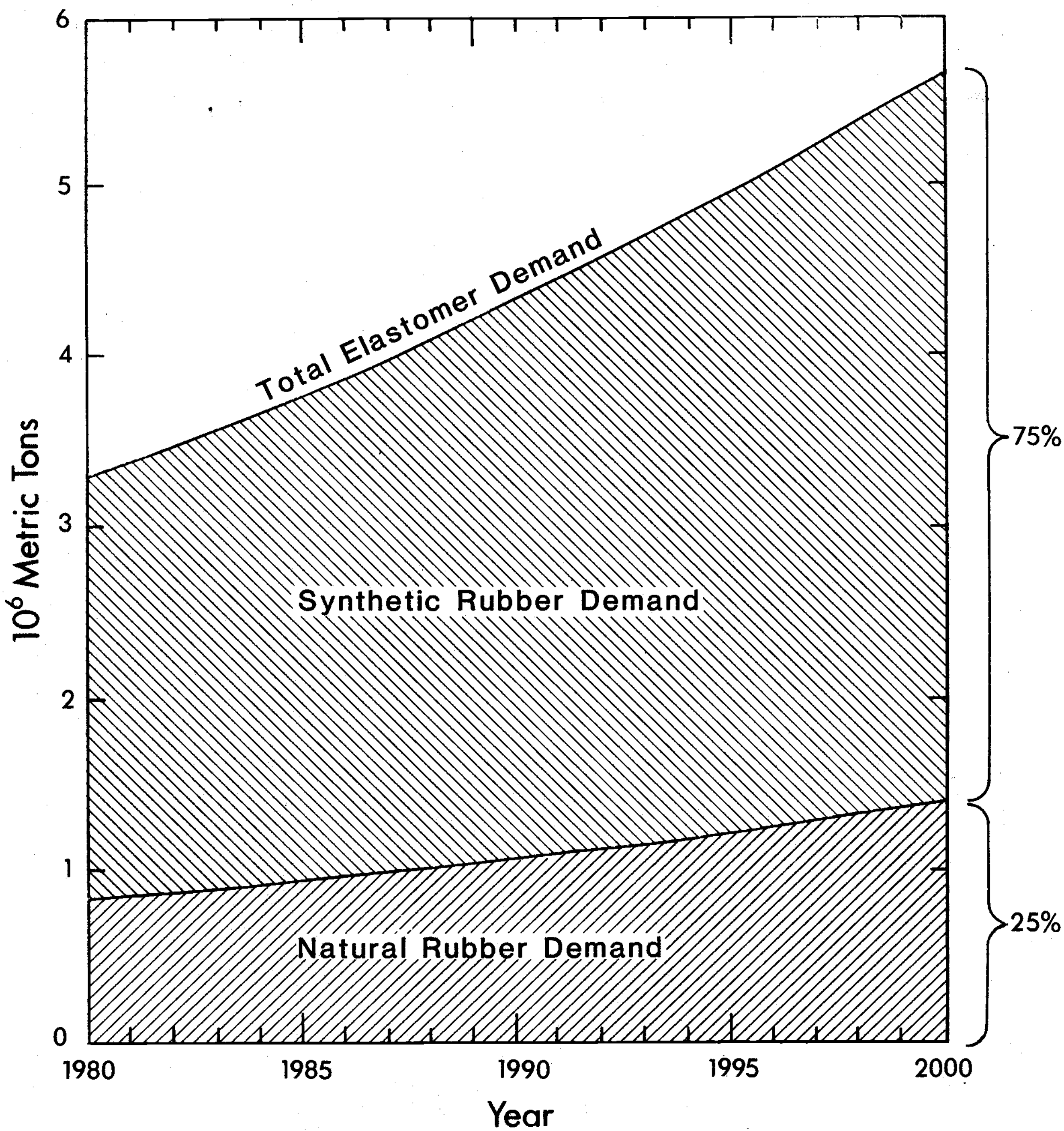

Figure II-8: PROJECTED U. S. ELASTOMER DEMAND, 1980 THROUGH 2000.

A compromise of IISRP and World Bank figures provided the data to construct Figure II-8. A total U.S. elastomer-demand growth rate of 2.8 percent per annum is assumed during 1980-2000. The 1980 consumption level is estimated to be 3.3 million metric tons.

C. Alternative Elastomer Markets

The alternative elastomer markets discussed in this section are based on predictions of changes in natural and synthetic rubber supplies and consumption patterns.

1. Changes in elastomer supply: Natural rubber is derived from various plant species native to tropical, semitropical and arid regions of the world. Synthetic rubber is derived from crude oil that is available in varying quantities from many regions of the world. Natural rubber plants, the future of rubber plantations in Brazil and Africa, alternative sources of crude oil, synthetic cis-1,4-polyisoprene, and coal-derived rubber feedstocks are the topics of this subsection.

a. Alternative sources of natural rubber: Natural rubber is obtained as latex, a milky, sticky fluid, from various plants and trees. Wild species of latex-producing plants and their native habitats include Hevea brasiliensis (Amazon River Basin), Manihot glaziovii (Central and South America), Castilloa elastica (Central America and Brazil) Ficus elastica (India, Burma, and Java), Landolphia spp (African Congo), and Parthenium argentatum (Mexico and Texas). Of these plants, Hevea brasiliensis has been cultivated with commercial success, principally in Malaysia, Indonesia and other parts of Southeast Asia. In the United States and Mexico, guayule (Parthenium argentatum) is potentially an important commercial source of natural rubber.

i. Hevea brasiliensis rubber tree, diseases and control: Early in this century, H. brasiliensis stands in South America were decimated by South American leaf blight, Dothidela. Crossbreeding of several types of high-productivity Hevea clones has not been particularly successful in developing trees resistant to Dothidella. Some trees resistant to leaf blight have been grown in Costa Rica, but they are of low productivity. Hevea brasiliensis trees in Southeast Asia also are susceptible to this disease.

Dothidella is controlled by sulfur, fungicides containing copper, or, more recently, by benomyl (Benlate TM), a carbamate fungicide. Benomyl is applied near ground level with an aerosol-fogging generator that projects fine droplets of the fungicide 50 to 70 feet to contact the leaves (Bonner, 1979a).

Another method of combating leaf blight involves grafting a disease-resistant crown to the trunk of a high-productivity Hevea brasiliensis clone. This technology is practiced in Malaysia and is effective in combating similar diseases.

Root diseases such as dry root rot and Fomes lignosus also are a threat. Young trees often are attacked by fungi. Decaying stumps may promote fungal-spore formation. Root diseases are controlled by application of pentachloronitrobenzene, a common soil fungicide.

ii. Prospects of increasing Hevea brasiliensis stands: A new strain of H. brasiliensis has been developed in South America that is immune to leaf blight. A new, immune crown is grafted when trees are about 10 feet tall, about one year after planting. The old, disease-susceptible crown is pruned after the graft is successful (Bonner, 1979a).

At present it is possible only to speculate about the possibility of re-establishing large stands of leaf- blight-immune H. brasiliensis in the Amazon River Basin. Whatever level of natural rubber development does occur in Brazil must be supported by the Brazilian government and must include credit and tax incentives, land and water allocations, skilled and semiskilled labor sources, and research and development. U.S. companies such as the Goodyear Tire and Rubber Company and the Firestone Tire and Rubber Company, and the Michelin Company of France can assist in this development, but the final decision, level of effort, and timing of events lies with the Brazilian government.

Present annual production of natural rubber in Brazil is estimated to be 45 million to 55 million pounds, or 0.6 percent of the world's total annual production of natural rubber. If Brazilian stands are to be of economic importance, supplying perhaps 10 percent of the world's annual needs for natural rubber, a massive and sustained development program of at least 10 to 15 years would be required. Such a program is not planned by the Brazilian government at this time (Klein, 1979).

iii. Other developments in rubber plantations by U.S. firms: The Firestone Tire and Rubber Company announced in early 1978 that it would increase its natural rubber operations by an additional 22,500 acres in Liberia and by 7,500 acres in Ghana. Total present holdings by Firestone amount to 130,000 acres in Africa, Brazil, the Philippines and Guatemala. These holdings will be expanded to 180,000 acres by 1992 (Anonymous, 1978a). Goodyear Tire and Rubber Company recently expanded its rubber-growing capacity near Belem, Brazil, and is acquiring an 11,000-acre plantation in Sumatra.

b. Alternative sources of synthetic rubber: The availability of additional sources of oil from Alaska and Mexico and the availability and use of synthetic cis-1, 4-polyisoprene are discussed in this section.

i. Oil from Alaska: In mid 1977 the port of Valdez, Alaska, began receiving North Slope crude oil from fields near Prudhoe Bay via the trans-Alaskan pipeline. By the end of 1977, oil flow was 1.2 million barrels per day. Tankers transport 70 percent of the crude oil to the U.S. West Coast and 30 percent to the Gulf Coast for refining and distribution. The result has been an oil glut on the West Coast and a continuing threat of severe oil shortages in the Midwest.

Alaskan oil, characterized as "sour and heavy," contains a relatively high sulfur content (1.04 percent by weight) and has a relatively high specific gravity (26.8 API or specific gravity 0.893) (Weismantel, 1977). Because North Slope crude oil is high in sulfur, refineries must be equipped with desulfurization units to comply with emmission standards for oxides of sulfur, hydrogen sulfide and other noxious components, as required by the Clean Air Act.

Principal West Coast refineries able to process sour oil are in Cherry Point, Washington, and the San Francisco Bay and Los Angeles- Long Beach regions in California. Approximately 30 percent of North Slope crude oil must be shipped to Houston refineries for processing and distribution to the Midwest via pipeline.

At present, Alaskan oil is not available to the Japanese who continue to buy oil from the Arabian Gulf region. Trade negotiations are under way in Congress to sell up to 100,000 barrels of Alaskan oil per day to Japan. In turn, the United States would buy an equal quantity from Mexico that would then be shipped to the Gulf Coast for refining and distribution. An estimated net savings of $2.00 per barrel in transportation costs would accrue to the United States in this exchange (Jenny, 1979).

ii. <u>Oil from Mexico</u>: President Carter met with President Jose Lopez Portillo in mid February 1979 in Mexico City to discuss mutual economic and social problems. At stake was the potential role that Mexican oil and gas could play in meeting American energy needs, and in meeting Mexican goals of economic growth and development and the social needs of Mexican people. Estimates of proven reserves of oil and gas in the southeastern state of Tabasco and in the Gulf of Mexico have ranged from 20 billion to 40 billion barrels, and potential reserves have been estimated to be more than 200 billion barrels. Present production is near 1.5 million barrels per day. According to Pemex, the Mexican government oil and gas monopoly, production is expected to rise to 2.5 million barrels per day (1980). The United States imports approximately 9.1 million barrels per day, and, in principle, Mexico could supply approximately 10 percent of this amount. According to energy experts, Mexican oil and gas could delay the projected shortfall in U.S. crude oil supply from the late 1980s to the early 1990s.

President Carter's trip in mid-February 1979 did not produce a trade agreement. However, by October 1979, as the result of a second meeting between the two presidents in Washington, D.C., Mexico and the United States formally agreed to begin negotiations concerning both oil and immigration. The United States agreed to purchase 300 million cubic feet (mcf) of natural gas per day at $3.625/mcf and has signed scientific and technological agreements to help improve housing and agriculture in Mexico. Although both nations have much to gain from negotiation and cooperation, Mexico's role in supplying U.S. needs for crude oil and gas and the resulting effects on the U.S. synthetic rubber industry are not clear.

The total U.S. demand for rubber presently relies upon natural hevea rubber and crude oil. If these are in short supply for any reason, the case for commercialization of domestic guayule rubber is strengthened.

The flow of oil from Alaska could be increased from 1.2 million barrels to as much as 1.6 million barrels per day, according to experts. At the higher flow rates, the proven Alaskan oil reserves of 9 billion barrels would last only until 1995-2000 (Jenny, 1979). The United States is expected to continue to depend primarily on oil imports from the Arabian Gulf region unless supplies are limited. The U.S. petroleum-based synthetic rubber industry, including manufacture of synthetic cis-1, 4-polyisoprene, remains vulnerable to changing international political, social and economic conditions.

iii. <u>Synthetic cis-1, 4-polyisoprene (polyisoprene)</u>: Synthetic cis-1, 4-polyisoprene* has nearly the same composition as hevea rubber but may differ in average molecular weight, molecular weight distribution, degree of crystallinity, gel content, non-rubber content and cure properties. It is produced by solution polymerization of isoprene or 2-methyl-1, 3-butadiene, using stereospecific catalysts.** Isoprene is obtained from crude oil under severe cracking conditions. Domestic consumption of polyisoprene in the late 1970s was approximately 150 million to 160 million pounds annually.

Historically, the economics of domestic cis-1, 4-polyisoprene production have been unfavorable as compared with hevea rubber importation. Anderson (1979), however, has estimated that domestic polyisoprene should become economically competitive as hevea rubber prices reach $0.60 per pound. By the end of 1979, the price of hevea rubber surpassed $0.70 per pound. Currently, the only domestic producer of polyisoprene is Goodyear Tire and Rubber Company at Beaumont, Texas. B.F. Goodrich Chemical Company has placed its polyisoprene plant at Orange, Texas, in "mothballs." This facility should be fairly easily reactivated when the price of polyisoprene warrants increased domestic production.

Foreign sources of polyisoprene include Canada, France, Italy, the Netherlands, Rumania, the Soviet Union and Japan. World annual production capacity of cis-1, 4-polyisoprene; trans-1, 4-polyisoprene; and other 1, 2- and 3, 4- enchained polymers is nearly 1.6 billion pounds. The countries that have centrally planned economies that are developing cis-1, 4-polyisoprene plants in efforts to become

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* Other polyisoprenes include trans-1,4- and 1,2- and 3,4- enchained polymers.

** Catalysts include butyl lithium and Ziegler-Natta types such as titanium tetrachloride with butyl aluminum.

independent from imported hevea rubber include Bulgaria, Czechoslovakia, Poland and the Soviet Union.

iv. Rubber feedstocks from coal: In the near future (1990), coal may provide chemical feedstocks for the synthetic rubber industry. Until the recent oil price hikes, those processes under research and development were not economically feasible. Yet, coal-based technologies can provide a constant source of chemical feedstocks, distillates, gasolines, oils etc., as they did before World War II.

President Carter's "energy speeches" during July 1979 called for establishment of an Energy Security Corporation, a government body to manage $88 billion for research and development programs. The goal of the Corporation would be to make available synthetic fuels (synfuels) from domestic coal- and oil-shale reserves in sufficient quantities to replace 2.5 million bbl/day of imported oil. By the end of 1979, the President's energy plan had not been enacted. Controversy that arose from a proposed "windfall tax" on oil company profits to finance the plan has delayed Congress in drafting the appropriate legislation.

Synfuels, including chemical feedstocks, can be made from coal by gasification and application of the Fischer-Tropsch process. Gasification, a highly endothermic process, converts coal, oxygen and steam into a mixture of hydrogen gas and carbon monoxide, and small amounts of carbon dioxide and methane gas. The hot gaseous mixture is passed over an iron or cobalt catalyst to yield various hydrocarbons that can serve as bases for chemical feedstocks.

The Fischer-Tropsch process has not been economical to date. The SASOL-1 plant in Sasolsburg, South Africa, produces gasoline, diesel oil, solvents and chemicals from non-coking, high ash, bituminous coal. The costs of producing these synfuels and chemicals are underwritten mostly by the South African government for national security reasons.

A second method of obtaining synfuels and chemicals from coal involves dissolution of coal followed by catalytic treatment with hydrogen gas. Various research and development programs sponsored by the Department of Energy (DOE), industries, and the Electric Power Research Institute (EPRI) include such processes as SCR-I, -II, H-coal, HYGAS etc. Efficient catalytic systems (e.g., tin and zinc halides) will be important in reducing operating temperatures and pressures to make these processes economical.

2. Changes in elastomer demand: The following factors have affected recent trends in U.S. natural rubber consumption: changes in automotive design, changes in flammability standards for automotive upholstery, changes in automobile tire size, changes in consumer driving habits, and changes in general rubber consumption as reflected by the Gross National Product (GNP). Each of these factors is described briefly.

Changes in automotive design can have powerful impacts on natural rubber consumption. Anti-impact bumpers are being manufactured by the Ford Motor Company. The bumpers require approximately 20 million pounds of natural rubber annually (Lindley, 1970). On the other hand, the continued use of natural rubber for engine mounts is in jeopardy, due to increased engine operating temperatures, but estimated market loss is small, approximately 2 million pounds of natural rubber annually.

Changes in flammability standards for automotive upholstery, as promulgated by the Department of Transportation, have generated an increase in the use of natural rubber as backing material for fabric.

Changes in automobile-tire sizes, highway legal speed limits of 55 mph and driving habits have slowed growth in the tire market. Tire sizes have become smaller with the growth in sales of compact and subcompact cars. As the price of gasoline continues to rise, consumers may opt to drive less, thus, reducing tire wear and replacement rates.

Real U.S. GNP growth rates of 3 percent to 5 percent are forecast for the near future. It is expected that increases in natural rubber use by the industrial sector will be approximately equal to that of real GNP growth.

U.S. consumption of natural and synthetic rubber will increase during the next 10 years, but when compared with the last 10 years the growth rate will slow. Table II-6 lists major natural- and synthetic-rubber-end-use demands in the United States and Canada, beginning in 1965 and forecast to 1990 by the World Bank (Grilli, et al, 1978). Use of elastomers for tires is expected to double from 1965 to 1990. But the growth rate probably will fall from 4.1 percent to 1.9 percent per year. Non-tire uses are expected to triple by 1990 as compared with 1965 data. The total elastomer demand is forecast to increase from 2.2 million metric tons in 1965 to 5.3 million metric tons in 1990. The five-year-average elastomer-demand growth rates for this period vary from 3.1 percent to 3.9 percent per year. Based on World Bank projections, the future supply of both natural and synthetic rubber may not meet the demand of new technology and growing industrial and consumer markets in the United States.

D. New Elastomer Technologies:

New elastomer technologies, including new rubber-tire technology, elastomer reclamation, and recent competitors with natural rubber, are discussed in this section.

1. New rubber tire technology: Perfection and mass production of a cast tire would affect the demand for natural rubber. Research and development are underway to develop a cast tire. Two manufacturers have announced tests of experimental cast tires. LIM-Holding S.A.,

TABLE II-6

ELASTOMER DEMAND IN THE UNITED STATES AND CANADA BY MAJOR END-USES

	1,000 Metric Tons						Percent Per Annum				
	Estimated			Projected			Growth Rates				
	1965	1970	1974-76	1980	1985	1990	1965-70	1970-75	1975-80	1980-85	1985-90
Tire Uses											
Original equipment tires	393.0	380.0	482.0	555.0	640.0	720.0	- 0.7	4.9	2.9	2.9	2.4
Automobile a/	243.0	198.0	251.0	280.0	310.0	340.0	- 4.0	4.9	2.2	2.1	1.9
Commercial vechicle b/	150.0	192.0	231.0	275.0	330.0	380.0	5.1	3.8	3.6	3.7	2.9
Replacement tires	743.0	1,092.0	1,166.5	1,405.0	1,550.0	1,670.0	8.3	1.3	3.8	2.0	1.5
Automobile a/	452.0	704.0	708.5	795.0	820.0	850.0	9.2	0.2	2.3	0.6	0.7
Commercial vehicle b/	282.0	391.0	458.0	610.0	730.0	820.0	6.8	3.2	5.9	3.7	2.4
Other tires c/	90.5	119.0	136.0	165.0	200.0	240.0	5.6	2.7	3.9	3.9	3.7
Exports of tires	26.5	20.5	53.0	42.0	51.0	60.0	- 5.0	21.0	- 4.6	4.0	3.3
Automobile	10.3	8.3	32.0	15.0	18.0	20.0	- 4.2	31.0	- 14.2	3.7	3.2
Commercial vehicle	12.0	7.0	15.0	20.0	25.0	30.0	-10.2	16.5	5.9	4.6	3.7
All others	4.2	5.2	6.0	7.0	8.0	10.0	4.4	2.9	3.1	2.7	4.6
Other tire uses	183.0	136.0	114.0	91.0	85.0	80.0	- 5.7	- 3.5	- 4.4	- 1.4	1.2
Subtotal	1,427.0	1,747.5	1.951.0	2.258.0	2.526.0	2,770.0	4.1	2.2	3.0	2.3	1.9
Non-Tire Uses											
Subtotal	801.0	955.0	1,229.5	1,600.0	2,000.0	2,500.0	3.6	5.2	5.4	4.6	4.6
Total											
Demand	2,228.0	2,702.5	3,180.5	3,858.0	4,576.0	5,270.0	3.9	3.9	3.9	3.2	3.1

Source: The World Rubber Economy: Structure, Changes, Prospects. The World Bank, Washington, D.C. June 1978, p. 119.

a/ Including snow tires.
b/ Including light trucks.
c/ Farm, aircraft and industrial tires.

Luxembourg, has developed a polyair cast tire, and Phoenix Gummiwerke, Germany, has developed a steel-belted, polyurethane, non-pneumatic cast tire (Scroggy, 1979; Norbye and Scroggy, 1978).

Conventional tires are manufactured by layering different materials such as fabrics, steel belts and rubber together in a relatively labor-intensive process to form a tire. Manufacture of cast tires involves injecting a liquid raw material into a tire mold and is much less labor-intensive. The manufacture of cast tires is expected to require less hydrocarbon materials and energy than conventional tires. One source estimates that 7 gallons of crude oil are used to produce a conventional rubber tire as compared with 1 gallon of crude oil needed for a cast tire (Scroggy, 1979). Plastic cast tires easily could be recycled to reduce further raw material demands. Widespread use of pourable, synthetic liquid rubber or plastic to prepare a cordless cast tire could cause a significant reduction in the amount of natural and synthetic rubber currently used in tire building (Alliger, et al., 1971).

Plastic cast tires have three other potential advantages. Cast tires have much longer life and 10 percent less rolling resistance than conventional radial tires, and are able to be run while flat (Anonymous, 1978b). Despite potential advantages, experimental cast tires have not yet equaled the performance of conventional tires. Cast tires experience heat buildup and have a tendency to become out-of-round. The low coefficient of friction that helps lower rolling resistance hinders effective acceleration and braking. In spite of the announcement in 1971 by the Firestone Tire and Rubber Company of the development of a low-cost, cordless cast tire, it is not yet commercially available.

In the immediate future, the market for cast tires probably will be limited to tires for small to medium size equipment, including lawn, garden and farm implements, golf carts, and forklift trucks, none of which require the high-performance characteristics of radial tires such as excellent cornering and handling ability, and effective acceleration and braking (Klein, 1979).

2. Elastomer reclamation: Reclaimed rubber has provided some reusable rubber and carbon black in the past, and much future potential exists for increased production of both from reclaimed rubber. Interest in elastomer reclamation has increased recently as the prices of raw materials to produce both natural and synthetic rubber have increased. New concepts are being developed and tested to reclaim the two major sources of scrap rubber, manufacturers' rubber scrap and used tires. Manufacturers' rubber scrap is the trimmings, sprues and waste created during the manufacture of general rubber goods. It is estimated that at least 200 million pounds of scrap rubber are generated annually (Frable, 1976).

The two methods of reclaiming rubber are devulcanization and recycling of ground rubber. Devulcanization is a mechanical and chemical reduction of rubber to its original state. This material then is blended with virgin raw materials for reuse. Since devulcanized rubber loses some of its original properties, it can be substituted for raw elastomer materials only at a 5 percent level. Recycling ground rubber requires grinding scrap into particles as small as possible and blending the particles with virgin rubber. In the past, ground rubber affected the surface appearance and physical properties of the final rubber product, and thus was limited in use. A new process has been developed that grinds scrap into small enough particles that even when added at levels of 30 percent, it will not affect rubber-product appearance and properties (Anonymous, 1977; Frable, 1976).

Several problems are associated with the reclamation. Tires may contain fiberglass or steel that must be separated from the rubber. Used reclaimable tires are widely dispersed and collection can be costly. Nonetheless, tires are being reclaimed on a small scale. Several companies are reclaiming carbon black from tires for use in new tire manufacture. Carbon black is being recovered at rates of 30 percent to 50 percent. These rates make recovery economical. In this process, rubber is not recovered from tires but is being burned as fuel. The resulting ash is converted to carbon black. A process to separate the rubber component from tires and grind it for reuse reportedly is under development. This process has great potential if proven feasible; approximately 200 million tires, which contain 8 billion pounds of rubber, are discarded annually in the United States.

The present contribution of scrap rubber to the total rubber supply probably is limited to reclamation of ground, manufacturers' scrap. This technique seems feasible and economical. Several companies are using this approach to reclaim rubber. Reclamation of tires currently produces only carbon black and fuel, but a breakthrough in reclamation of tire rubber would make available a significant contribution to meeting rubber demands.

The DOE announced new goals for use of recycled rubber as part of the voluntary Recycling Targets subsection of the National Energy Conservation Act of 1978 (Anonymous, 1979e). By the end of 1987, tires, inner tubes, and other industrial rubber materials should contain 5 percent reclaimed rubber; tire retreading and repairing industries should be using up to 12 percent reclaimed rubber; and rubber footwear should contain up to 15 percent reclaimed rubber. None of these goals were being met in 1979.

Reclaimed rubber undoubtedly will be useful in such applications as shock absorbers, bridge supports and footwear. It is doubtful that much reclaimed rubber will be used in high-performance tires, although off-road vehicle tires may be good candidates for use of reclaimed rubber. Life support and other medical systems probably will continue to require use of virgin natural and synthetic rubbers.

3. Competitors for The Natural Rubber Market: Recent competitors of the natural rubber market include new kinds of elastomers, new elastomer technology that would decrease the overall consumption of rubber, the general replacement of natural rubber by plastics and the utilization of leather goods. New elastomers include polypentenamer (Bayer AG Farben-frabriken, West Germany), polypropylene oxide, and butadiene copolymer with propylene. Industry representatives support the view that such new elastomers will not be serious threats to natural rubber markets in the near future due to non-competitive production costs. Established substitutes for natural rubber include silicone elastomers, rigid, semirigid and flexible plastics, and leather goods.

Silicone elastomers are derived from crude oil. They offer little or no physical or economic advantages over natural or synthetic rubber. Silicone elastomers are approximately six times more expensive than rubber. Plastics, also derived from crude oil and coal, continue to replace rubber when the product does not require the full range of natural rubber attributes. Examples include, polyvinyl chloride in flooring products, footwear, cables, and garden hoses; polyurethanes/ polyethers in footwear, foams, threads, mattresses and cushions; and thermoplastic rubbers that possess rubber properties at normal temperatures but are processed as plastics at compounding temperatures. The principal uses of thermoplastic rubber are in adhesives, plastic, modifiers, footwear and sheeting (Mawer, 1972). These materials are about twice as expensive as natural rubber.

The U.S. leather-goods industry depends primarily on domestic beef and dairy cattle, horses and calves for hides. Raw and finished leather also is imported. Cattle hides are used in manufacturing shoe soles, belting, upholstery and harness, and in industrial applications. The leather-goods industry also uses hides from sheep, pigs, goats, seals, ostriches, reptiles and sharks. It is not realistic to expect that leather goods could displace any significant portion of the natural and synthetic rubber market.

Future competition in the natural rubber marketplace undoubtedly will include other elastomers and plastics that offer fabricating and compounding advantages. These include thermoplastics and powdered, pourable and castable rubber materials. Tires and industrial belting will continue to be the principal markets for natural rubber.

III. GUALYULE RUBBER TECHNOLOGY: A STATE-OF-THE-ART OVERVIEW

A condensation of the agricultural and industrial aspects of guayule technology is presented in this chapter. Phase II of the Technology Assessment included an in depth, state-of-the-art review of guayule. It was published in April 1979 as A Sociotechnical Survey of Guayule Rubber Commercialization: A State-of-the-Art Report. This chapter presents only the most pertinent findings included in the review. Readers who seek more detailed information about the various aspects of guayule agricultural and industrial technology are referred to that state-of-the-art report.

A. Climatic and Agricultural Conditions

The climatic conditions of the region in which guayule occurs naturally as well as the relationship between guayule growth and soils are discussed in this section.

1. Relation to climate: The distribution of natural guayule stands in the United States and Mexico is shown in Figure III-1. Guayule is native to an arid/semiarid region wherein it grows on outwash fans and foothill slopes. Climatic effects on guayule in its native range are discussed by Bullard (1946a). Bullard's discussion of these effects may help explain the importance of climate as a factor in commercial guayule production.

Mean annual precipitation in areas that have native guayule growth varies from 8 inches to 15 inches, with recorded highs of 25 inches. Rainless periods of four months are common. Dry periods of up to seven months have been recorded. Precipitation generally is biseasonal and peaks during spring and fall. In some areas, however, most of the precipitation occurs during summer and fall, with little occurring during winter and spring.

Although guayule grows in its native habitat with 8 inches to 15 inches of precipitation, runoff and percolation from higher elevations can increase effective moisture available to shrubs by as much as 50 percent. However, guayule grows slowly in its native habitat. More moisture is required for commercial production because biomass tonnage must be produced quickly to be economically feasible. Guayule roots extend to depths of 20 feet or more below the soil surface and could deplete soil moisture nearly to that depth. Fifteen inches of annual precipitation is considered the minimum requirement for good dryland

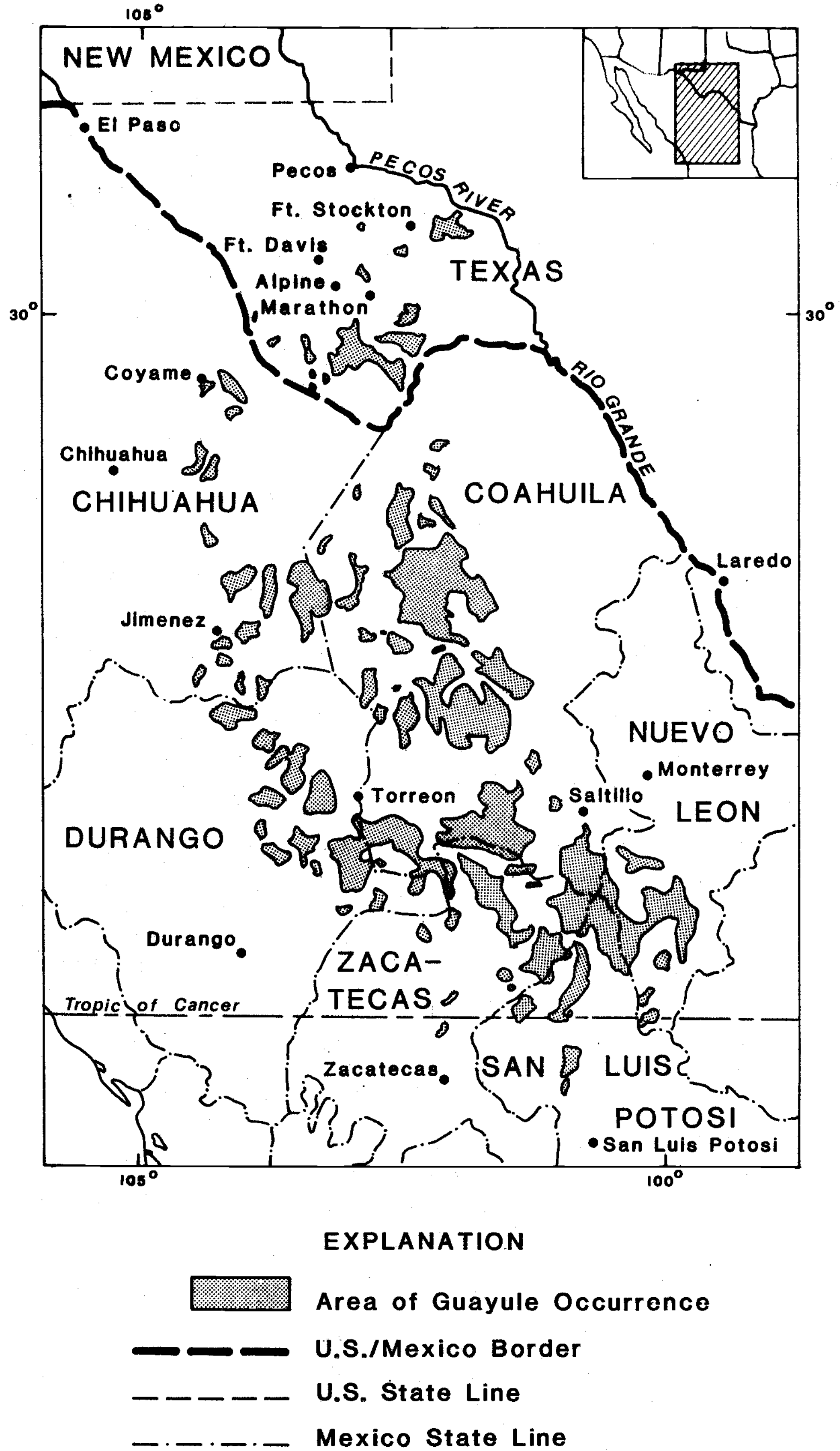

Figure III-1: DISTRIBUTION OF NATIVE GUAYULE IN MEXICO AND TEXAS. (Source: National Academy of Sciences, 1977) guayule culture. Twenty inches of precipitation probably is better for good rubber yields. Twenty-five inches or more of precipitation is unsatisfactory, expecially if it is distributed more or less equally throughout the year and not interrupted by periodic drought.

Rainfall distribution considerably influences guayule production. An ideal climate within which to cultivate guayule should have rainy periods during late winter and spring, and early summer. The last half of the summer-fall growing season should be dry.

Seasonal and diurnal temperature variations are fairly broad in those regions where guayule grows naturally. Maxima of 115 F and minima of 5 F have been recorded. However, the climate is relatively moderate and no cold season exists in most of the region. The warm season also is the wet season, but cloudiness tends to reduce temperatures. Winter and early spring are drier and sunnier so that guayule on slopes often is not exposed to extreme cold. Dry winds occur during the winter, but during the growing season humidity is rather high.

2. Relation to soils: Guayule is very sensitive to soil conditions. Soil is the dominant factor in guayule rubber production because of its relation to moisture control, and because it has considerable influence on shrub growth. The shrub varies in size, weight and rubber content according to minor changes in the retention and availability of moisture in the soil (Retzer and Mogen, 1945).

Soil moisture availability varies with soil texture. Guayule requires permeable, well-drained, well-aerated soils with a reasonably good supply of soil moisture most of the year for best growth. Unsatisfactory growth and rubber yields result when soil conditions make moisture easily available for short periods followed rapidly by extremely dry periods. However, when available moisture is reduced slowly and the shrub has time to "prepare" for the dry, dormant period, a xeric-type leaf develops and rubber deposition shows marked increases.

Soil moisture also is important in relation to disease. Attacks by various fungi usually coincide with excessive moisture, especially on heavier soils with slow drainage. Also, cold injury is related inversely to the available soil moisture and the growth activity of the plant. Dormant plants on some test plots in Texas withstood temperatures of 1 F to 4 F without appreciable injury, but on other plots considerable damage occurred to guayule plants when temperatures of 14 F and 15 F occurred (Bullard, 1946c).

Soil salt content is another significant factor in guayule growth rates. Guayule tolerates up to 0.3 percent salt anywhere in the soil profile, but salt content from 0.3 percent to 0.6 percent in the upper 2 feet of soils greatly retards growth. More than 0.6 percent salt in the surface soil kills the plant (Bullard, 1946c).

B. Guayule Plant Modification and Manipulation

Advances made to date in guayule genetic plant breeding and bioregulation research are presented in this section.

1. Rubber formation: Rubber in guayule exists as a colloidal suspension, or latex, that is confined to individual cells. No organized latex canals exist as in Hevea. Plants older than one year generally carry most rubber in the cortex and vascular rays of phloem and xylem. Small quantities of rubber occur in the primary cortex, pith, xylem parenchyma and epithelial cells of resin canals. Very small amounts of rubber occur in the leaf parenchyma (Lloyd, 1911).

Branches constitute approximately two-thirds of the defoliate plant dry weight and contain more than two-thirds of all rubber in the plant, branches having a higher rubber concentration than either roots or crowns. The whole plant bark contains 75 percent to 80 percent of the total rubber.

The function of rubber in guayule plants is not known. Rubber is not a storage product that the plant can draw on for nutrition, does not help resist drought, nor does it seem to have any protective value against browsing because the plant is eaten by both wild and domestic animals (Benedict, 1949).

The resin canals occur in well-defined systems throughout the plant but are principally in the bark where they are distributed rather uniformly. The resins include essential oils, parthenyl cinnamate and partheniol, betaine, fatty acids, an unidentified wax and other chemical constituents. Resin concentration in guayule bark, green stems and roots varies from approximately 7 percent to 10 percent of dry weight.

2. Reproduction and genetics: Many aspects of guayule rubber production and plant improvement to some degree are controlled genetically. The genetic makeup of a specific plant determines potential rubber and resin content, disease resistance, ease of defoliation and cold and drought tolerance. The rate and amount of growth and rubber production are determined by the interactions of genetic factors and environmental conditions.

Genetic characteristics are amenable to improvement. Guayule's unique and versatile reproductive charactristics simplify plant breeding and assure a more rapid rate of success than could be achieved with most other plants (National Academy of Sciences, 1977).

Guayule plants initiate seed formation in several ways. In some groups the female reproductive cell is fertilized in the usual way by the male, or pollen, gamete. Both male and female nuclei carry genes that transmit characteristics to the offspring. In other groups the pollen only stimulates the female cell without actually fertilizing it. This apomixis in guayule was discovered during World War II studies by Powers and Rollins (1945) and others.

In obligate apomictic reproduction, unlike sexual reproduction, the seed is developed through a multiplication of the unfertilized female cell. Progeny from such a seed inherit the characteristics of the mother plant only. In facultatively apomictic reproduction some of the progeny will show characteristics of both parents.

Inheritance of apomictic lines and the mechanisms whereby plants can be opened to cross-fertilization have been the subject of much research. Results of breeding studies indicate that certain strains are only facultatively apomictic and that it is possible to develop strains that will cross even when apomixis predominates. As a result it is possible to open plants for breeding and then close them so that they become fully apomictic (Rollins, 1979). A hybrid can be fixed by using this method so that it will be uniform from the first generation onward. The long process of plant selection to obtain true breeding hybrid lines is avoided by employing this methodology.

Guayule plants have chromosome numbers ranging from 2n=36 to 2n=108. A 144-chromosome plant has been produced through controlled breeding. Principal guayule strains used in commercial production during World War II and earlier were from 72-chromosome groups. Mariola (Parthenium incanum) plants with 72 chromosomes closely parallel 72-chromosome guayule reproductive behavior.

3. Plant breeding studies: Commercial guayule variety 593 was developed by the Intercontinental Rubber Company. It was the standard by which new strains and hybrids developed by Emergency Rubber Project (ERP) personnel were compared. It appeared to be the best overall variety for cultivation. Most ERP plantings, therefore consisted of this strain. Among the several hundred seeds collected by Powers in 1942, one group from Durango, Mexico, identified as 4265, produced plants that appeared to be superior to 593 plants in rubber yield. This strain however, was extremely variable because it reproduced sexually.

A number of guayule breeding and genetics discoveries were made during ERP studies conducted from 1942 to 1946. A significant finding was that interspecific crosses could be made between guayule (P. argentatum) and P. incanum, P. tomentosum, var. stramonium, P. tomentosum and P. hysterophorus.

Interspecific hybrids developed by crossing P. tomentosum var. stramonium and guayule were tested in Texas and California. Those tested in Texas were highly resistant to charcoal rot, a disease caused by Sclerotium bataticola Taub that is prevalent in that state. The hybrids tested had lower rubber-percent yields than the high-rubber- yielding strains of pure guayule, but some yielded more than the commercial variety 593 because they produced more biomass.

Lower rubber percentage in vigorously growing hybrids would increase the cost of milling the shrub (Hammond and Polhamus, 1965).

Guayule breeding research was conducted by the USDA Natural Rubber Research Project (NRRP) at Salinas, California, from 1948 to 1959. Seeds collected in Mexico by Hammond in 1948 were planted at Salinas during winter 1948-49. Some seedlings from these plantings were transplanted later in Texas. Several outstanding plant selections were made from these plantings.

When the NRRP was discontinued in 1959, enough seeds from the 25 highest rubber-yield lines to meet possible future research needs were sent to the National Seed Storage Laboratory at Fort Collins, Colorado. The rest were stored in airtight, metal drums and later declared government surplus to be given away, sold or discarded. A California company acquired much of this seed stockpile, the only large quantities of seed known to have been salvaged from either the ERP or NRRP breeding programs.

Guayule plant breeding research was reinstituted in the mid-1970s in California, Arizona, New Mexico and Texas utilizing Fort Collins seed and additional material collected in Mexico and Texas.

4. Future guayule breeding studies: Guayule breeding research still is in its embryonic stages. Findings of the NRRP postwar breeding program indicated that yields could be expected at least to double those of the standard 593 strain used by the ERP during World War II. Some researchers predict strain 593 rubber yields can be quadrupled by cross-breeding with strains that yield a high proportion of rubber, strains that develop rubber more rapidly and strains that produce bigger plants. Research on hybridizing guayule with larger *Parthenium* spp was very active and promising when all guayule research was abandoned in 1959. Some hybrids that were developed are seven times larger than guayule and some contain some rubber (National Academy of Sciences, 1977).

Some plant breeders believe it will take five to 10 years to develop good guayule varieties that have about 20 percent rubber content and that could be recommended for cultivation in various growing areas. Other plant breeders believe that genetic material presently available will produce plants that yield 20 percent rubber under favorable cultural practices and that commercial production could begin as soon as seed is available.

5. Bioregulation: Another approach to improve agricultural crop yields has emerged from studies on bioregulation of plant constituents. This concept is based on the discovery of bioregulators that appear to depress specific genes thereby inducing production of additional quantities of certain constituents. Genes basically determine plant enzymic potential. It is within this potential that bioregulators exert influence. The concept of bioregulation and its relationship to plant biochemical systems readily could complement plant breeders' work and could become a fertile research area. Plant constituent bioregulation

could improve certain features of cultivars not achieved readily through breeding. Bioregulation could reduce development time for new cultivars or allow use of crosses with broader genetic bases (Yokoyama, et al, 1977). Preliminary studies indicate that bioregulators stimulate rubber accumulation in guayule. Increases of rubber yields ranged from 220 percent to 600 percent when young guayule plants were treated with 2-(3,4-dichlorophenoxy) triethylamine under laboratory conditions.

In personal communication, Dr. Yokoyama (1978) stated: "From strictly biochemical considerations, without taking into account the stresses, penetration and other relevant factors, bioregulatory treatment should work equally well on 3- or 4-year-old irrigated and dryland shrubs. Bioregulatory agents, affecting rubber synthesis, directly influence the isoprenoid biosynthetic pathways."

Plant-growth regulators such 2,4,5-trichlorophenoxy acetic acid and 2-chlorethyl phosphonic acid have revolutionized hevea rubber production. These and others also may benefit guayule rubber production (National Academy of Sciences, 1977).

6. <u>Summary of present status of guayule plant modifications</u>: A variety of genetic material is available for breeding purposes. A limited amount of seed also is available. Test plantings have been made and can be expanded rapidly because guayule is a prolific seed producer after the first year of growth. Guayule can produce up to several hundred pounds of seed per acre during the later years of plant life. Ample seed supplies to begin production cultivation will be available in three or four years.

Available seed varieties exhibit good to excellent growth under irrigation. These varieties could yield 10 percent to 20 percent rubber by weight during the fourth year and perhaps 5 percent to 10 percent after one year in the shorter growth cycle. Up to 763 pounds of rubber per acre have been produced in a year with close plantings, and up to 2,000 pounds per acre when harvested at the end of four years. Strains are available that have produced plants that have 20 percent rubber yields. If this rate could be maintained under field conditions, a per acre yield of 20,000 pounds of shrub with a rubber yield of 4,000 pounds is possible in four years based on shrub weights obtained by ERP.

Agronomic-physiological studies to determine rubber production under various environmental conditions are as important as breeding studies. To date concrete information exists about the effects of external conditions on guayule in achieving its full genetic potential.

It is not known yet how much rubber existing strains can produce. It is possible that cultivation research on existing strains should be emphasized rather than continuation of plant breeding explorations to create plants that can produce more rubber but that could fail under field conditions or produce material difficult to mill. A many-faceted research program should be developed that will have interlocking dependencies to prevent failure in any critical area that would jeopardize the success of the whole (Rollins, 1979).

C. Propagation Methods and Alternatives

The means by which stands of guayule are established can have a significant effect upon the economic viability of the guayule industry. Both nursery and greenhouse propagation techniques are excellent means for producing seedlings to be transplanted to the field. Costs of seedlings and of transplanting, however, constitute a significant portion of the agronomic costs of guayule production. Reduction of seedling costs or development of a viable, large-scale, direct-seeding technique for use in the field could greatly improve the economic viability of guayule commercialization.

1. Seeds: When soil moisture and air temperature are favorable, guayule plants of all ages bloom and set seed profusely throughout the growing season. Seed* yields per acre vary widely according to the number, age and vigor of plants. Each flower stalk bears an average of seven composite-type flowers; and each flower consists of five female florets with two attached sterile disk florets. Each of the former may produce an achene, or seed (U.S. Forest Service, ERP, 1946b).

Yields in 1943 of clean, unthreshed seed from ERP plantations established in 1942 ranged from 10 to 300 pounds per acre, depending on plant size and blooming season length as influenced by moisture. In a few instances, under especially favorable conditions, yields of 1,000 pounds per acre were recorded. The usual collected-seed yield is only 25 percent to 30 percent of all seed produced because of losses to wind and cultivation, and because of scattering of seed before harvest (U.S. Forest Service, 1946a).

Guayule seed germination characteristics differ from those of most other seeds. Only a few guayule seeds will germinate if sown immediately after being collected due to two types of dormancy: an embryo dormancy of short duration, and a seed coat dormancy that makes the inner seed coat impermeable to gas exchange.

Seed coat dormancy can be eliminated by chemical treatment with sodium or calcium hypochlorite that renders the seed coat permeable to oxygen. Dormancy can be shortened to a period of a few months by

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*The term "seed" in this discussion includes an achene (or true seed) with attached bract and a pair of dry male florets. "Threshed seed" refers to the achenes alone; "filled seed" refers to either normal or threshed seed that contain fully developed embryos; and "empty seed" refers to either threshed or unthreshed seed in which the achenes do not contain embryos but usually a pithy proliferation of the inner wall of pericarp.

threshing and removing floral parts normally attached to the seed. Aeration and moisture content of the seed affect the persistence of seed coat dormancy as well as the keeping qualities of the seed. Dormancy can persist for many years under certain storage conditions.

2. <u>Sowing and emergence</u>: Temperature, particularly at night, is the most critical factor to consider in selecting the sowing season for guayule, either in the nursery or the field. Germination and total emergence slow progressively when night air temperatures are below 60 F regardless of higher daytime temperatures. When temperatures drop lower than 50 F, germination and total emergence are inhibited. The stands are poor or fail entirely. Temperatures of 10 F to 15 F are dangerous to guayule seedlings. Prolonged temperatures as low as 20 F or exceeding 95 F can be damaging to seedlings.

Guayule seed is very sensitive to depth of cover. However, in both greenhouse and nursery trials the absence of cover reduced germination.

Weeds in young guayule stands generally are a severe problem. It is particularly important to eliminate or reduce weed competition during the 45- to 60-day period of seedling establishment because guayule seedlings are very intolerant of shade.

The dinitroanilines or other new herbicides undoubtedly will be selective on guayule. Like the oil herbicides previously used, the new herbicides will be selective on many weed species as well. Weeds sheltered by guayule plants are difficult to eradicate. Once guayule achieves a relatively closed canopy it competes well with weeds and chemical herbicides are not necessary.

Hardening or conditioning greenhouse and nursery stock before transplanting to the field is very important. Bringing young plants into dormancy slowly by gradually reducing irrigation water toughens them to withstand the shocks of topping, root pruning, lifting and transplanting. Low temperature also limits growth and induces dormancy. The percentage of plants that survive transplanting and the promptness with which they start new growth are directly related to the degree of dormancy, or hardening off, to which they have been subjected.

After lifting from nursery beds, it is possible to hold properly packed seedlings in storage with a temperature range of 32 F to 38 F for as long as 30 days before transplanting to the field without injury to the plant.

3. <u>Nurseries</u>: The method of establishing field plantings most widely used by the ERP involved transplanting nursery shrubs 4- to 12-months old, or occasionally older. Experiments demonstrated that guayule could be grown successfully by direct seeding. But the amount of labor and cost of preparing a very level seedbed, of the frequent irrigations necessary to establish seedlings, and of weed control appeared to make transplanting nursery shrubs more practical and economical.

Nursery methods used by ERP personnel to produce guayule seedlings were not greatly different from general nursery techniques used to grow many species of forest tree seedlings, particularly those irrigated with overhead systems. Seeds were sown by mechanical drills in 4-foot beds irrigated by overhead irrigation systems. Plants were weeded, watered, pruned, cultivated and otherwise cared for during a four- to eight-month period. Then plants were lifted, culled, packed and distributed for planting in the field. Under optimum conditions seedlings normally attained planting size when they were about 4-months-old.

Climates suitable for growing guayule in the field are generally favorable for growing good nursery stock. A number of pests may jeopardize seedling production, including pocket gophers, ground squirrels, birds and various insects. Guayule seedlings are no more susceptible to disease than seedlings of other species grown under similar conditions.

4. Greenhouse techniques: Field nursery plants face potential hazards from extreme temperatures, storms and high evaporation rates. ERP experiences indicate that guayule transplants from field nurseries must be at least 4-months-old.

It is possible that new greenhouse management technology could provide a more economical means to produce stock for year-round transplanting to the field. Current research findings indicate that greenhouse- grown seedlings 2- to 3- months old can survive transplanting successfully, thus reducing the total length of time of nursery stock production (Rubis, 1979).

Proper irrigation management and regular fertilizer applications are considered essential to healthy growth of guayule plants in the greenhouse. Plants remain in the greenhouse for two to three months. Pots then are moved to the nursery for two to four weeks to harden before being transplanted to the field.

5. Direct seeding: Germination and emergence behavior of guayule seed determines the conditions under which successful direct seeding can be accomplished. These conditions include daily temperatures no lower than 50 F except for limited periods of the day; very shallow cover, not to exceed one-eighth inch for best results, with no soil crusting to impede emergence; and abundant soil moisture at the sowing level during the germination and emergence period (C. Taylor, 1946).

Weed control must be initiated soon after seed emergence. When the primary leaves appear on the seedlings to indicate that a root depth of 8 to 10 inches has been achieved the surface soil can be allowed to dry to reduce the risk from damping-off disease. This drying causes some loss of weaker seedlings, but losses are fewer than from disease when higher moisture is maintained (C. Taylor, 1946).

Direct seeding is beset with difficulties, especially under dryland farming conditions. Elimination of transplanting costs and loss of time while plants recover from transplant shock make it desirable to overcome direct seeding problems. Direct seeding may be feasible only with irrigation. Transplanting seedlings may be the only practical plantation establishment method for dryland conditions or for particular soil types (Benedict, 1979).

Many of the difficulties encountered in direct seeding are a result of the large percentage of non-germinable seeds in even the best seed batches, as well as the difficulty of handling each achene as a unit. Equipment is available today that is better able to separate the filled from the unfilled achenes than the gravity separator formerly used. A method for pelletizing achenes has been developed by California Farm Management Company in Bakersfield to make it easier to separate the individual achenes and to handle them as distinct units. This method introduces more precision into the direct seeding process (Benedict, 1979).

D. Alternative Agronomic Practices

Although guayule is not currently grown commercially a remarkable amount of information is available about the agricultural production of the plant. Almost 1,000 scientific papers have been written about guayule, including excellent manuals about germinating seed, caring for seedlings, transplanting, fertilizing, irrigating and harvesting (National Academy of Sciences, 1977). Present knowledge about guayule is based largely on empirical observations made during 20 to 30 years of commercial production, by empirical observations and research by ERP agencies during World War II, and by the Agricultural Research Service (ARS) Crops Research Branch during an approximate 10-year period that ended in 1957. The scope of observations made during World II is based on ERP cultivation of more than 30,000 acres of guayule, mostly in California (K. Taylor, 1979).

1. Soils: The best growth of both irrigated and dryland guayule plantings occurred in light- and medium-textured soils. The same cultural treatment and planting stock on a single plantation produced larger shrubs more often in loam and sandy loam than in other soils, but the highest percent of rubber was yielded by smaller plants grown in other soils. Plants grown in clay soils had higher concentrations of rubber than those grown in light soils.

Guayule can tolerate iron or manganese deficiencies and up to 0.3 percent salt in the soil. It is very sensitive to boron deficiency. Potassium and calcium seem to be necessary for best growth. It grows well in soils with pH values from 6.0 to 8.5 but is stunted at pH 4.5 or 10.5. Optimum growth occurs from pH 7.2 to 8.3 (Bullard, 1946b).

Guayule grows best in fertile soils but it does not respond noticeably to most fertilizers except in soils with low fertility. Guayule has shown no marked response to nitrogen unless the soil is nearly sterile. Guayule is native to calcareous soils but grows well on granitic or sedimentary non-calcareous soils. Required fertility levels and moisture capacities seem related more to spacing and competition between plants than to general plant needs.

2. Spacing: Standard spacing of 28 inches between rows and 20 inches within rows, and 28-by-16 inches for irrigated guayule stands were employed by ERP personnel.

Spacing combined with survival, expressed as stand density, had considerable effect on rubber development. Competition for soil moisture was greater in denser stands. Thus plants grew under a certain degree of stress most of the time. The resulting somewhat slower growth generated a higher rubber deposition.

ERP personnel used rather close spacings to obtain high yields within a short time. Somewhat wider spacings may be preferable. Irrigated shrubs on better soils with 28-by-20 inch spacing formed a closed canopy in the third year of growth that made cultivation unnecessary but made irrigation operations difficult. Also, as a result of shading, some inner and lower branches contained a fraction of dead wood and the quantity and quality of the rubber was reduced.

3. Survival and stand density: Within reasonable limits, the yield of any crop is related to the number of plants per unit area. This is also true for guayule. Greatest survival losses occurred during stand establishment. Losses were relatively small after the first growing season except when disease occurred. Considerable correlations existed between soil type and survival and between nursery stock condition and survival.

4. Growth: Cultural methods affect the growth habit of guayule. When abundant irrigation water was available shrubs tended to have open crowns with coarse, heavy branches and no central stems.

The type of plant growth considerably affected harvesting and milling operations. Plants cultivated under dryland conditions had relatively higher leaf bulk per unit weight of entire dry shrub than irrigated plants. This resulted in increased transportation and other handling job loads per unit of mill capacity because the leaves are non-productive and the shrub usually was defoliated before milling. Dryland shrubs had a higher rubber content and could be milled more efficiently. They also had the highest rubber-to-resin ratio and therefore tended to produce a better grade of crude rubber. Irrigated shrubs, however, produced more pounds of rubber per acre in almost all instances.

5. Root development: From the time of transplanting in the field root systems of guayule seedlings provide the most important contact between the shrub and the growing environment. Although the general condition of planting stock at planting time was important, subsequent root growth was contingent primarily upon soil depth, aeration, penetrability, and moisture capacity and availability. These characteristics in turn depended on soil texture, stand density, rainfall and irrigation practices.

Guayule roots penetrated porous soils to a depth of 8 to 10 feet during the first growing season; 14 to 16 feet during the second season; and some roots ultimately attained depths of more than 20 feet. Thick strata of clay, gravel, and coarse sand prevented uniform deep penetration. When root growth was poor, top growth was limited. Portions of guayule shrubs above ground contain the greatest proportion of rubber and constitute 85 percent to 90 percent of the mill shrub bulk.

6. Field plantations: Guayule is suited to highly mechanized agricultural practices in each production step from seed gathering to baling the harvested shrubs. It lends itself to many modern agricultural implements: conventional tillage equipment to prepare the land; vegetable planters to transplant seedlings; corn or cotton cultivators; digger-harvesters; and hay balers to bale the shrubs for easy transportation (National Academy of Sciences, 1977).

The best planting season appears to be the dormant, winter season, according to data generated during the many plantings by ERP staff. On irrigated sites the beginning of the planting season can be hastened by pre-irrigation. Pre-irrigation should begin close to September 1 in the California valleys so that soil moisture conditions will be favorable for planting as soon as the planting stock is in a dormant condition. This generally will be close to October 1 (U.S. Forest Service, ERP, 1943a).

Planting in Texas, Arizona and New Mexico can occur from October 1 to April 1. Friable soils and a rather even distribution of rainfall in these planting areas provide generally favorable planting conditions during this period. The planting season frequently may need to be changed for non-irrigated lands in Texas because of drought periods (U.S. Forest Service, ERP, 1943a).

a. Irrigation: Basin irrigations should be avoided except on very well-drained soils because guayule is much more sensitive to flooding than most cultivated crops. Special care must be exercised when distributing water to irrigation furrows because of the plant's sensitivity to flooding and the economics of water conservation.

The objective of irrigating guayule is to supplement soil moisture derived from precipitation in amounts necessary to ensure early and rapid plant growth. However, irrigation must not hinder maximum rubber production. Disease losses resulting from improper irrigation also must be avoided.

Because rubber formation seems to take place during periods of semidormancy and is produced either by low temperatures or limited soil moisture, it may be necessary to induce or prolong a semidormant period in hot areas by limiting or withholding irrigation.

Process water from a variety of factories, including hevea rubber mills, has been used successfully as irrigation water. Guayule fields near a guayule milling operation could be irrigated, at least in part, with effluent water from that operation (Bonner, 1979b).

b. Cultivation: The principal function of machine cultivation is to control weeds to conserve soil moisture. Standard models of integral and pull-type vegetable cultivators can be used. The actual cultivation presents few problems that are not encountered in cultivating other closely spaced row crops such as sugarbeets and beans.

c. Weed, pest, and disease control: Wild guayule appears to be be remarkably free of disease and insect pests, but under cultivation the plant is susceptible to both. Although few plants died from disease or pest damage in cultivated ERP plantations, infestations did occur. Diseases that affect guayule are common and affect other crops as well, including cotton and lettuce. Some diseases are quite serious, such as cotton root-rot, charcoal rot, dieback and wilt.

Oil sprays used by ERP staff killed weeds in planted rows without hand hoeing. A mechanical hoe was developed by ERP personnel that was effective in weed control, and in most cases was less expensive than oil sprays. Trifluralin has been used recently as a pre-emergence, pre-planting herbicide. The combination of simazin and oryzalin has been used as a pre-emergence, post-planting herbicide (Benedict, 1979).

Several species of insects infested the ERP guayule plantings, but only grasshoppers and lygus bugs caused serious economic losses. In limited areas grasshoppers fed on guayule leaves and on the bark of young stems. Lygus bugs fed on terminal buds, flowers and immature seeds. Defoliation by grasshoppers occasionally killed the shrub, or at least retarded shrub growth. Lygus bug damage retarded shrub growth and reduced seed yield.

Ants and termites caused some minor damage either by defoliating shrubs or by eating root bark. Lacebugs, which suck juices from leaves, caused some injury in certain areas in Texas. None of the insect attacks assumed serious proportions.

Fungus control was achieved primarily through preventive measures. Soil moisture in excess of field capacity for extended periods promoted disease infestation. Disease losses were reduced by wider row spacing, deeper furrows and increased slope, or by planting in soils that had high infiltration rates.

E. Potential Growing Areas

Cultivated guayule grows best at temperatures of 90 F to 100 F, according to research findings. Growth was markedly less at temperatures below 60 F. Plants were not damaged by maximum temperatures of 120 F, but were often injured by temperatures below 15 F. The most suitable climate for dryland guayule culture would be one with a mean annual temperature range of 56 F to 62 F and extreme minimum temperatures always above 15 F. For irrigated culture, mean annual temperatures up to 70 F would be satisfactory, but minima should not be lower than 25 F.

Warm, dry summers were conducive to growing guayule that had a higher rubber content, but maximum rubber production required relatively low night temperatures. Daytime temperatures from 65 F to 80 F combined with nighttime temperatures of 35 F to 45 F promoted satisfactory rubber accumulation in young shrub more or less without regard to vegetative growth, although growth tended to be slow during cool nights.

Areas considered suitable for potential guayule cultivation are delineated in Figure III-2. These areas have appropriate temperature and moisture ranges as well as appropriate soils. Regions are delineated by county boundaries to allow assessment of guayule production in relation to county agricultural and water statistics. Figure III-3 shows the relationship of these potential guayule regions (showing county boundaries) with the physiographic provinces considered appropriate during the ERP (solid lines) and with Bullard's 15 F minimum temperature line (shaded area) (Bullard, 1946a).

The North Coastal Hydrographic Region of California was excluded from consideration as a potential guayule growth area due to excessive precipitation. The northern extreme of the Sacramento Basin also was excluded because of excessive precipitation and increasing elevation associated with cold in the northernmost portion of this hydrographic region. The mountainous region of eastern California has low temperatures that limit guayule production potential.

The potential guayule growth area in Arizona is included within the warmer portion of the Basin and Range physiographic province. The Mogollon Rim bisects Arizona and marks a dramatic elevation change. Low temperatures north and east of the Mogollon Rim restrict the growth of guayule.

Areas north and east of the New Mexico potential guayule growth region are excluded either because of high elevation or winter temperature fluctuations.

The Edwards Plateau lies between two potential guayule growth regions in Texas but has restricted potential for guayule production due to low temperatures and poor soil quality. Eastern Texas has annual precipitation of 36 inches or more that restricts guayule production in that region.

A more detailed analysis of the potential guayule growth region was undertaken as part of the scenario development process. Specific counties and hydrographic units were evaluated according to precipitation, soils, urbanization pressure, and agricultural area characteristics. Appendix B contains a detailed map that shows areas considered appropriate for guayule development and areas considered restricted in guayule development potential. A more detailed discussion of the rationale for area selections also is included in Appendix B.

F. Projected Yields

Previous production experiences do not provide a completely reliable base for projections. The varieties grown and conditions under which they were grown may not represent future production possibilities as new varieties and cultural practices are developed.

Predicted rubber yield may be inferred from available data supplemented by some assumptions. Rubber yield varies according to age and spacing of plants. It is conditioned by both high and low temperatures and the amount and distribution of moisture. New varieties of guayule may increase the amount of rubber through changes in plant anatomy and physiological processes; but it is not expected, at least in the near future, that they will materially modify the age-space relationship. Bioinduction procedures, on the other hand, might stimulate higher rubber production in young plants or eliminate the need for stressing.

Two broad types of rubber production may be considered: a) rubber production from plants grown from seed and harvested in three years or less; and b) rubber production from plants grown from seed in a greenhouse or nursery, transplanted to the field and harvested in the field at the end of three or more years. This type of rubber production would include both dryland and irrigated crops. An alternate practice would be to mow the tops and harvest for rubber at two or more years, and then dig the entire plants after one to several years of regrowth.

1. Previous yield studies and past production information: Two reported studies of harvested plants grown from seed were made during the ERP. Kelly, et al (1946), conducted research using two interior valley nurseries from which guayule transplants had not been taken because of ERP termination. Reduced densities were obtained by eliminating one to five of the seven rows planted and by thinning within rows. Guayule in one of the coastal nurseries produced 1,336 pounds of rubber per acre under the closest spacing in 21 months; guayule in all four nurseries produced more than 800 pounds per acre under the closest spacing in 21 months. Irrigation increased rubber production at the interior nurseries but not at coastal nurseries. Fertilizers did not increase rubber production at any of the four nurseries.

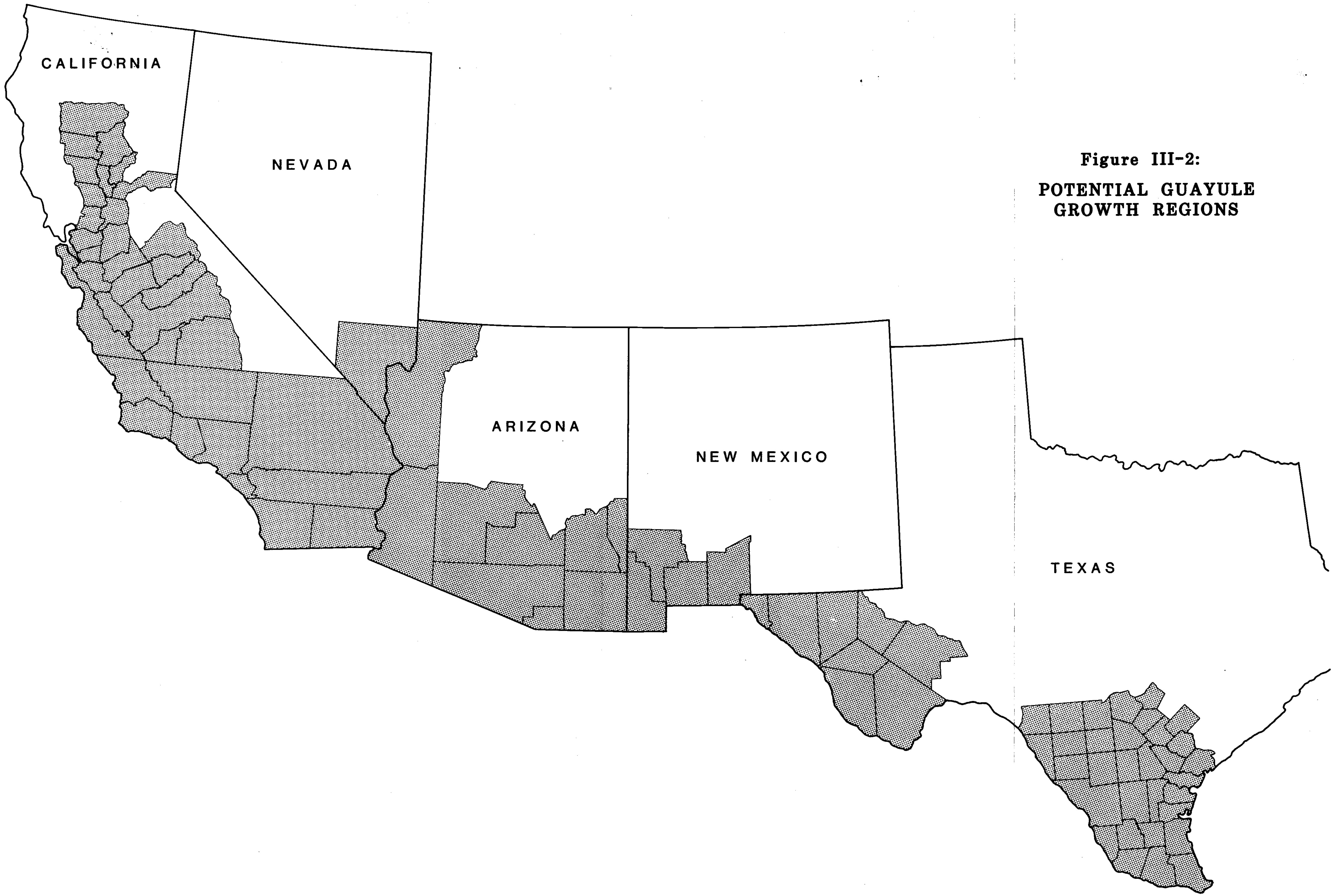
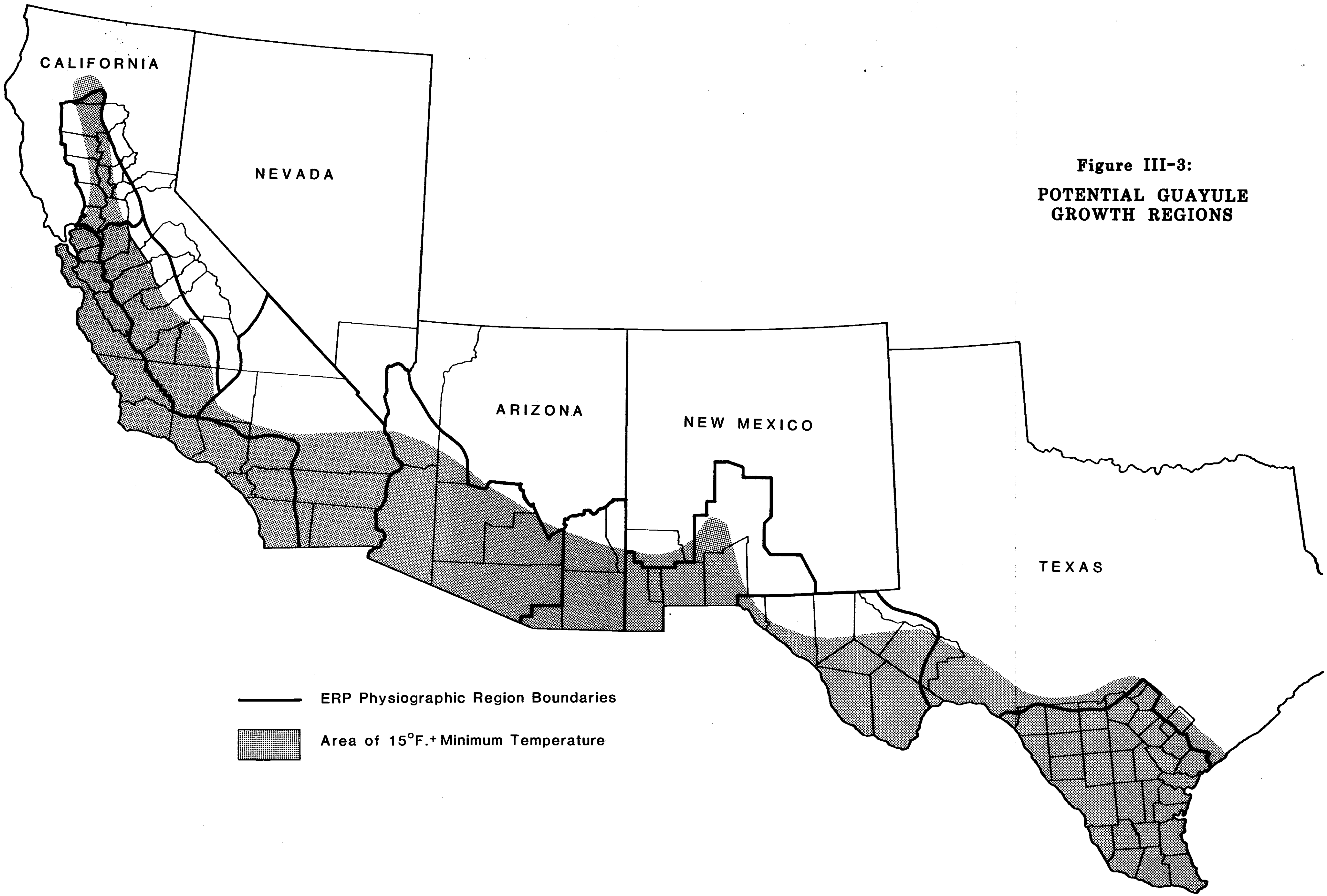


Figure III-2:

POTENTIAL GUAYULE GROWTH REGIONS

Figure III-3:

POTENTIAL GUAYULE GROWTH REGIONS



Tingey (1952) direct-seeded guayule at Salinas, California, and provided various spacings by thinning. He used three irrigation treatments: a) heavy; b) light; and c) none during the second year and one during the third year. Tingey found that the number of plants per unit area was the most important factor affecting rubber and shrub production. Irrigation was the most important factor affecting rubber dry weight percentage. Guayule, grown in rows 14 inches apart, unthinned and with light irrigation, produced 1,708 pounds of rubber per acre in 33 months. The widest spacing yielded only 569 pounds per acre over the same time period.

Sources of information about rubber production in various parts of the United States have to be viewed in light of the strain or variety involved and the particular conditions under which the shrub was grown and harvested, including plant spacing, climate (both temperature and precipitation), soils, irrigation and age at time of harvest. It is difficult to isolate the effects of these individual factors; a representative value must include comparisons and interpretations. The five main sources of information are harvesting data from the Intercontinental Rubber Company, field production data from the ERP, data from experimental ERP plots, data from ERP indicator plots and estimates based on growth and rubber content of small samples.

Guayule production under irrigation was not successful in terms of rubber yields per acre before ERP trials. The Intercontinental Rubber Company gave up its 6,000 acre irrigated plantation 25 miles south of Tucson, Arizona, at Continental because, according to McCallum (1941), "the rubber was slow in forming in the plant because of irrigation and also because the rains came in the summer and promoted plant growth just when the plants should be drying out." Contrasting with McCallum's experiences was one of the highest ERP rubber producing indicator plots that was cultivated under irrigation at Marana, Arizona, 25 miles north of Tucson.

In spite of McCallum's experience it was decided by ERP technicians to make major plantings on irrigated land because war needs were critical and the earliest possible production was desired. It was believed that harvests could be made after four years or less under irrigation, while shrub grown under precipitation alone would require five or more years to mature. ERP was terminated too soon to provide a sufficient data base to project accurately rubber yields under irrigated cultivation. Preliminary data collected by ERP personnel who observed planting in California are presented in Table III-1.

Because of lack of adequate previous experience, ERP per acre yields probably were lower than might be attainable under the best cultural practices. The necessity of stressing was not recognized fully in the beginning of the project and the season and amount of stressing by withholding moisture was determined empirically. Stressing was not applied uniformly to all fields. As a result there were considerable

TABLE III-1

ESTIMATES OF SHRUB AND RUBBER PRODUCTION ON GUAYULE PLANTATIONS IN CALIFORNIA

Age of Shrub in the Field	Estimated Survival 1/	Entire Dry Plant Weight	Rubber Hydrocarbon 2/	Shrub Weight per acre 3/	Crude Rubber per acre 4/	
Years	Percent	Grams	Percent	Short tons	Pounds	
		Irrigated - 28x20-inch spacing			total	per year
Salinas & So. California						
1	70	150	3.1	1.7	110	
2	67	420	5.3	4.5	510	255
3	65	700	7.4	7.3	1,140	380
4	63	800	9.9	8.0	1,700	425
5	61	865	11.3	8.4	2,050	410
Bakersfield						
1	80	200	3.1	2.6	170	
2	77	550	5.3	6.8	780	390
3	75	825	7.4	9.9	1,560	520
4	73	965	9.9	11.3	2,390	598
5	71	1,040	11.3	11.8	2,880	576
Tracy-Newman						
1	69	185	3.1	2.0	140	
2	66	500	5.3	5.3	600	300
3	64	760	7.4	7.8	1.230	410
4	62	860	9.9	8.6	1,800	450
5	60	925	11.3	8.9	2,160	432
		Dryland - 28x24-inch spacing				
Salinas & So. California						
1	65	65	3.2	0.6	40	
2	63	300	6.0	2.5	320	160
3	62	520	8.8	4.2	810	270
4	61	640	11.1	5.1	1,230	308
5	60	725	11.7	5.7	1,440	288
Colusa						
1	55	60	3.9	0.5	40	
2	53	230	7.3	1.7	260	130
3	52	390	10.4	2.8	620	207
4	51	520	11.6	3.6	900	225
5	50	630	12.0	4.3	1,120	224

1/ Based on records of the 1943 plantings
2/ As percent of entire dry weight of shrub.
3/ Shipping weight at 25 percent moisture content.
4/ Assuming 70 percent rubber hydrocarbon content in the crude and 100 percent mill recovery.

Source: Bullard, 1946b

differences from field to field in percentage of rubber and rubber yields. The magnitude of yield was subject to very small differences in the moisture capacities of soils, often within the same field. Plant spacing and survival also were important factors in yield determination. The ERP staff used rather close spacings to obtain high yields within a short time, but wider spacings might be better for longer growth cycles to prevent shrubs from developing the closed canopy that makes cultivation and irrigation operations difficult.

Indicator plots properly planted and well tended (weed control and optimum irrigation) showed good results. The Litchfield plot in Arizona, corrected for 100 percent survival, had a three-year yield of 1,400 pounds of rubber per acre with 25-by-12-inch spacing. The Marana, Arizona, plot yielded 1,391 pounds of rubber in three years with standard 28-by-20-inch spacing; Picacho and Queen Creek, Arizona, plots produced an average of 1,500 pounds; and the Date Garden at Indio, California, produced 1,400 pounds of rubber in three years under standard spacing.

In the Mesilla Valley, New Mexico, the ERP experimental work during World War II was curtailed before any definitive production and yield results were obtained. However, experimental direct seeding plantings of guayule near Anthony, New Mexico, produced 300 to 400 pounds of rubber per acre per year under irrigation (Davis, 1945).

Wartime ERP studies in Texas were more extensive than in other states and continued during a longer time span (1943 to 1946). Rainfall farming studies in the vicinity of Pearsall showed some direct seeding potential, but often produced erratic results because of weather vicissitudes. Production from transplants was more consistent because of generally higher survival rates than those from direct seeding, but production was lower than that obtained from unirrigated areas in California. After three years and in a 28-by-20-inch spacing, the average rubber percentage was about 8 percent in the Pearsall, Texas, vicinity. The average rubber production was 500 pounds from three tons of shrub.

2. Estimated future yields: Based on review of available information, the following yield estimates are considered to be realistic predictions of production that can be obtained under modern cultural practices using the best guayule varieties available.

Table III-2

EXPECTED SHRUB AND RUBBER PRODUCTION USING GUAYULE VARIETIES AVAILABLE IN 1979

Region	Age at Harvest	Spacing	Rubber (Percent)	Short Tons Shrub Per Acre	Pounds Rubber Per Acre per Year
California Rainfall	5	28" x 24"	12	6	288
Warm Irrigated Valleys	4	28" x 20"	10	10	500
Texas Dryland	5	28" x 24	8	6	192
Southern Texas	Probably same as for warm irrigated valleys if growth can be controlled.				

This table is based on actual production under field conditions. Because several varieties of guayule now in seed production have a potential to yield 20 percent rubber by dry weight, it is possible that without further genetic change production could be increased in all of these regions with improved cultural practices, biochemical regulation or both. Assuming rubber production at a 20 percent rubber yield, the Table III-2 estimates would increase to levels shown in Table III-3.

Table III-3

ESTIMATED RUBBER PRODUCTION BASED ON FULFILLMENT OF 20 PERCENT POTENTIAL

Region	Age at Harvest	Spacing	Rubber (Percent)	Short Tons Shrub Per Acre	Pounds Rubber Per Acre Per year
California Rainfall	5	28" x 24"	20	6	480
Warm Irrigated Valleys	4	28" x 20"	20	10	1,000
Texas Dryland	5	28" x 20"	20	6	480
Southern Texas	4	28" x 20"	20	10	1,000

Ultimate guayule rubber production potential is based on increasing percentage of rubber yield per shrub or increasing tonnage of shrub per acre. These increases would be mostly as a result of intra- and interspecific changes created by genetic manipulations. The limits for increasing yields and tonnage are unknown. Conservative estimates might be a 50 percent increase in either one or both. On the basis of these increases the yields shown in Tables III-4 and III-5 can be postulated.

Tingey (1952) and Kelley, et al, (1946) have demonstrated that more than 500 pounds of rubber per acre per year can be produced in two to three years by using close plant spacing. Selected production results show that a similar yield can be expected by harvesting 4-year-old irrigated shrub grown by using wide plant spacing. Without irrigation, rubber production has a lower potential. Several strains undergoing breeding tests have shown rubber percentages of up to 20 percent by dry weight. Yokoyama (1977) has been able to increase rubber percentage by 220 percent to 600 percent under experimental conditions. Artschwager (1945) has shown that a plant rubber storage area to accumulate a higher rubber percentage is within anatomical expectations. Finally, the potential biomass capabilities, as determined for other plants, are far above the tonnage yield that has been achieved thus far with guayule.

It is possible also that irrigated guayule spaced to allow planting more than 11,000 plants per acre could be harvested after three years and that such a system would prove to be more economical than harvesting at four years. In this case the annual yield per acre could be as much as 25 percent greater than shown in Tables III-2,3,4 and 5.

If direct seeding proves unsuccessful, plants could be transplanted with closer spacing within and between rows. Under such conditions the plants might be harvested in one or two years (Tingey, 1952; Kelly, et al, 1946).

Finally, clipping (pollarding) plants once or several times before digging could be advantageous because the time between planting and digging would be lenghtened to spread planting costs over a longer period.

G. Harvesting Techniques

Individuals associated with ERP guayule research and production during World War II agreed that all phases of guayule production must be interrelated (McGinnies and Taylor, 1979). The end result of all research and production should be to deliver to the mill: 1) shrub in a form appropriate to the milling process selected; 2) shrub with the highest practical hydrocarbon content (milling costs are directly related to per-plant rubber percentage); 3) shrub produced at costs that, when added to milling costs, produces a competitive marketplace product; and 4) a continuous supply, consistent with storage facilities to allow continuous operation of the mill (Byrne, 1979).

TABLE III-4

POTENTIAL RUBBER PRODUCTION BASED ON A 50 PERCENT INCREASE IN BIOMASS PRODUCTION

Region	Short Tons of Shrub Per Acre	Rubber Content (Percent Dry Weight)	Rubber Increase (Pounds Per Acre Per Year)	Total Rubber (Pounds Per Acre Per Year)
California Rainfall	9	20	240	720
Warm Valleys	15	20	500	1,500
Texas Drylands	9	20	240	720
Southern Texas	15	20	500	1,500

TABLE III-5

POTENTIAL RUBBER PRODUCTION BASED ON COMBINATION OF INCREASE FACTORS*

Region	Short Tons of Shrub Per Acre	Rubber Content (Percent Dry Weight)	Rubber Increase (Pounds Per Acre Per Year)	Total Rubber (Pounds Per Acre Per Year)
California Rainfall	9	30	360	1,080
Warm Valleys	15	30	750	2,250
Texas Drylands	9	20	360	1,080
Southern Texas	15	30	750	2,250

*Shrub tonnage increase by 50 percent, rubber content increase to 30 percent dry weight.

1. Rubber deposition: Knowledge about the occurrence of rubber in the guayule plant will aid in development of the richest and most productive shrub and therefore is equal in importance to advances in shrub production and rubber extraction.

Marked seasonal fluctuations occur in overall rubber concentration. It is highest during cool seasons and periods of moisture stress, and lowest during periods of lush growth when xylem tissue production increases at the expense of the phloem tissue that has higher rubber-producing potential. Once formed, rubber is not lost in live plant material, but the ratio of rubber to shrub bulk may decrease as additional shrub growth occurs.

Increments in the rate and amount of rubber accumulation have been correlated to the degree of physiologic stresses (within limits of individual plant tolerance) induced by cold, drought and other factors including the alkali content of the soil. Genetic differences and soil fertility also affect rubber yield, but mostly according to the stresses imposed.

While stress is believed to be necessary for high rubber yields, some conflicting evidence indicates that although slow growing plants produce the highest percent of rubber, faster growing plants almost always produce more pounds of rubber per acre.

2. Preharvest conditioning: Conditioning shrubs before harvest is desirable for two reasons: 1) moisture content and leaf bulk are reduced to lighten the strain on harvesting and transportation facilities; and 2) rubber content is increased to improve per acre yields and to make the most efficient use of available mill capacity (Bullard, 1946b).

During periods of most intense rubber formation, shrubs need a crop of healthy leaves to continue photosynthesis under relatively cool conditions. It was found that low winter temperatures caused cessation of vegetative growth and slowed rubber formation (Bonner and Galston, 1947). Temperatures most effective in instigating rubber development, however, were never definitively determined in the field. When temperatures were low enough to damage the plant, there was no increase in rubber production (Bullard, 1946b).

Rubber accumulation usually is greatest during cool weather or under reduced moisture conditions, but guayule can be harvested for rubber at any time during the year. Harvested guayule shrubs, therefore, can be milled year round. It would be necessary to adjust milling practices to seasonal shrub conditions. Adjustments would not entail any major modification in milling methods.

3. Harvest methods: Guayule harvesting methods may have a very important effect on the quality and quantity of rubber obtained.

The best time to harvest guayule apparently is when the canopy is nearly closed, according to available information. Harvesting after that time will result in losses of lower branches (because of shading) and subsequent losses of rubber. Dead branches cause milling difficulties and tend to lower the overall rubber quality obtained from the milled shrubs. Canopy closure depends on soil and moisture conditions and plant spacing. Canopy closure will occur during the second or third year when conditions include a 28-by-20 inch spacing, irrigation, and favorable soil. Wider or narrower plant spacing would produce a longer or shorter harvesting cycle, respectively. Also, available evidence indicates that the older plants would have a higher percent of rubber but would not necessarily produce a higher yield per acre (USDA Natural Rubber Research Station, 1953).

a. Digging: The Intercontinental Rubber Company developed a system for harvesting guayule that used an undercutting device for severing plant roots at a depth of about 8 inches, a side delivery rake for gathering undercut plants into windrows, and a large ensilage cutter mounted on tractor drawn running gear that cut shrubs into fairly small pieces to be loaded into trucks and hauled into the mill (C. Taylor, 1946). The ERP used similar methods for undercutting, but windrowed the plants and baled them.

Usual field harvesting operations took all the aboveground portion of plants plus 6 to 8 inches of the root system. Although the roots contain fair amounts of recoverable rubber, they do not contain as much as the stems and branches. Attempts to extract more of the roots by "lift harvesting" the plants was judged not worth the effort (Bullard, 1946b)

b. Pollarding: The practice of clipping or pollarding shrubs rather than removing the entire plant would eliminate the expense of ground preparation and replanting. The amount of rubber accumulated in the roots does not decrease and would be retained until future harvest of the entire plant. After pollarding new shoots should grow more vigorously because of the already established root system.

Only very limited pollarding trials have been made. Time of clipping relative to the growing season was found to be an important factor in plant survival. The best survival generally resulted when guayule was clipped during the dormant season when the highest rubber yield could be obtained.

It will be necessary in future research to determine the effects of clipping and the number of times a plant can be pollarded before planting stock must be renewed. More must be learned about milling "tops." Findings from limited studies indicate that leaf removal is a problem. Finally, an economic study is needed that compares pollarding with undercutting (USDA Natural Rubber Research Station, 1953).

4. Postharvest conditioning: Because the rubber hydrocarbon is distributed throughout the shrub, some method must be developed for disintegrating , the plant tissues, releasing the rubber from the individual cells, and then recovering the rubber. Rubber in the plant tissues must be in a form and condition that permits subsequent separation and recovery. During the ERP guayule production period it was believed that field curing before milling was desirable. Plants were sunned four to seven days after digging. Then the harvested shrubs were baled in the field, hauled to the mill, and placed in storage until the moisture content dropped to about 18 percent to 20 percent. Later it was found that this procedure was not only unnecessary but that it resulted in lowered rubber quality and in reduced rubber yields. Best results were obtained by milling freshly harvested shrub (K.W. Taylor and R.L. Chubb, 1952).

H. Processing Alternatives

Rubber occurs in the liquid within the plant cells throughout the growing guayule plant. Rubber can be extracted in a dispersion of the latex by solvent extraction, or agglomerated as a resinous or deresinated rubber. Agglomeration has been the standard extraction practice.

Processing harvested guayule consists of a number of sequential operations to release the rubber from plant tissues: separating as much rubber as practical from other plant constituents; freeing the crude rubber from contaminant materials; applying necessary preservatives; and drying and packaging the rubber for consumer use. Conventional processing begins with harvested shrubs and ends with crude boxed rubber. Processing also may include recovering various byproduct materials that have existing or potential uses. Alternative methods exist for accomplishing many of the operational steps.

1. Postharvest handling and storage: One major problem in handling guayule for sustained milling operations is maintaining a constant shrub supply. It may be necessary to store harvested shrub for some period of time to sustain continous processing. Once the shrub is harvested, however, the rubber in the plant undergoes degradation in storage, an important consideration in handling shrubs during the period between harvesting and processing (Campos-Lopez, et al, 1978).

Increased storage periods of foliaged plants causes decreased yields of rubber hydrocarbon. An apparent decrease of rubber in the shrub and a slight decrease in the crude rubber resins occurs, but not enough to make appreciable difference in rubber quality. The total amount of crude rubber recovered per ton of harvested shrub decreases as shrub storage time increases (USDA Natural Rubber Research Station, 1953).

2. Cleaning and defoliation: Leaf materials constitute approximately 25 percent of the dry weight of the plant, but contain no recoverable rubber. This material is not only a non-productive load on the milling system but also contains deleterious constituents and should be removed before processing begins. Parboiling has been accepted as an initial defoliation step.

3. ERP processing operations: The ERP program could be described as an attempt to secure the maxium amount of rubber of acceptable quality in the minimum amount of time because of wartime urgency. The ERP process technology that evolved, based on the factory operation experience of the Intercontinental Rubber Company, is summarized below.

Field-baled foliate shrubs were stored at the mill for 30 to 60 days. After being parboiled, bales were broken open. Shrubs were defoliated in a screened rotary trommel and then comminuted in a hammermill and weighed. Shrubs then were dried, crushed, mixed with water and fed through four or five pebble mills. Slurry from the last milling was discharged into a flotation tank.

Bagasse was removed from the tank bottom, dried by flue gasses and charged to the firebox of a Scotch boiler as fuel. Rubber and cork were skimmed from the tank top and subjected to pressure. The cork was added to the bagasse; the rubber was scrubbed, rinsed, treated with an antioxidant, dried and blocked into 100 pound-bales.

4. Postwar studies of guayule processing operations: Postwar pilot plant studies investigated modifying various processing operations. A flow chart of alternate milling processes is shown in Figure III-4.

a. Deresination: Postwar research indicated that rubber approaching hevea rubber in quality could be produced from guayule. However, during the milling process commonly used to recover guayule rubber, approximately half of the total shrub resin became incorporated in the crude rubber as a major impurity. Flooded percolation on relatively thin beds of rubber worms from lush millings seemed to produce the most uniform and reliable deresination. Comminuted guayule shrubs also can be deresinated by the same method. The advantages of shrub deresination over worm deresination are the possible recovery of water solvent materials; and recovery of more resin, possibly containing fractions not found in the resin derived from worm deresination (USDA Natural Rubber Research Station, 1953). Whether comminuted shrub or crude rubber is deresinated may depend primarily on the economic value of the resin as a byproduct (K. Taylor, 1979).

b. Rubber extraction methods developed in Mexico: In 1974, the Mexican Project for Industrialization of Guayule* began development of an improved guayule rubber extraction method that makes possible

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*The Project is conducted under the auspices of the Consejo Nacional de Ciencia y Tecnologia (CONACYT) and the Commision Nacional de las Zonas Aridas (CONAZA).

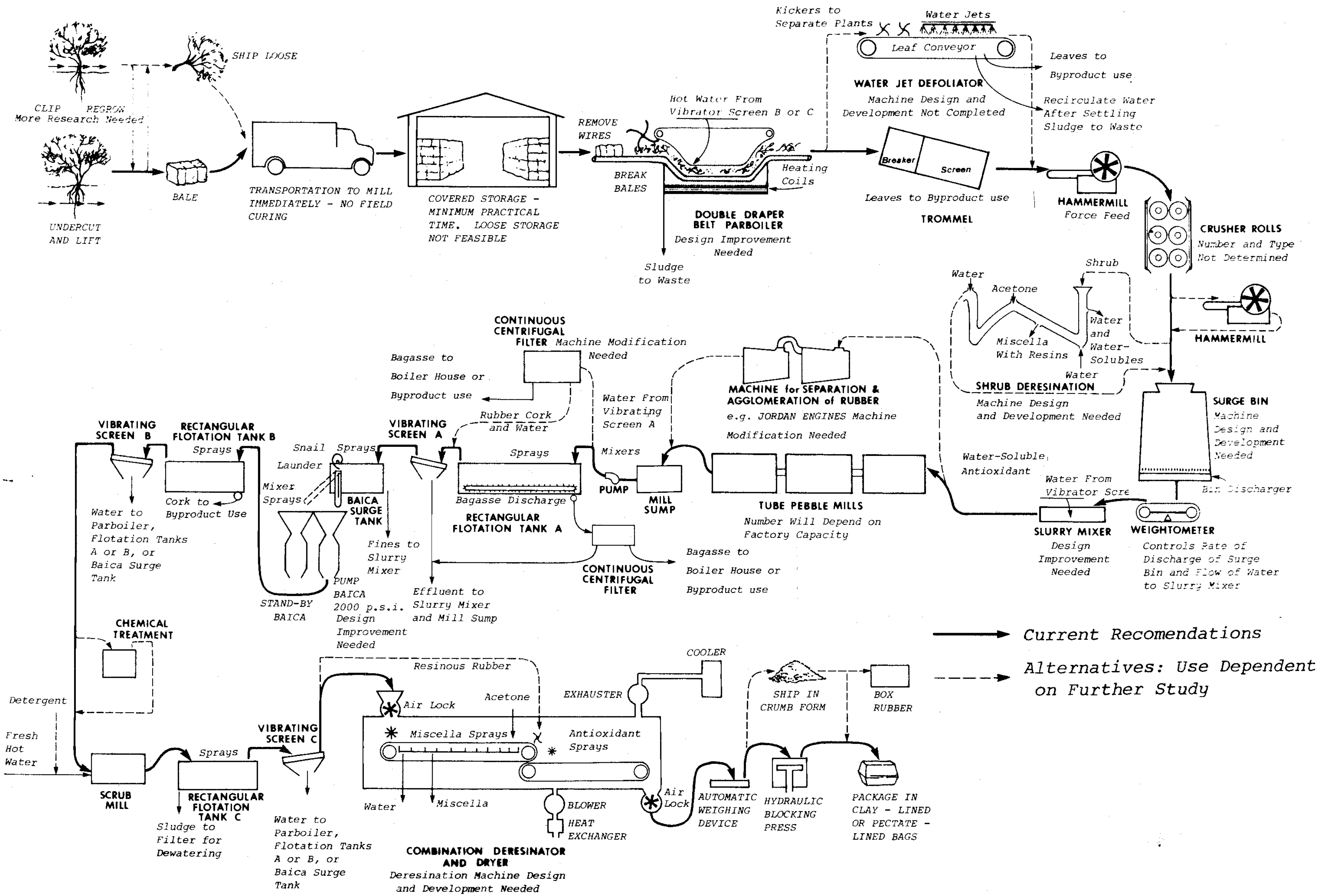

FIGURE III-4: FLOW CHART FOR PROCESSING RUBBER FROM GUAYULE step-by-step recovery of the different byproducts and provides shrub or rubber deresination alternatives. The process has been used experimentally since 1976 at the pilot guayule processing plant operating in Saltillo, Coahiula, Mexico, under the auspices of the Centro de Investigacion en Quimica Applicada. The pilot plant has the capacity to process 1 ton of shrub per day.

Baled shrubs are parboiled and defoiliated. The biomass then is passed through a hammermill and a Bauer mill (a device used in paper making) to break open the rubber-filled cells. Caustic soda (sodium hydroxide) added during the pulping process helps break open the rubber-filled cells. Pulping is done in water and causes the crude rubber to agglomerate into spongy worms. This material is passed through a series of flotation tanks three times. The waterlogged bagasse sinks and is pumped off. Floating rubber worms are skimmed from the surface. The resinous worms are rinsed to remove the caustic soda, then warmed in water with detergent.

Milled guayule worms contain 17 percent to 25 percent resins. Acetone extraction removes about 95 percent of these resins. The acetone then is distilled from the resin water mixture, filtered and recycled. After steam treatments remove residual acetone, the gray-white guayule rubber contains about 2 percent resin. The deresinated rubber is dissolved in hexane and filtered in a final purification to remove residual insolubles (cork, fiber, dirt). During this stage of the process the filtered solution is homogeneous and the rubber can be bleached, protected with antioxidants or treated with reagents so that ultimately a high-quality, uniform product can be produced. While in solution the rubber also can be altered by polymerization chlorination, copolymerization with methacrylates and by other chemical reactions that eventually will lead to production of types of rubber that have different properties (National Academy of Sciences, 1977).

The rubber-hexane solution is mixed with steam during the next step of the process. The rubber-hexane steam solution is pumped into a series of two coagulators where the solvent is vented off and rubber is recovered as variable-size crumbs depending on operating procedures (surface agents, stirring, etc). The wet, purified rubber is routed to an extruder dryer where all but 0.6 percent of the moisture is removed. The crumb rubber then is cooled in a long, aerated gutter, baled and packaged in 75-pound blocks (Campos-Lopez, 1979a).

c. <u>Rubber extraction methods developed by Firestone Tire and Rubber Company</u>: The Firestone Tire and Rubber Company is investigating a direct-solvent extraction method to extract both resins and rubber. Nivert, Glymph and Snyder (1978) described this process as detailed in the following paragraphs.

"Fresh guayule shrub is received from the fields in bales, loaded on a conveyor and sent through a soaking pit where the bales are parboiled at 70 C for 10 to 20 minutes to loosen the leaves and any dirt. The bales are cut and shrub is passed under a high pressure water spray to remove the leaves. The leaves can be further processed to remove the hard cuticle wax, however, this is not included in this process scheme.

"The wet shrub is chopped and ground in a series of (hammer) mills. The finely pulverized shrub is then conveyed to a countercurrent percolation type extractor where the resins in the shrub are extracted with acetone. Total contact time is one to two hours. Initial contact with acetone dehydrates the shrub. The deresinated shrub is desolvenized and deodorized in standard equipment similar to that used in the oil seed extraction industry. Acetone-resin mixture, acetone-water from shrub dehydration and acetone from the desolventizer are combined in an acetone refining column. Resins and water leaving the bottom of the column are decanted giving a crude resin byproduct. Facilities for refining the crude resin are not included.

"The deresinated, desolventized shrub is next conveyed to a countercurrent immersion type extractor where it is contacted with hexane for two to three hours to extract the rubber. Antioxidant is introduced at this point with the hexane. The pulp is desolventized in a similar fashion as in the acetone extraction step and the majority of it is burned for steam generation and in plant generation of electricity. The remainder is byproduct.

"The miscella from the extractor (7 percent rubber in hexane) is heated to flash off a portion of the hexane. The remaining rubber solution is sent to a series of stripping columns where the rubber is coagulated with water and hexane is stripped with steam. Hexane from these stripping columns, the flash vessel, and the desolventizer is condensed. Water is separated from the hexane in a decanter. The hexane is then recycled.

"The coagulated rubber in water is sent to a standard rubber drying section where it is screened, washed, dried and finally baled."

A schematic of this process is shown in Figure III-5.

Nivert, et al, reported in 1978 that this processing method would require considerably more research before it could be considered as an alternative method of processing. However, recent research breakthroughs in the solvent extraction process (perfection of efficient separation column extraction of rubber) and in the "Saltillo- type" process (addition of water to the hexane solution allowing an increased rubber

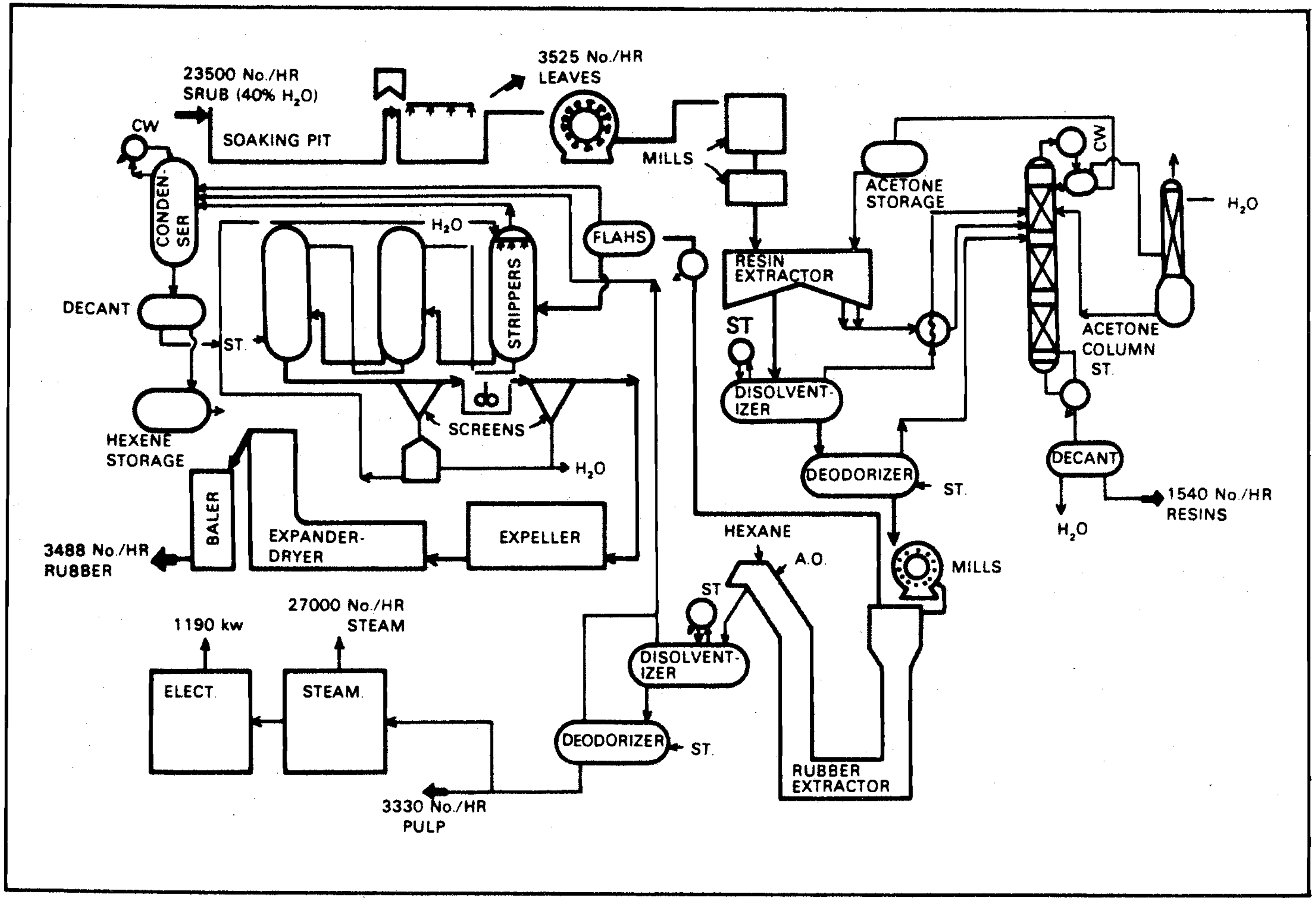

Figure III-5: FLOW DIAGRAM OF GUAYULE EXTRACTION PLANT WITH RUBBER CAPACITY OF 25 MILLION POUNDS ANNUALLY.*

*Source: Nivert, Glymph and Snyder, 1978.

percentage in solution up to four times previous levels) have greatly improved the economics of guayule processing (Nivert, 1979).

Dr. Enrique Campos-Lopez, Director of the Centro de Investigacion en Quimica Aplicada, has stated that extracting rubber from the shrub is the most important stage of the process because it has the greatest impact on total cost of the process. Also, it is the stage at which the greatest amount of water is used and resultant effluents could be a problem. Campos-Lopez recommends that research emphasis be placed on the rubber recovery process especially of various types of mills, and experiments with ultrasonics to obtain cellulose fiber by means of recently developed high pressure systems (Campos-Lopez, 1979b).

I. Rubber Quality and Utilization

Reasons for removing resin from guayule rubber are compelling. Rubber quality is greatly improved, and the recovered resin may have a profitable market. The major argument against removing resin is the added cost of equipment and operation. These costs, however, probably could be offset by income from the recovered resins and higher price for the higher quality rubber (E. Taylor, 1975).

Guayule resins contain a pro-oxidant that causes accelerated degradation of rubber. Guayule does not contain a natural antioxidant as does hevea rubber and tends to become tacky during storage unless protected by antioxidants. Removing the resins reduces this degradation potential and improves the physical properties of guayule rubber vulcanizates (E. Taylor, 1975).

1. Chemical structure: The microstructure of natural isoprene rubber is one of the determining factors of its mechanical properties (e.g., green strength).* Its capacity to crystallize under stress is due to a highly regular polyisoprene chain exculsively composed of a head-to tail cis-1,4 structure as identified within the detecting limits of modern equipment. Available synthetic polyisoprenes contain no more than 98 percent of this structure. Recently it has shown that guayule has a microstructure made up exclusively of head-to-tail, cis-1,4 structure. Although questions about the presence of carbonyl groups in the chain (correlated with gel formation in hevea rubber) exist, the identical microstructures of guayule and Hevea essentially are assured (Campos Lopez, et al, 1978).

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*See Section I-2, "Mechanical Porperties."

Guayule rubber in its native state has important differences when compared with hevea rubber. Findings of recent studies show that the molecular weight is in the order of 10 and is unimodal with a polydispersity lower than 2.5. Tests of guayule rubber from four Mexican states of Zacatecas, Coahuila, Nuevo Leon and Durango have demonstrated that variation in macromolecular size is not influenced materially by the geographic locations where plants are grown (Angulo-Sanchez, et al, 1979), although the rubber content is influenced by both geographic location and shrub variety. It will be helpful in the genetic improvement of guayule if, unlike Hevea, rubber characteristics are not markedly affected by modest genetic changes (Compos-Lopez, et al, 1978).

2. <u>Mechanical properties</u>: Green strength is a measure of the strength of raw rubber during extension. Preliminary measurements show that the green strength of guayule rubber is intermediate between that of synthetic polyisoprene and hevea rubber. If further studies confirm guayule rubber green strength to be intermediate, it might limit the percentage of guayule rubber that would be blended with other elastomers for tire manufacturers. Green strength is important only during fabrication, before vulcanization, and does not affect the quality of the final manufactured product; it is primarily important to large corporations that manufacture tires (National Academy of Sciences, 1977). Preliminary studies indicate that chemical promoters could increase guayule green strength to that of hevea rubber (Campos-Lopez, et al, 1978).

"Building tack" measures how well layers of raw rubber stick together before they are vulcanized, a property that is very important in fabricating certain types of tires. Synthetic elastomers have a lower building tack value than do hevea and guayule rubber. The excellent flow as well as tack characteristics of guayule rubber should make it suitable for tire manufacture (National Academy of Sciences, 1977).

The plasticity-retention index measures rubber rheological stability. Although the guayule sample tested fell short in comparison with the highest quality hevea rubber, it was in the range of the hevea rubber used in tires (National Academy of Sciences, 1977).

The percent changes due to age in tensile properties of hevea and guayule rubber were equivalent, indicating that the guayule rubber was sufficiently stablized to age at the same rate as hevea rubber (Winkler, et al, 1978).

Guayule rubber does have physical properties similar to those obtained with hevea rubber vulcanizates. If a "technically specified" type of guayule is commercially feasible, it can become a direct substitute for hevea rubber, but additional research directed at developing vulcanization recipes is needed (Winkler et al, 1978).

3. <u>Processing characteristics</u>: Hevea rubber is produced commercially with a series of impurities including proteins and sugars. Some of these impurities are important because they are agents in further processing steps such as milling and vulcanization. Guayule rubber now produced in the Mexican pilot plant also contains impurities but they are chemically different from those present in hevea rubber. Inherent impurities constitute one of the major differences between hevea and guayule rubber. These differences will be reflected both in processing characteristics (milling, vulcanization, extrusion, etc.) and in mechanical properties (tensile, modulus, etc.) if identical curing formulations are used (Campos-Lopez, et al, 1978). The lack of vulcanizing activators in guayule rubber causes it to vulcanize slower than hevea rubber, but adding accelerators to the formulation can overcome this problem (National Academy of Sciences, 1977).

No difficulties are expected in processing guayule rubber with standard equipment because of its structural similarity to hevea rubber. The presence of resins in guayule rubber could facilitate milling and extrusion, and even reduce energy consumption during these processes. The aspects of resin in guayule rubber are being studied.

4. <u>Performance</u>: Until recently, very little was known of the performance of unblended guayule rubber. Virtually all of the 120,000 tons of resin- containing guayule rubber purchased by rubber companies between 1903 and 1946 were blended with hevea rubber. Guayule rubber may have been used as much for its tackiness as for its rubbery nature (National Academy of Sciences, 1977).

Various Mexican, U.S. and European rubber companies have been testing guayule rubber for both tire and non-tire use. The University of Akron and the Goodyear Tire and Rubber Company recently have confirmed that guayule can yield high quality natural rubber, based on laboratory and field trials. Automobile and truck tires that contain 35 percent to 40 percent guayule rubber have passed a number of vigorous U.S. Department of Transportation high speed, endurance and diagnostic tests (Dyckman, 1978). Results of these tests have led Goodyear researchers to conclude that guayule rubber is acceptable as a replacement for hevea rubber and synthetic rubber (cispolyisoprene) in many tire formulations. The U.S. Navy, in 1979, tested rebuilt aircraft tires with 100 percent guayule rubber tread replacement compounds. Results of these tests have led U.S. Navy engineers to conclude that guayule rubber is an acceptable substitute for hevea rubber for these high-stress applications (Berger and Fontonoz, 1980). It is believed that the data variability in tests of pilot plant batches of guayule rubber would be decreased greatly by testing samples of large-volume commercial guayule rubber production; and that if guayule rubber were available now at a competitive price, it would find a place in the international rubber market. Goodyear researchers are optimistic that additional research will make guayule rubber a viable product, competitive in price with Hevea, (Riedl, and Creasey 1978).

Initial use of guayule rubber probably would be in blends with hevea and synthetic polyisoprene rubber and with the more widely used styrene-butadiene synthetic rubber. Slight property and processing differences between guayule and hevea rubber are not noticeable under such circumstances, a factor that could facilitate greatly introduction of commercial guayule production (National Academy of Sciences, 1977).

J. Byproducts Characterization and Use

Commercial use of guayule byproducts could affect guayule rubber production economics, perhaps more than any other factor. Each ton of guayule rubber extracted produces about 2 tons of wood fiber (bagasse), 0.5 ton of resins, and about 1 ton of leaves (National Academy of Sciences. 1977). The components of harvested guayule shrubs listed in Table III-6 are from the National Academy of Sciences (1977) report on guayule.

TABLE III-6
HARVESTED GUAYULE SHRUBS

Components	Percent
Moisture	45 - 60
Rubber	8 - 26*
Resins	5 15*
Bagasse	50 - 55*
Leaves	15 - 20*
Cork	1 - 3*
Water Solubles	10 - 12*
Dirt and Rocks	Variable

*Dry-Weight Basis

1. Resins: Identifying and characterizing guayule acetone- soluble constituents received major attention during the 1940s research efforts. The resins seemed to offer the most promise of financial return. It was found that by deresinating shrub variety 593 approximately 0.5 pound of resin could be obtained from each pound of rubber produced. Deresinating rubber extracted in the form of worms resulted in yield of about half that amount.

Hammond and Polhamus (1965) have described the potential use of guayule resin components. Approximately 37 percent of the resin obtained from rubber worms consisted of unsaturated, long-chain fatty acids, notably linoleic acid, with traces of linolenic and oleic acids. Linoleic acid is a chemical with an established use in the paint and varnish industries.

Cinnamic acid is present in resin as the ester of parthenoil and can be released by saponification. It has established value in the comestics and pharmaceuticals industries.

Guayule terpenes constitute a potentially valuable "naval stores" type of byproduct. Three percent to 5 percent of the worm resin and a much higher proportion of leaf resin contain volatile terpenes including alpha-pinene, dipentene, cadinene, parthenoil and others. Sesqui-, di-, and higher terpenes also are readily obtainable in significant quantities from the non-volatile, unsaponifiable fraction.

A "drying resin" fraction readily obtainable from guayule shrub resin is a hexane-insoluble, alcohol soluble shellac-like gum resin that is polymerized easily to produce a heat-resistant, clear coating that has good solvent resistance. This fraction constitutes 35 percent to 50 percent of the guayule shrub resin, but a much smaller proportion of the worm resin. Apparently all rubber-making plants produce some amount of cyclic tri-terpene alcohols that are combined as esters. Sometimes they are present as oxidized carboxyl-group- containing derivatives. The drying resin fraction may have a tri-terprene nature, possibly with di-terpenes such as abietic and pinaric acids. If this is true, the drying resin fraction could have economic potential in the naval stores industry because this industry needs a new source of higher cyclic di- and tri-terpenes for a variety of products including paint and paper sizing (Bonner, 1979b).

Betaine, a constituent of guayule resins contained in water extracts of guayule shrub, is also a byproduct of the sugarbeet industry. It has a limited market as a pharmaceutical and as an intermediate in producing surface active agents, disinfectants and other chemicals (Hammond and Polhamus, 1965).

Centro de Investigacion en Quimica Aplicada studies of guayule resin include work to develop varnishes and adhesives. Possible other uses such as pigment dispersers for rubber and tackifiers are being evaluated.

Research is needed to devise commercially feasible techniques to separate resins to produce salable byproducts. It is conceivable that guayule resins could prove to be more valuable than guayule rubber (National Academy of Sciences, 1977), a factor that would influence profoundly production methods and the quality of the rubber recovered (K. Taylor, 1946).

2. Bagasse: The importance of bagasse as a fuel source for guayule processing is indisputable. ERP work showed that properly dried bagasse can supply all the heat requirements for large processing operations. Studies of bagasse as a soil amendment and fertilizer indicated, as a general rule, that it should not be added to soil unless it is combined with nitrogen (K. Taylor, 1946).

Guayule bagasse has been pressed into fuel logs and satisfactorily burned in fireplaces. Bagasse and guayule leaves, in varying ratios, also were subjected to pressure and heat. The resulting products have possible uses as insulation or wall board (K. Taylor, 1946).

3. Leaves: Guayule leaves removed by parboiling can be used as a fertilizer or soil amendment. They are also an important untapped source of resins, especially the volatile terpenes, wax and plant pigments. However, much of the leaf resin value would be lost in the parboiling process.

4. Wax: The dry matter weight of guayule leaves is 2.5 percent cuticle wax that has one of the highest melting points (169 F) ever recorded for a natural wax. However, in view of the small quantity involved and the fact that the wax would have to be removed by solvent extraction, wax production from guayule leaves may not be economically viable (Bonner, 1979b).

5. Oil: A volatile oil with a distinctive lingering, spicy odor can be separated from guayule resins and leaves by steam distillation. The oil contains mono- and sequi-terpenes including A* and B* pinene, limonene, cadinene and partheniols 3 and 4, and could be valuable to industry (National Academy of Sciences, 1977).

6. Cork: Guayule cork is obtained conveniently and has been suggested as a possible linoleum filler. To date no tests have been conducted to verify this suggestion (Hammond and Polhamus, 1965).

7. Seeds: Guayule seeds contain oil and have a protein content of 11 percent to 14 percent. Its potential as human and animal food is unknown.

8. Other uses for guayule: Palatability and nutritional studies are needed to ascertain whether guayule could be a supplemental browse shrub for livestock. The growing shrub also has potential for controlling soil erosion and for landscaping. All of these other potential uses are important in semiard regions where water conservation is of critical concern. Intercropping guayule with food crops might prove useful.

IV. PROSPECTS OF GUAYULE COMMERCIALIZATION

U.S. commercial guayule production depends on the technical and agronomic aspects of production as well as interactions between economic, environmental, social and political factors. These factors, which can encompass regional, national and international concerns and which could promote or constrain guayule development, are analyzed in this chapter.

A. Driving Forces

A number of factors at local, regional, national and international levels are operating to stimulate guayule industry development. These factors include potentials for economic returns, water conservation and arid-land use for farmers in the U.S. Southwest, possible worldwide shortages of natural rubber, increasing prices for natural rubber and synthetic rubber feedstocks, and the need for adequate stockpiling of rubber as a strategic material.

1. Economic benefits to farmers and other producers: The economic benefits to farmers relate directly to the annual net returns per acre that might be realized from guayule production when compared with net returns per acre for other, more conventional crops. At the present experimental development stage estimates of net returns per acre for guayule are inexact. Furthermore, estimates of net return per acre for conventional field crops vary greatly from year to year, from region to region, and from one method of estimation to another. However, a relative competition potential can be developed from available data.

Firestone's Glymph and Nivert (1978) estimate guayule growing costs, in 1985 dollars, of \$.29 to \$.38 per pound of rubber. Lacewell (1979), Texas A & M University, estimates approximately \$.35 per pound of rubber in 1979 dollars. Wright (1979), University of Arizona, estimates \$.45 per pound of rubber in 1979 dollars. In the economic drive scenario (Scenario A), a straight \$30 per acre annual profit has been factored into guayule production economics. This was based on average returns per acre for certain agricultural areas in central Arizona.

The latest estimate received from Nivert (1979) indicates that a net cash flow of \$6.35 million per year could be realized by a processing facility that produced 50 million pounds of rubber per year. This estimate is based on forecast processing costs of \$.20 per pound of rubber, Wright's agricultural production costs of \$.45 per pound of rubber, resin values of \$.20 per pound and a bagasse credit of \$.01 per pound of rubber. For an $18 million to $20 million facility, this estimated cash flow would represent a 27 percent discounted return on investment. Allowing a 15 percent return on investment for the processing facility would release $2.85 million for farmer profit, or $28.50 per acre per year. Increasing the resin value to $.25 per pound (considered probable by several researchers) and holding the processing profit to a 15 percent return on investment would release $4.26 million, or $42.60 per acre per year. Based on the highest agricultural production cost estimate available, an annual range from $28 to $42 net return per acre is a conservative estimate for comparison with estimated net returns for other field crops in the potential guayule growing region.

The USDA Economics, Statistics and Cooperatives Service, Oklahoma State University, provides the only estimated net crop return budgets that cover the entire guayule growth region. These estimates are incomplete, but provide sufficient information for a preliminary state-by-state indication of crop profitability. Table IV 1 lists the net returns for six major field crops grown in the potential guayule growth region. To indicate variability of net farm returns two Arizona net return estimates are provided for comparison. As illustrated by this comparison, regional estimates may vary by as much as an order of magnitude, e.g. see cotton, Arizona, 1977 in Table IV-1 . The more qualitative question of crop profit or loss appears to be estimated more reliably.

Of the major field crops under consideration in the region, only cotton and hay showed profits in 1979. Although sugarbeets showed profits in Arizona in 1977, the trend is clearly down from +$75 in 1976; +$30 in 1977 and -$30 in 1978. If guayule can be grown for a net profit, it should compete with grain crops and sugarbeets in the U.S. Southwest.

Cotton continues to be a favorite annual crop in the region; in 1979 cropped acreage was at an all-time high. A comfortable market for cotton continues as the price of competitive synthetic polyester materials is pushed upward by increasing oil prices (Anonymous, 1979f).

A combination of profitability and the water conservation potential could make guayule an attractive alternative crop to wheat, barley, sorghum, pasturage and sugarbeets. Further, if the guayule commercialization infrastructure allows involvement of farmer cooperatives, Indian communities, or other local organizations in guayule rubber extracting and byproduct processing, economic benefits associated with jobs and added value also could accrue to regional guayule producers. A producer/processor combination would have the added benefit of an expanded market for the product, i.e., the world rubber and resin markets vs. a single guayule processing facility.

TABLE IV-1

CROP PROFITABILITY ESTIMATES (DOLLARS/ACRE/YEAR)

	Texas		New Mexico 1/	Arizona		California	
	South 1/	West 2/		Estimate 1/ one (1977)	Estimate 3/ two (1977)	Central Valley	Colorado Desert
Cotton	-46 to -95	-80 to -95	+37	+ 8	+85	+28	-168
Hay (including alfalfa)	----	+35 to -93	----	+ 14	+90	+11	----
Wheat	-35	-129	----	- 58	-45	-78	-134
Barley	----	-189	----	- 83	-58	-67	----
Sorghum	-47 to -59	-146	----	-128	-93	-89	----
Sugarbeets	----	----	----	----	+30	----	----

1/ 1977 Net return per acre estimates. (USDA, Economics, Statistics and Cooperatives Service, 1979).

2/ 1979 projected input and crop prices. (Condra, 1979).

3/ Actual returns per acre computed from historical procduction costs, production per acre and returns per unit production data. (Mayes, et al, 1979)

2. <u>Economic benefits to U.S. tire and rubber companies</u>: Guayule cultivation offers U.S. tire and rubber companies opportunities to stabilize natural rubber supplies and prices, and to counter price increases by the Association of Natural Rubber Producing Countries (ANRPC).

Natural rubber supplies from Southeast Asia have been fairly steady during the past three years. However, recent supply-and-demand forecasts suggest little guarantee that natural rubber supplies in sufficient quantity will be available to the United States in the future. Forecasts of supply-and-demand patterns for natural rubber indicate increasing supply shortfalls beginning during 1980. As a countermeasure, the tire and rubber companies already have taken steps to expand Hevea plantations in Africa and South America.

Guayule cultivation, either in the form of large plantations or many smaller plantings, offers another alternative that conceivably could supplement any shortfalls in overseas natural rubber production that might result from leaf blight, labor strikes, political turmoil, sabotage, war or other causes. Guayule fields could be viewed as living stockpiles to be nurtured and harvested when required, if the necessary processing facilities were in place to provide rapid rubber production.

Natural rubber price trends from January 1977 ($.42 per pound), to December 1979 ($.66 per pound), indicate greater increases in price than forecast by the World Bank and others. There is little doubt that these price hikes are caused by increased labor demands, increased taxes levied on growers and sellers, and by rapidly rising crude oil prices (note Figure IV-2). Forecasts of supply and demand for natural rubber suggest that even greater price hikes are expected from 1980 to 2000, and that prices may reach $1 per pound by the end of 1985. U.S. tire and rubber companies could use domestic guayule rubber as a bargaining tool in price negotiations. Guayule could be used domestically to reduce imports or could be sold abroad to counter price hikes by hevea rubber producers.

In October 1979, under the auspices of the United Nations Conference on Trade and Development (UNCTAD), major elastomer producing and consuming countries reached an agreement aimed at stabilizing natural rubber prices and supplies (Anonymous, 1979g). The arrangement, effective October 1, 1980, provides for maintaining natural rubber prices within a $.31-to-$.56 per pound range. (The price will be based on RSS1, RSS3 and TSR 20 grades of natural rubber). Further, the agreement creates a natural rubber buffer stock of 550,000 metric tons of which 150,000 metric tons are designated "a contingency stock to be used under exceptional circumstances." Producing and consuming countries equally will fund the buffer stock.

The buffer stock manager is obligated to: a) buy natural rubber for the buffer stock if the price falls to $.35 per pound, and b) sell from the buffer stock if the price rises to $.53 per pound based on a variation of plus or minus 20 percent from the current midpoint or reference price of $.44 per pound.

In essence, this agreement provides a floor price to ensure incentives for continued production by the least efficient producer and provides a ceiling price that protects consuming countries from what may be considered "excessively high" prices. In late November 1979, the price of natural rubber was near $.58 per pound in Malaysia and was near $.66 per pound in New York. Since the current maximum permitted price of $.56 per pound already has been exceeded, the agreement lacks credibility. It is likely that the reference price of $.44 per pound will be raised in the near future and that the maximum price will be set near New York price quotations.

The rubber agreement, is expected to be moderately successful only, in stabilizing supplies and prices. It may be quite successful in assisting the least efficient producers. However, the price of natural rubber appears to be influenced strongly by world crude oil prices; smallholders naturally would benefit from this relationship without relying on the rubber agreement.

Thus, the rubber agreement including the variable buffer stock will be of limited value as a tool for controlling prices. U.S. tire and rubber companies may acquire more leverage on supplies and prices of natural rubber through extensive domestic guayule cultivation and expansion of their own plantations around the world.

3. Regional interests: A number of regional factors have the potential to stimulate guayule commercialization. These factors include making more productive use of arid lands, growing crops that consume less agricultural water, and diversifying crop patterns.

a. Arid-land usage: Future growth of guayule commercialization and cultivation of guayule could occur on three types of land: agriculturally productive land; retired agricultural land; or undeveloped land. Irrigation will be required in all three categories in Southern California, Arizona, New Mexico and West Texas. Under natural rainfall conditions, portions of California and southern Texas conceivably could sustain guayule production without irrigation. In those areas where irrigation would be required, a dependable supply of water, not land availability, would be the limiting factor in guayule production.

Traditionally, irrigated agricultural production in the U.S. Southwest has been accomplished on the best land to maximize yields. Farmers have increased acreage only in cycles of high crop return. Those lands not considered prime agricultural lands generally lie fallow if commodity prices do not merit their use.

In the native guayule habitat, annual rainfall can be less than 9 inches, but ERP researchers concluded that 11 inches to 25 inches per year is needed for commercial rubber production. The guayule plant can survive arid conditions; but if annual rainfall is less than

14 inches, supplemental irrigation is needed to stimulate sufficient plant growth in a reasonable time.

The highest rubber yields recorded for cultivated guayule were obtained with irrigation. Irrigation allows the farmer to control the moisture that the plants receive, forces growth and shortens the production cycle.

With sufficient water to sustain prime land agriculture, acreage expansion to accommodate guayule on new or "marginal" lands is not expected to occur. (Marginal lands are defined to be deficient in adequate water for traditional crops or as having poor soil characteristics for plant growth). Guayule may be integrated best into the U.S. Southwest agricultural economy as a water-saving crop. Existing prime land will become available as farmers search for cash crops that require less water and energy to produce. Those lands previously farmed, but now having marginal water supplies for existing crops, also may be prime guayule growth areas. Thus, new land would not have to be brought into production and non-productive prime land already developed for irrigation could be used.

b. Agricultural water use and conservation: As an arid-land-adapted crop, guayule could be grown with less water than many of the agricultural crops being farmed in the U.S. Southwest. Figure IV-1 compares guayule water consumption with six other crops grown at El Paso, Texas.

Guayule can become a water-conserving crop in those irrigated agriculture areas where dwindling water supplies are impacting on the agricultural and economic potential of more conventional crops. A dwindling irrigation water supply typifies agricultural development in much of Arizona, New Mexico and West Texas.

In general, irrigation in Arizona, New Mexico and West Texas can be expected to decline. Irrigated acreage in the Arizona potential guayule growth region is expected to decline from 1.2 million acres in 1970 to 700,000 acres in 2020. New Mexico has only 200,000 acres of irrigated agriculture in the potential guayule growth region, which is expected to decline to 140,000 acres by 2020. The El Paso-Trans Pecos region in west Texas had approximately 250,000 irrigated acres in 1974. If Texas Water Development Board projections of increasing irrigation efficiency were realized, irrigation acreage might remain relatively stable in that region. Although theoretically possible, these efficiencies appear high when compared with assumptions made by other state water resource agencies. If present water efficiencies are maintained, the El Paso-Trans Pecos region probably would experience an irrigated agriculture decline to less than 150,000 acres by 2020.

The southern Texas area within the potential guayule growth region had nearly 1.25 million irrigated acres in 1974. Some areas, such as the

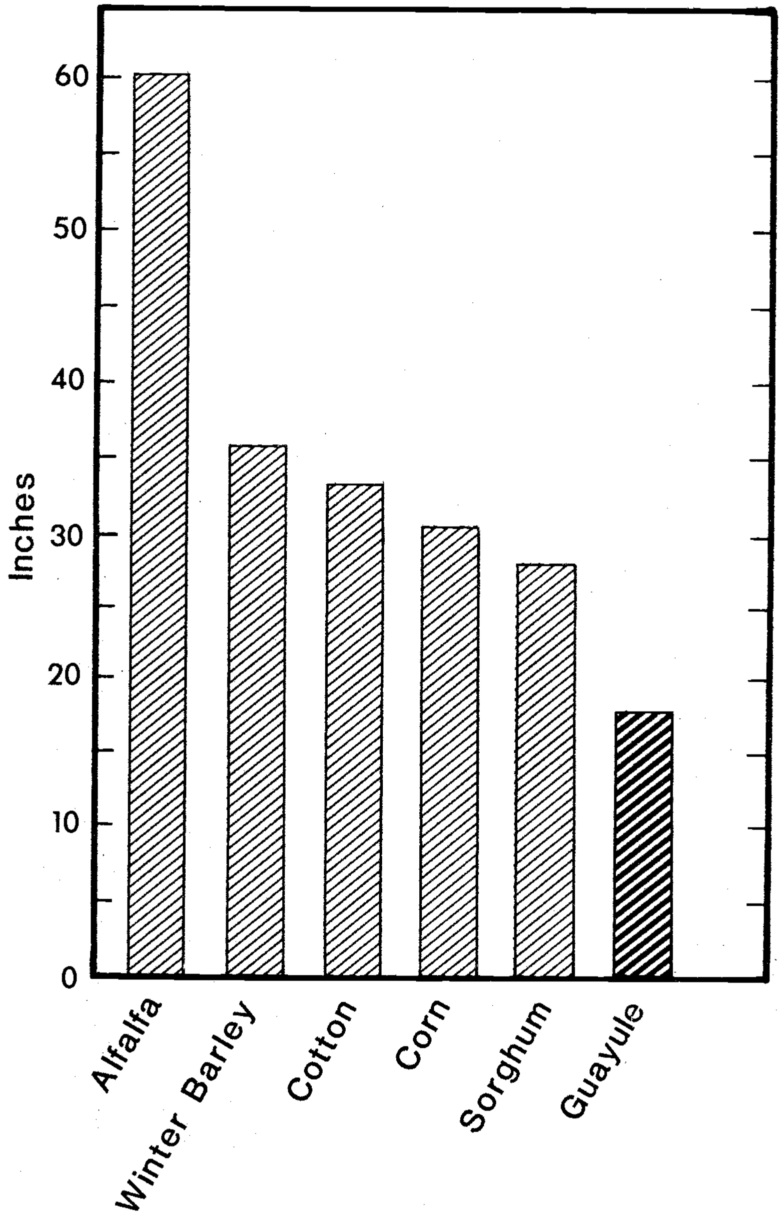

Figure IV-1: COMPARATIVE CROP WATER CONSUMPTION
Estimated water consumption by guayule compared with selected irrigated crops grown at El Paso, Texas (National Academy of Sciences, 1977).

Winter Garden Irrigation District, are experiencing groundwater decline due to aquifer overdrafts. This situation, plus a reported 1.5 million acres of "potentially irrigable soils" in an area where rainfall ranges from 20 inches to 34 inches, suggests a good possibility for dryland guayule development (Texas Water Development Board, 1977).

The California guayule growth region is a potential area of adequate water supply. Irrigated acreage in San Joaquin Valley/Tulare Lake Basin region was 4.1 million acres in 1967 and is projected to increase to 5 million acres by 2020. An additional 2 million irrigated acres are in the Colorado Desert and South Lahontan hydrographic units and include lands with Colorado River water rights. Most California land considered for potential guayule development would require some irrigation for successful guayule production.

A more detailed discussion of the relationships between agricultural land and water availability throughout the potential guayule growing region can be found in Chapter III of A Sociotechnical Survey of Guayule Rubber Commercialization: A State- of-the-Art Report (Foster, et al, 1979).

TABLE IV-2
ESTABLISHED FIELD CROPS WITH WHICH GUAYULE MIGHT COMPETE

Crop	Acres
Cotton	1,655,000
Hay	1,334,000
Wheat	862,000
Barley	751,000
Sorghum	713,000
Pasturage*	336,000
Corn	294,000
Sugarbeets	701,000

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* Only California lists pasturage in field crop statistics.

As discussed earlier, many of these crops are becoming economically marginal or are showing a net loss in much of the potential guayule growing region. This is due primarily to dwindling water supplies and escalating energy costs. Even cotton has become marginal in much of the El Paso-Trans Pecos region of West Texas. In portions of the U.S. Southwest, particularly central Arizona and West Texas, commercial development of more arid-adapted crops would be desirable not just for agricultural diversification; it has become imperative if agriculture is to survive.

4. Other national interests, including security: Incentives for U.S. guayule commercialization are partly related to national security; they hinge upon political events in Southeast Asia that may affect hevea rubber availability. These incentives also are vulnerable to political events in the Middle East that could affect the availability and the price of crude oil. National security concerns, the effect of recent events in Cambodia, Vietnam and Iran, and a short discussion of natural rubber as a strategic material to the United States are discussed in this section.

a. Natural rubber supply and crisis in Southeast Asia: The invasion of Cambodia by Vietnam and subsequent invasion of Vietnam by China threatened Southeast Asia supplies of hevea rubber to the United States. Political uncertainties and changes in the balance of power in this part of the world are powerful driving forces. They cause the United States to seek other sources of natural rubber, such as guayule, to guarantee access to this strategic and economically important resource to preserve national security.

Concerns about natural resources in Southeast Asia go beyond issues of political influence and the balances of power. This part of the world contains the principal deposits of tin ores and supplies approximately 92 percent of all hevea rubber. These two commodities are strategic materials for all technologically advanced countries and are of extreme importance to developing countries.

At present the hevea rubber supply from Southeast Asia is threatened, but is not yet affected. The rubber plantations in Cambodia, although intact, are becoming overgrown with vegetation. However, at full production, these plantations supply less than 2 percent of the world natural rubber needs. Plantations in Thailand supply approximately 10 percent of the world natural rubber needs, and approximately 5 percent of the U.S. needs. To ensure continued availability of natural rubber, it seems advisable to develop a domestic source of natural rubber to make up for potential shortfalls in natural rubber imports from Southeast Asia.

b. Crude oil supply and the Middle East crisis: In late 1979, the world consumed 57 million barrels of oil a day; 31 million barrels came from the Middle East. Three percent to 5 percent of total U.S.

consumption, approximately 19 million barrels per day, comes from Iran. Since the 1973-74 OPEC embargo, it has been clear that this oil supply is politically vulnerable. Since the crisis in Iran, prices have risen higher than had been anticipated and the Iranian supply has been cut drastically, causing a worldwide shortage of up to 2 million barrels per day.

A key to world oil supplies and prices has been the moderate pro-Western position of Saudi Arabia, a position that could be affected by any major change in Iran. Together, Saudi Arabia and Iran produced almost 25 percent of the world oil supply and had considerable moderating influences on the other members of (OPEC).

Since the 1979 revolution, Iran has been able to produce about 3 million barrels of oil a day, 50 percent of its prior production, and has supplied the United States with approximately 700,00 barrels a day, about 4 percent of U.S. consumption. This quantity has been enough to meet crude oil demand that has been slowed due to higher prices and conservation efforts. But the United States faces a continuing shortfall that it must attempt to make up with oil from other sources. In November 1979, the U.S. government ceased all purchase of Iranian oil in response to the seizure of the U.S. Embassy and embassy personnel in that country. This has exacerbated further the U.S. oil import situation. Other OPEC countries have not been affected directly by the internal turmoil in Iran and are continuing to produce oil steadily. Indirectly, many countries and dealers have taken advantage of the uncertain world oil supply and have raised prices; more oil is being sold on the European spot market at prices nearly twice the long-term contract prices. This surely will cause OPEC countries to set 1980 market prices much higher, thus causing all oil prices to rise considerably in the near future.

In the immediate future, higher oil prices and potential shortages with corresponding price increases and feedstock and petrochemicals shortages are forecast.

c. Recent price trends for rubber and crude oil: Figure IV-2 shows the dramatic effect the 1972-73 oil embargo and sharply rising prices have had on synthetic rubber prices; oil and rubber prices doubled. It would appear that the rising oil prices and the potential shortfall in supply will cause general price increases and/or shortages in all primary petrochemicals and petrochemical products including synthetic rubber, rubber products and rubber processing chemicals. These price increases and/or shortages can be met by finding other sources of oil outside the Middle East; by importing and using more hevea rubber; or by commercializing domestic guayule rubber. The first two options have inherent difficulties and uncertainties caused by social political and change They point to the need for a reliable, domestic rubber source such as guayule.

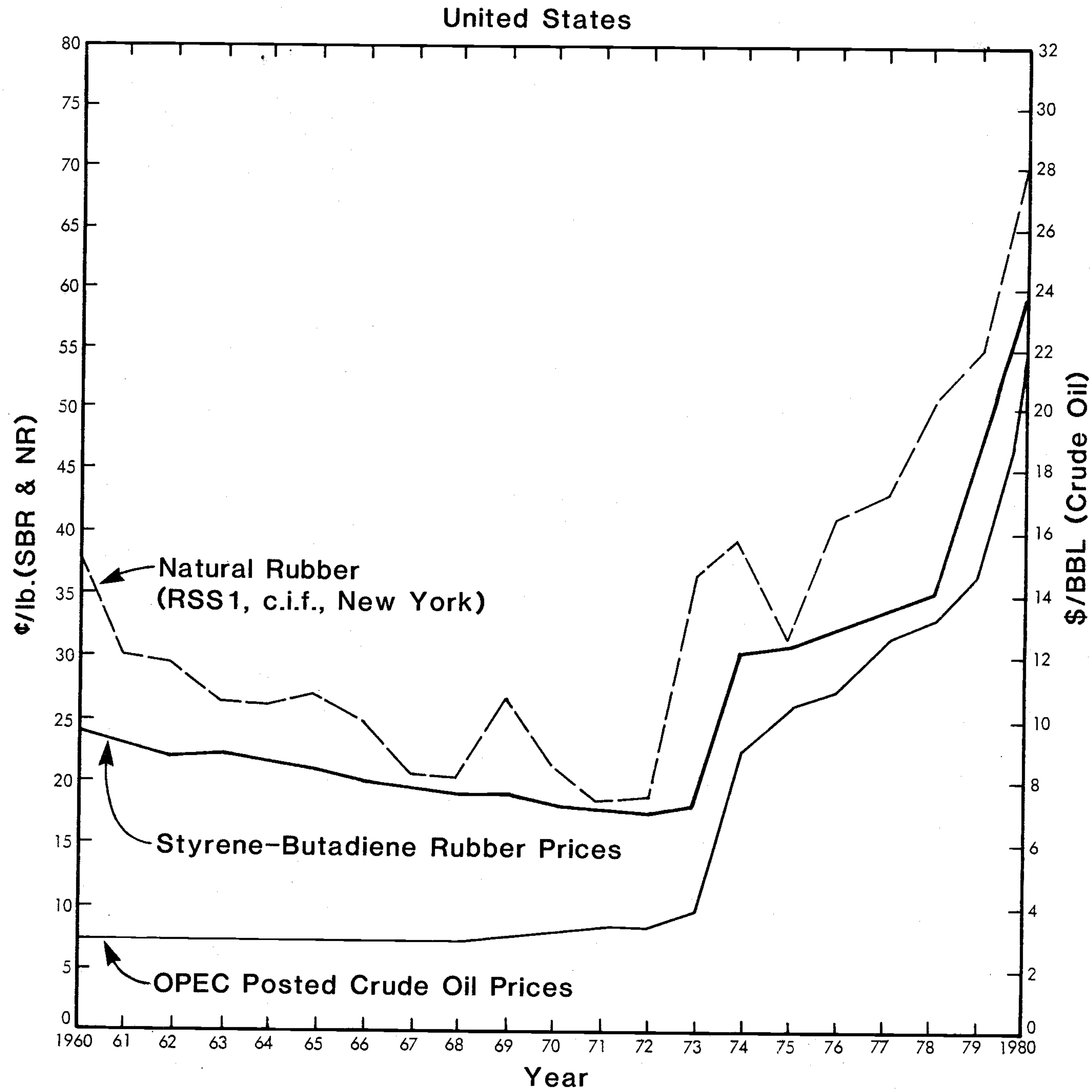

Figure IV-2: OIL AND RUBBER PRICES

d. Stockpiling and rubber specification: Driving forces for commercializing guayule include stockpiling natural rubber for U.S. Department of Defense use and strengthening the U.S. economy during times of conflict and times when normal foreign supplies are disrupted. The Strategic and Critical Materials Stockpiling Act of 1979 clearly identifies as essential certain metals and other materials, including hevea rubber. In 1978, the Federal Preparedness Agency established a stockpile goal of 520,00 metric tons of crude natural rubber. The stockpile currently contains approximately 120,000 metric tons; thus, there is an approximate 400,000-metric- ton shortfall to be filled by future natural rubber acquisitions. Crude natural rubber purchased for the stockpile must conform to U.S. Department of Commerce national stockpile purchase specifications, for crude natural rubber (1977). These specifications cover the following grades: No. 1 RSS-- standard quality rubber ribbed smoked sheets; No. 2 RSS-- good-fair-average quality rubber smoked sheets; and No. 3 RSS-- fair-average-quality ribbed smoked sheets. These specifications conform to the type and quality described in the International Standards of Quality and Packing for Natural Rubber Grades (IRQPC, 1968).

Experimental tests of guayule rubber will be required to determine if it will meet the same specifications as ribbed smoked sheets of hevea rubber. The U.S. Department of Defense has developed tests to evaluate guayule rubber as a substitute for hevea rubber used in military aircraft and truck tires (Dyckman, 1977).

A lack of guayule specifications led Winkler, Schostarz and Stephens (1978) to evaluate Mexican guayule rubber in an effort to determine its physical properties and vulcanization characteristics. Guayule rubber has physical properties similar to those obtained with hevea rubber vulcanizates. They conclude that if a "technically specified" type of guayule is commercially feasible, this form of rubber can become a direct substitute for hevea rubber.

In October 1979, the U.S. Department of the Navy tested jet aircraft tires containing substantial amounts of guayule rubber. Repeated takeoffs and landings by a modern Navy jet aircraft were made without incident.

e. Balance of payments: In 1978, the United States imported about 670,000 metric tons of natural rubber, about 20 percent of world production, that was valued at or near $750 million (IRSG, 1979). Furthermore, the United States imported about 36 million barrels of oil valued at $500 million to supply the American synthetic rubber industry. Imports of hevea rubber and oil destined for the rubber industry amounted to approximately $1.3 billion compared with an estimated $28.5 billion overall U.S. trade deficit in 1978.

Table IV-3 presents aggregate U.S. export-import trade data for selected rubber and plastics commodities (Anonymous, 1979h). In 1978,

TABLE IV-3

U.S. EXPORT-IMPORT TRADE OF SELECTED RUBBER AND PLASTICS COMMODITIES*

Category	Export/Import Total ($ Million)		Trade Balance ($ Million)
	Export	Import	
Crude rubber (total)	386	840	-454
Natural rubber, latex, gums	16	690	-674
Synthetic rubber and latex	369	149	+220
Synthetic resins, rubber and plastics materials, including scrap (total)	2,088	518	+1,570
Tires, tubes, rubber or plastic, (total)	280	923	-643
Clothing (total)	49	731	-682
Industry-related commodities (total)	120	186	-66
Miscellaneous manufactured articles, NEC (total)	828	744	+84
Total rubber and plastics trade	3,862	3,941	-79
Total merchandise trade	143,575	172,062	-28,451

*Anonymous (Rubber and Plastics News) 1979d.

total crude rubber experienced a trade deficit of $454 million that would have been larger ($674 million) if there were not a trade surplus of $220 million in synthetic rubber and latex. The category of synthetic resins, rubber and plastics materials, including scrap, had a trade surplus of $1.57 billion, testifying to the strength of the total U.S. synthetic rubber industry. By contrast, U.S. tiremakers suffered a trade loss of $643 million.

On balance, however, the total U.S. rubber and plastics export-import trade experienced a relatively small deficit of $79 million. Domestic cultivation of guayule for rubber that involved perhaps 1 million to 2 million acres, and that produced between $200 million and $400 million worth of natual rubber annually, could significantly impact on the U.S. trade balance for rubber and plastics commodities.

B. Constraints

A number of forces are operating at the local, regional, national and international levels to inhibit guayule industry development. These forces include uncertain guayule economics and potential hevea rubber price flexibility, recent trends toward depression of the tire industry, crop displacement conflicts, antitrust and other infrastructure restraints, and U.S. international trade relationships with Hevea producing nations.

1. Economic uncertainties: Recent instabilities in the U.S. tire and rubber industry, as well as a lack of clear economic leadership in guayule development, potentially could restrain guayule development.

a. Economic health of the U.S. tire and rubber industry: The economic strength of the U.S. tire and rubber industry declined in late fall 1979 as significant changes in tire supply-and-demand patterns began to unfold (Anonymous, 1979i). The causes of the industry's slump are traceable to several factors as follows.

i. Because of a possible strike action by the United Rubber Workers Union (URW) in spring 1979, tire-rubber producers acquired huge inventories. However, the strike did not materialize since the industry leaders reached an agreement with the URW. This agreement resulted in an increase in hourly labor costs estimated at 35 percent to 40 percent during the next three years.

ii. During spring and summer 1979, the large inventories of tires were drawn down sufficiently because of a sagging demand for passenger car tires as consumers reacted to tight gasoline supplies and to presidential and the U.S. Department of Energy gasoline conservation suggestions. Total tire sales in 1979 were estimated to be approximately 9 percent less than the previous year. Both new and replacement tire sales for autos and trucks, especially recreational vehicles, were significantly lower than forecast.

Prices of raw materials (smoked rubber and rubber processing chemicals and additives) rose faster than anticipated. Raw rubber rose from approximately $.55 per pound in mid-1978 to approximately $.65 per pound in late 1979, and briefly reached $.70 per pound in June 1979.

Although these natural rubber prices constrain a viable tire market, they provide a potential stimulus for guayule production as a stabilizing and possibly less expensive source of natural rubber. However, Dr. James Bonner, as well as a number of other researchers, considers the world hevea rubber price to be artificially inflated. In this case natural rubber prices could be reduced greatly if guayule rubber were believed to be a threat to the existant price structure.

Competition among the major tiremakers had cut profit margins drastically. Two industry leaders accounted for 55 percent of the total market. Other tiremakers openly accused these companies of attempting to increase market shares at the expense of profits, i.e., undercutting bids and price-shaving.

Specific company-related problems include loss in consumer confidence due to tire recall by the U.S. Department of Transportation; differential labor costs resulting from separate URW contracts with tire manufacturers; and problems in some companies characterized by insufficient capital available for investing in new plants and equipment or plant improvements for radial tire manufacture.

Against this backdrop of company-related economic problems is the general consumer preference for radial passenger and small truck tires at the expense of the older, bias-ply tires. Radial-tires now account for approximately 55 percent of the tire market and are forecast to increase in the market by approximately 9 percent annually.

As a result, many tire companies have phased out or are phasing out older, bias-ply tire plants and are building highly efficient facilities to meet the rising demand for radial tires.* For example, B.F. Goodrich Company will spend $40 million to expand its domestic radial-tire production (Anonymous, 1979k); and Firestone Tire and Rubber Company closed out a bias-ply passenger tire plant in Los Angeles in 1979 (Anonymous, 1979g). Similar action is expected

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* Radial truck tires last longer, run cooler and provide up to 6 percent better gas mileage than bias-ply tires (Anonymous, 1979j).

by Goodyear Tire and Rubber Company regarding its bias-ply tire plant in Los Angeles California, and in Conshohocken, Pennsylvania.

A decided geographic shift in the tire fabrication industry took place during the 1970s. Akron, Ohio, and the Northeast are no longer predominant tire centers. The most modern tire facilities now are in the U.S. Midwest and South, specifically in Iowa, Missouri, and Oklahoma. It is expected that Texas soon will have a radial tire plant.

The depressed U.S. tire industry shares a generally gloomy short-term economic forecast involving tight energy supplies, inflation and shortage of investment capital (Anonymous, 1979m; Anonymous, 1979n). The United States is becoming increasingly dependent on imported oil; total requirements in 1979 were 43 percent vs. 23 percent in 1969. During the early 1980s foreign oil supplies are expected to level off but with little or no let up in price increases. An expected U.S. shortfall of oil imports may be from 5 percent to 10 percent depending on policies adopted by OPEC.

Contract price of Middle East crude oil jumped considerably in 1979, and was more than $25 per barrel in January 1980. Crude oil spot market prices in Europe may be double that amount.

Annual U.S. inflation rates may continue at 7 percent to 9 percent in the 1980s. Principal reasons are related to oil prices, industry and consumer price expectations, and spot shortages in raw materials.

Current high U.S. interest rates, the general shortage of investment funds, the general decline or leveling off of productivity and relatively low economic growth rates may continue through the early 1980s. These and other unknown and uncontrollable geopolitical factors and events can make it only more difficult for the tire and rubber industry and the United States to sustain or advance the standard of living. These factors and events can constrain the demand for all rubber, whether it is Hevea, guayule or synthetic.

b. Guayule economics: The inexact and "laboratory nature" of cost and profit estimates for guayule production and processing act to constrain orderly guayule commercialization. Field plantings of sufficient scale and pilot processing, above the laboratory scale, are needed in the United States before farmers or processors can venture into guayule production and processing facility development, or before lenders will venture into investing in either operation. Further, the nature of guayule development would require close coordination between production and processing. No growers can be expected to plant significant acreages of guayule without assurances that there will be a processing facility when his crop matures. Conversely, no processor can afford to invest in facility construction without guarantees of a reliable supply of guayule shrub.

High interest rates, particularly high interest on agricultural loans coupled with a three-to-four-year growing cycle, tend to place a restraint on commercial guayule development. In addition, the extended growing cycle can inhibit guayule development if there is no established price guarantee mechanism. The world price of rubber can be predicted fairly reliably to continue to increase, but to the U.S. agricultural community guayule remains a relatively unknown commodity.

Finally, some mechanism for equitable payment to growers must be worked out. If a processing facility is to be served year round harvesting guayule with differential rubber content will be required. The easiest mechanisms to apply might be standard land rent or payment by average rubber yield per acre during the year. However, a more equitable system might be worked out that could take into account the farmer's differential ability to grow successfully high rubber-yielding guayule; the time of year of harvest relative to maximum possible yields; the use of freed land; and the number of required water applications.

These problems in guayule development are exacerbated by a lack of clear leadership and economic commitment from either the government or private sector. Although the Native Latex Commercialization Act of 1978 established a lead policy for government in guayule development, only a very small portion of approved monies actually have been allocated. Although industry, notably Firestone, is pursuing processing technology, there is little evidence of a necessary scale of industrial research into guayule production agronomics. Both the government and the private sector are filing patent applications for portions of guayule processing technology. Until clear leadership is taken in an economic commitment to develop guayule, in coordination with the production and processing sectors, guayule commercialization may be realized on paper but not in the field.

2. <u>Regional and environmental considerations</u>: A number of regional factors have the potential to constrain guayule commercialization. These factors include land, water and commodity trade-offs, and environmental concerns.

a. <u>Land, water and commodity trade-offs</u>: Full-scale guayule commercialization would imply resource and product development trade-offs. In general, committing agricultural land, water and labor to guayule would be at the expense of producing certain other field crops.

Guayule cultivation may save water and energy in those areas where irrigated agriculture is practiced because it is a relatively low-water-demanding crop. Potentially, guayule could be brought into production: 1) as a non-irrigated crop where traditional crops require some supplemental irrigation; 2) as a non-irrigated crop where precipitation and/or irrigation water are insufficient for traditional crops; 3) as an irrigated crop where water costs are too high for producing traditional crops (idle farmland); and/or 4) as an irrigated crop to replace traditional crops where irrigation costs are rising.

Conserving scarce water resources or re-introducing idle farmland into production are positive incentives for guayule introduction; however, introducing guayule might be constrained by future food and fiber needs of the nation and institutional decisions to conserve water for municipalities. Table IV-4 shows average production of the 10 major field crops grown in the potential guayule growth area. It is unlikely that guayule will replace either orchard crops or vegetables in the foreseeable future.

Extensively developing guayule production could result in significant reductions in national cotton production. Declines also could occur in national sugarbeet, barley and sorghum production if guayule cultivation consumes large acreages. Barley, cotton and sugarbeets all require at least twice the precipitation and/or irrigation water necessary for guayule production. Sorghum requires approximately one-and-a-half times as much water as guayule.

Although guayule uses less water in comparison with more conventional crops, there are conditions under which introducing guayule would constitute an additional depletion of diminishing water supplies. In Arizona, New Mexico and West Texas, much developed, irrigated farmland is predicted to become idle due to declining water-demanding sectors of the economy. In instances when the water savings inherent in guayule production would be sufficient to warrant returning these idled farmlands to agricultural production, institutional water resource allocations could prohibit guayule production.

The extent to which guayule can compete with conventional crops is dependent upon the economic dynamics of those crops. Cotton, for example, shares with guayule the driving force of oil price increases raising the price of competitive commodities. Sugarbeets, which represent one of the best agricultural feedstocks for alcohol production, may increase in competition as the use of gasohol in automobiles becomes more widespread.

The extent to which guayule development potentially could impact on the agricultural land base in the U.S. Southwest is depicted in Figure IV-3. Bar 1 shows 6.9 million acres harvested in potential guayule growth region during the mid-1970s, as reported by the respective state crop and livestock reporting services and the Bureau of Indian Affairs (1976). Bar 2 shows the projected harvested acreage in the potential guayule growth region for the year 2000. Bar 2 reflects the same agricultural assumptions as those of Bar 1. Additional lands with Colorado River water rights are incorporated in Bar 3 as well as increased Indian land acreage and projected guayule dryland farming acreage that, at present, are not developed for agriculture.

TABLE IV-4

AGRICULTURAL PRODUCTION OF SELECTED FIELD CROPS FOR THE POTENTIAL GUAYULE GROWTH REGION AND FOR THE NATION

Average for Crop Years 1975 through 1977

Crop	National[1] Production	Regional[2] Production	Percent of National Production
Cotton[3] (1,000 bales)	11,091	3,287	30
Sugarbeets (1,000 tons)	28,068	5,730	20
Barley (1,000 bushels)	387,550	49,669	13
Sorghum (1,000 bushels)	754,503	34,336	5
Hay (all types) (1,000 tons)	127,758	6,575	5
Wheat (1,000 bushels)	2,096,871	44,155	2
Flaxseed (1,000 bushels)	13,154	83	0.6
Corn (1,000 bushels)	6,150,915	31,835	0.5
Oats (1,000 bushels)	645,424	2,818	0.4
Soybeans (1,000 bushels)	1,517,092	106	-

1/Source: U.S. Department of Agriculture, Agricultural Statistics, 1978.

2/Source: Sums of totals for the potential guayule growth regions of Arizona, California, Nevada, New Mexico and Texas.

3/The guayule region grows virtually all of the U.S. Pima cotton produced.

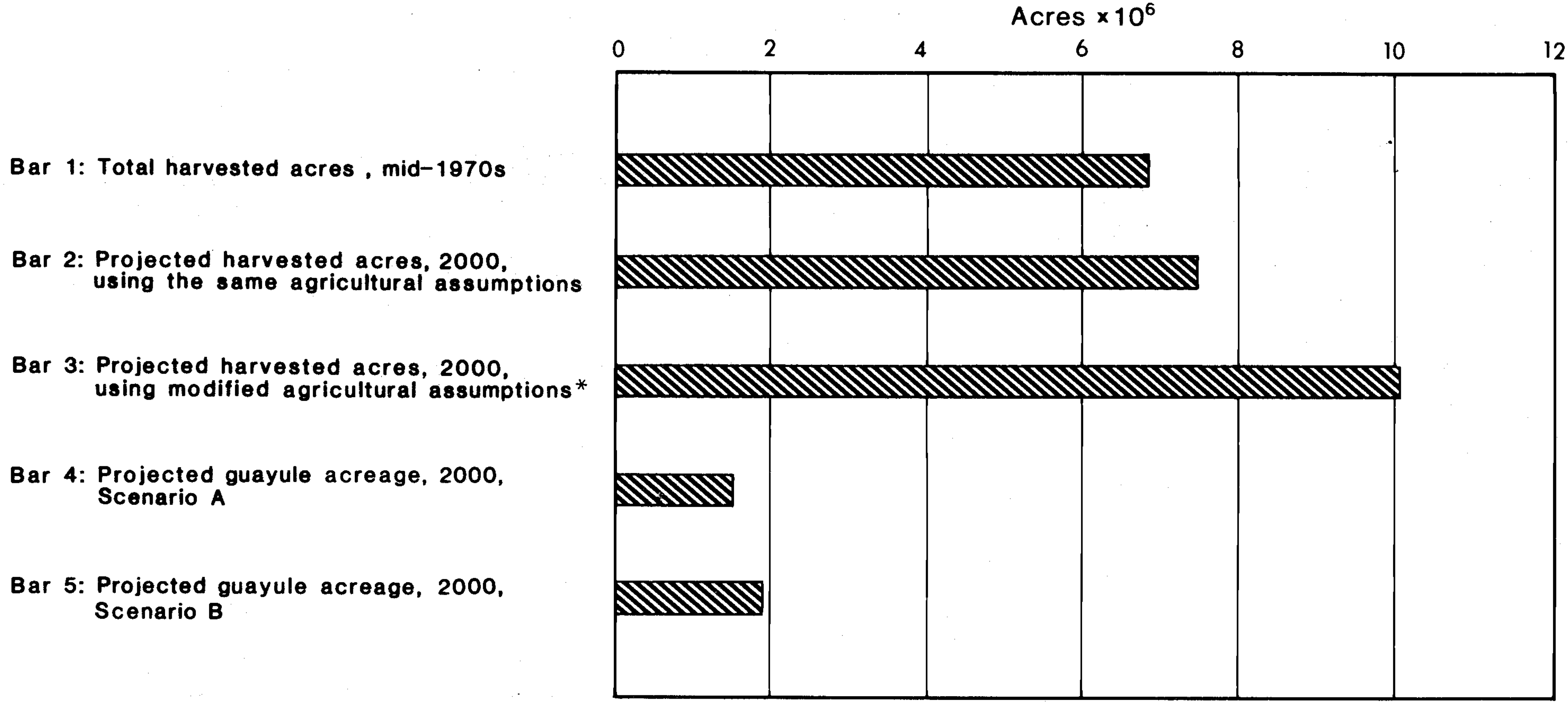

Figure IV-3: RELATIONSHIP BETWEEN ACREAGE PROJECTED FOR GUAYULE DEVELOPMENT AND TOTAL HARVESTED AGRICULTURAL ACREAGE IN THE POTENTIAL GUAYULE GROWTH REGION.

*INCLUDES THE FOLLOWING ADDITIONAL ACREAGES: 1,321,000 ACRES WITH COLORADO RIVER WATER RIGHTS; 500,000 ACRES OF INDIAN AGRICULTURAL LANDS; AND 300,000 ACRES FOR DRYLAND GUAYULE DEVELOPMENT.

Bar 4 shows the 1.55 million acres projected for guayule development under Scenario A, and Bar 5 represents the 1.95 million guayule acres projected in Scenario B for the year 2000.

Relating the projected guayule acreages (Bar 4 and 5) with the modified projected agricultural acreage (Bar 3), guayule would require 15 percent of the areal agricultural land under Scenario A, and 19 percent under Scenario B.

b. Environmental considerations: Table IV-5 is an interaction matrix that indicates environmental factors that can affect guayule development. Guayule has relatively high salt tolerance, low fertility requirements, relatively low water requirements, and a low temperature tolerance to 15 F. However, guayule is relatively sensitive to soil physiology. Water, rather than land, is the limiting factor for agriculture for the majority of the potential guayule growth region. Hence, these combined restrictions indicate that developed or retired farmland, rather than marginal lands, would be used for the bulk of guayule development.

Further, trends toward greater environmental concern and responsibility in the United States have resulted in passage of a number of laws that could restrain guayule development. All biocides that might be used on guayule stands would have to be registered for that use. Processing facilities would have to control air and water effluents and comply with Occupational Safety and Health Administration (OSHA) regulations. If the federal government became involved directly, environment impact statements might be required. However, these restraints would apply equally to any other competing commercial endeavors in the region. Therefore, environmental regulation is considered to have a very small relative constraint on guayule commercialization.

3. Sociocultrual considerations: There are a number of sociocultural constraints on guayule development in the U.S. Southwest. These are best described in terms of barriers affecting the regional lifestyles. Some of the barriers that will limit growth and potential in the area are social barriers, access barriers and facility barriers.

a. Social barriers: Social barriers are divided between two primary components: community attitudes; and labor. Community attitudes can be barriers if leaders are against growth or if the community is unwilling to commit resources necessary to serve industry. Labor force skill levels, availability and cultural values also are important development-related concerns. Wage rates in the areas, especially the rural areas, generally are low and unemployment often is somewhat high; therefore these areas may be extremely attractive to the manufacturer of labor-intensive products. However, employee absenteeism and turnover are somewhat high, skill levels generally are low and communications are difficult due to language and cultural differences. In addition, the

TABLE IV-5

ENVIRONMENTAL CONSTRAINTS TO GUAYULE DEVELOPMENT

	Irrigated Agriculture	Dryland Agriculture
Water Quantity	18 inches to 24 inches total water required. Requires water withholding or other stress for rubber formation. Water accumulated below normal root zone may be utilized by guayule. Avoid ponding. Avoid areas with shallow water tables (5 feet or less).	Areas with as little as 18 inches rainfall can support commercial guayule development. Deep water (as low as 20 feet) may be drawn by guayule. Avoid areas with rainfall in excess of 28 inches to 30 inches. Avoid areas with shallow water tables (5 feet or less).
Water Quality	Moderately high salt tolerance. Up to 0.6 percent salinity. Deep rooting may facilitate subsurface flushing of moderate, irrigation salt buildup.	N/A
Soil Chemistry	Lethal salinity = 0.6 percent. Moderate salinity, up to 0.3 percent may stimulate rubber produciton. Low fertility requirements. pH range 6.0 to 8.5, optimum 7.2 to 8.3.	With relatively high salt tolerance and deep rooting, may be able to utilize soils retired because of salt problems.
Soil, Physical Characteristics	Fairly sensitive to soil physiology. Requires well-drained soils without shallow impervious layers or too porous subsoils. Avoid droughty or poorly drained soils.	Avoid impervious layers, droughty, poorly drained soils. Lighter textured, fine sandy loam preferred. If plantable, rocky soils okay.
Slope	Must avoid ponding. Slope tolerance determined by irrigation technique (sprinkler, furrow, etc.).	Limits set by excessive runoff and use of planting and harvesting equipment. Avoid ponding.
Temperature	Minimum temperature 15 F using present varieties. Higher minimum temperatures can damage guayule if changes are too rapid. No maximum temperature limit known.	Same
Pests	Disease tolerance/resistance similar to other crops. Susceptible to cotton rootrot, charcoal rot, dieback and wilt. Aggravated by poor drainage conditions. Susceptible to grasshopper and lygus bug attack.	Same

labor pools are small and widely dispersed, adding to labor supply problems. In many of the rural areas new employers are viewed as intruders; and the local population tends to express feelings of fearfulness and resentment that the increased activity will disrupt the community lifestyle or established individual positions within the community. In many instances throughout this area it is difficult to obtain local financing due to local attitudes toward industry.

b. Access barriers: Access barriers are associated with specific transport modes, or more physical and less easily corrected barriers, i.e. great distances or mountain ranges. Carrying large inventories is costly; most of the region's firms prefer to receive supplies in small quantities, usually from distant sources, on a regular basis. Given the increased costs of transportation it is likely that transportation will be more unreliable in the future and will delay receipt of some supplies. As a result, manufacturing firms will suffer and probably will find it easier to locate in other parts of the country.

Highway transportation in the region generally is good. The area is well-served by the interstate highway system. Communities not on this network usually are served by a well-designed and properly maintained federal and state highway system. Nevertheless, because great distances between cities and local communities exist in the area some of these communities are relatively isolated. This restricts resident interactions with and commuting to larger, more diverse centers or central work locations. It is unlikely that this problem will change in the near or long term. The rail network throughout the area also is fairly well developed although improvements and increased maintenance are needed.

c. Facility barriers: Facility barriers include activities that directly or indirectly serve an industrial, or associated establishment. Sometimes these barriers are related to the quality or the availability of services within a community. In other cases facility barriers might include such capital items as land and buildings or water or fuel availability. Desired facilities in many instances are totally absent or are poorly developed. Current problems in the potential guayule development area include the lack of sound, moderately priced housing. This tends to discourage any migration of labor from manufacturing firms. Other types of industries such as retail trade and tourist-serving functions also are discouraged. Sewer, water and other community facility barriers also limit development. Given current trends in the area, it is unlikely that these facilities will be upgraded in the near future.

4. Institutional and governmental considerations: There are numerous constraints to guayule commercialization with respect to institutional and govermental considerations. The major constraints and areas of impact or consequence are shown in Table IV-6.

TABLE IV-6

CONSTRAINTS ON GUAYULE COMMERCIALIZATION (INSTITUTIONAL AND GOVERNMENTAL CONSIDERATIONS)

Possible Constraint	Area of Consequence/Impact				
	Rubber Sources	Product Production	Product Use	Regulation	Government Relations
New Polymers	*			*	*
Increasing use of synthetics	*			*	
New producers	*				*
Cultivation of other rubber plants	*				*
Increased planting of Hevea	*				*
Tire recycling		*	*	*	
Use of substitutes/extenders		*	*	*	
Vertical integration				*	*
Shifts in transportation use from private to public				*	*
Trade agreements	*				*
Political stabilization	*				*

Substantial research in new polymer development continues. If these developments prove to be fruitful, commercialized guayule rubber use potentially would be limited Another constraint would suggest that any shortfalls of natural rubber could be made by increased use of synthetics.

In addition to guayule development a number of other rubber-producing plants exist that could be cultivated. Also, the potential exists for increasing hevea rubber cultivation in existing or new plantations or by small landholders. These two issues could be constraints to guayule development.

Using recycled tires could decrease the need for rubber; substitutes or extenders also could be used to reduce rubber demand, thus constraining guayule development.

Other areas of concern relate to governmental involvement in rubber supply and industry development. If the rubber tire companies make a total effort to vertically integrate their operations, guayule development may be affected. Shifts in transportation use from private to public means would alter the demand for rubber and, consequently, guayule commercialization.

Trade agreements between the United States and rubber-producing countries could be used to inhibit guayule commercialization. Lastly, political stabilization in the rubber-producing countries may result in some attitudinal changes with respect to stabilized sources of supply and would affect commercialized guayule production development.

V. SCENARIOS FOR THE FUTURE

The purpose of these technological forecasts is to make time and state-of-society assumptions for two different guayule growth scenarios and to make forecasts based on these assumptions.

A. Scenario A: Present Trends Continue

Discussed in this section are the state-of-society, technological and sociopolitical assumptions inherent in guayule commercialization assuming that present trends continue. This discussion is developed from a relatively "surprise-free" set of state-of-society assumptions during a 20-year forecast period, as partially outlined in Table V-1. This scenario presents a reasonable course of events that assumes minimal governmental involvement.

1. State of society assumptions: The surprise-free state is dictated primarily by an economic demand for guayule to provide rubber as a worldwide shortfall develops. Guayule production in this scenario is forecast from the perspective of the current and future costs and supply of Hevea and the corresponding planting, production and processing costs of guayule. Particular attention also is given to technological advances (e.g., in genetics, weed and pest control), energy and water use and yield increases.

This foreast is begun at the level of existing planting and processing technology and is built as a function of estimated costs, using projected yield increases. As this growth occurs, potential production units are assumed at specific southwestern United States sites. Two types of growers are assumed in projecting this technological forecast scenario: a) the private growers; and b) the rubber companies.

2. Rubber market assumptions:

a. World elastomer production and future world and U.S. demands are presented below and in Table V-2. See Figure II-3, II-4 and II-8 for graphic representations of these future projections.

i. World elastomer demand increases 6 percent annually during the 1980-2000 period.

TABLE V-1

SURPRISE-FREE STATE-OF-SOCIETY ASSUMPTIONS FOR SCENARIO A

- No natural disasters or wars of worldwide dimensions will occur.
- International tensions between major powers will ease somewhat, but big-vs.-small- and small-vs.-small-country conflicts will increase.
- World population will continue to increase, but rate will slow.
- Work, food, public health, materials and energy demands will continue to challenge capabilities; the United States remains a major food-stuffs exporter and net-energy importer.
- The U.S. government, economy and societal institutions will not change dramatically.
- The gross national product (GNP) will increase at a rate of 1 percent to 3 percent per year (inflation-free basis). Investment capital interest rates will fluctuate too much to allow 20-year projections.
- Employment trends: an increasing percentage of the work force will be in the information, service and governmental sectors while the percentage in the industrial and agricultural sectors will decline slightly. The cost of labor will increase, and the unemployment rate will be in the 4 to 8 percent range.
- Federal research and development activity will be at 4 percent to 7 percent of the federal budget or 1 percent to 1.5 percent of the GNP. All other research and development will hold at approximately 1 percent of GNP. Innovation will continue to be a goal in the governmental and private sectors.
- The costs of energy, minerals, materials, chemicals and equipment will increase as will the costs of food and fiber products.
- The population growth rate of the United States will slow. Average age of the population will increase greatly. The shifts to "sunbelt" states and from urban areas to smaller communities will continue.
- Concern over occupational public health and safety, and environmental hazards will remain high, but demands for increasingly strict controls will be tempered by an economic- and social- costs consciousness. Concern about general "quality of life" will increase.
- Concern about adequate water supplies, particularly in the southwestern United States, will increase.

TABLE V-2

WORLD AND UNITED STATES RUBBER-SUPPLY-DEMAND PROJECTIONS
SCENARIO A

Year	Hevea Production (10^6 metric tons)	World Natural Rubber Demand (10^6 metric tons)	World Natural Rubber Shortfall (10^6 metric tons)	U.S. Percentage of World Natural Rubber Demand %	Projected U.S. Natural Rubber Shortfall (10^3 metric tons)
1980	4.34	4.34	0	19	0
1981	4.49	4.6	0.11	19	21
1982	4.65	4.88	0.23	18.0	41
1983	4.81	5.17	0.36	17.4	63
1984	4.98	5.48	0.50	16.9	85
1985	5.15	5.81	0.66	16.5	109
1986	5.33	6.16	0.83	15.9	132
1987	5.52	6.53	1.00	15.4	154
1988	5.71	6.92	1.21	15.0	182
1989	5.91	7.33	1.42	14.5	206
1990	6.12	7.77	1.65	14.1	233
1991	6.36	8.24	1.88	13.7	258
1992	6.61	8.74	2.12	13.2	280
1993	6.87	9.26	2.39	12.8	306
1994	7.14	9.81	2.67	12.5	334
1995	7.43	10.40	2.97	12.1	359
1996	7.73	11.03	3.29	11.7	385
1997	8.04	11.69	3.65	11.3	412
1998	8.36	12.39	4.03	11.0	443
1999	8.69	13.13	4.44	10.5	466
2000	9.04	13.92	4.88	10.4	508

ii. U.S. elastomer demand increases 2.8 percent annually during the 1980-2000 period.

iii. Natural rubber constitutes 30 percent of the world elastomer demand and 25 percent of the U.S. elastomer consumption.

iv. Hevea supply increases 3.5 percent annually during the 1980-2000 period.

v. The world natural rubber shortfall is expected to be 1.65 x 10^6 metric tons by 1990 and 4.88 x 10^6 metric tons by 2000.

vi. The U.S. percentage of natural rubber consumption will decrease to 19 percent by 1980, 14.1 percent by 1990 and 10.4 percent by 2000.

vii. The degree to which the United States might distort the distribution of the projected world natural rubber shortfall through economic or political pressures is unknown. Therefore, the U.S. natural rubber shortfall is computed as U.S. percentage of natural rubber consumption times world natural rubber shortfall. This would equal 233,000 metric tons in 1990 and 508,000 metric tons in 2000.

b. The price of crude oil in 1979 rose far above prices previously forecast by oil experts. Assuming a price increase of 7 percent compounded annually at the contract price of oil of approximately $25 per barrel in January 1980, the price will be nearly $50 per barrel by 1990. In late 1979, spot (non-contract) market oil prices were in excess of $42 per barrel.

Natural rubber prices probably will continue to increase commensurate with the world's oil prices. It is assumed that the price of natural rubber increases at a 5 percent to 7 percent rate, compounded annually. This rate of increase reflects two factors: a) that natural rubber prices will continue to increase correspondingly with synthetic rubber prices; and b) that labor costs to produce Hevea will continue to escalate. On October 24, 1979 the Wall Street Journal quoted the price of smoked sheets of natural rubber in New York as $.67 per pound. On the basis of the above assumption, natural rubber costs would increase to the following approximate ranges: from $1.15 to $1.41 per pound by 1990 and from $1.87 to $2.77 per pound by 2000 (Table V-3).

The 1981 through 1989 world shortfall of rubber (6.32 X 10^6 metric tons) before the projected time of significant guayule entry into the U.S. rubber market will have several results:

i. Cause the United States to buy a higher proportion of the existing world natural rubber supply, thus, increasing rubber prices above the assumed 5 percent to 7 percent annual increase;

TABLE V-3
PROJECTED PRICES FOR NATURAL RUBBER AND COSTS TO PRODUCE GUAYULE
1980 THROUGH 2000
(in dollars per pound)

Year	Projected Natural Rubber Prices[1]		Projected Guayule Rubber Production Costs[2]	
	(@ 5%)	(@ 7%)	(@ 5%)	(@ 7%)
1979	.60	.67	.455	.615
1980	.63	.72	.48	.66
1981	.66	.77	.50	.70
1982	.69	.82	.53	.75
1983	.73	.88	.55	.81
1984	.77	.94	.58	.86
1985	.80	1.01	.61	.92
1986	.84	1.08	.64	.99
1987	.89	1.15	.67	1.06
1988	.93	1.23	.71	1.13
1989	.98	1.32	.74	1.21
1990	1.03	1.41	.73	1.21
1991	1.08	1.51	.72	1.22
1992	1.13	1.61	.71	1.24
1993	1.19	1.73	.71	1.25
1994	1.25	1.85	.71	1.27
1995	1.31	1.98	.71	1.30
1996	1.38	2.12	.71	1.33
1997	1.44	2.26	.71	1.36
1998	1.52	2.42	.72	1.39
1999	1.59	2.59	.72	1.43
2000	1.67	2.77	.73	1.47

1/ Quoted price for October 24, 1979 = $.67 for 1RSS, $.625 for SMR, and $.60 for standard Indonesian rubber (Klein, 1979).
2/ Assumes profit for both grower and processor and byproduct credit.

ii. Cause Eastern European sources of synthetic cis 1,4 polyisoprene to fill a greater portion of the elastomer market during this time period; and

iii. Allow the U.S. rubber stockpile to meet no more than 10 percent of the U.S. shortfall demand.

3. <u>Sociopolitical assumptions</u>:

a. Through the Native Latex Commercialization Act of 1978, Congress authorized $30 million to stimulate guayule research, development and demonstration during the period 1980 to 1984.

Appropriation and implementation lag one or more years behind the authorized schedule.

b. Guayule rubber is defined in technical terms based on physical and chemical tests. The federal government and the rubber industry jointly develop the standards.

c. Guayule industrial and consumer items are accepted by the public and by the products industry.

d. The U.S. government rubber stockpile initially serves as an auxiliary market for guayule.

4. <u>Guayule Technology Assumptions</u>:

a. Guayule development could meet 100 percent of the projected U.S. natural rubber shortfall by 1991.

b. Costs of growing guayule at an annual production rate of 500 pounds of rubber per acre have been estimated by Firestone's Glymph and Nivert (1978) and by University of Arizona's Wright (1979). These agricultural costs range from $.29-$.38 to $.45 per pound of rubber. These projected costs can be considered to reflect disparities in land values and water costs throughout the guayule growing region. Glymph and Nivert (1978) also projected 1985 processing costs for obtaining rubber from guayule shrub at $.205 to $.28 per pound of rubber. Combining agricultural and processing costs yields a total cost range for producing guayule rubber of $.495 to $.73 per pound of rubber. This cost range assumes no profit or byproduct credit factors. Nivert, Glymph and Snyder (1978) and Glymph and Nivert (1978) estimate byproduct credits as shown in Table V-4.

TABLE V-4

BYPRODUCT VALUES

Byproduct	Cents Per Pound of Byproduct	Pounds of Byproduct per Pound of Rubber	Cents per Pound of Rubber
Resin	15-25	0.7	10.5-17.5
Leaves (including wax)	1.0	0.77	0.77
Pulp	1-2		1.5-3.0
		Total	12.77-21.27

These byproduct values have been questioned by several researchers. Dr. Russell Buchanan, Northern Regional Research Center, USDA, Peoria, Illinois, has suggested that perhaps resin values should be comparable with naval-stores values, significantly lower than the suggested value of $.25 per pound. Conversely, Dr. Howard Stephens, University of Akron, Institute of Polymer Science, reports preliminary indications that there may be antioxidant and breakdown aids in the guayule resins worth $1 to $1.50 per pound. Thus, the Glymph, Nivert and Snyder published estimates represent a more median position and are used here as present-best-state-of-the-art estimates of byproduct values.

These researchers also estimate a 12 percent to 15 percent per year return that is necessary for venture capital investment; thus, a 13.5 percent increase is added to processing costs as profit. A comparable percentage return for farming operations at $.45 per pound production costs would provide $30 per acre annual profit, which is competitive with several grain crops in south-central Arizona and other areas within the guayule growing region. Thus, the costs of producing guayule rubber including profit are modified, as illustrated in Table V-5.

TABLE V-5

ESTIMATED COSTS OF PRODUCING GUAYULE

	Dollars per Pound of Rubber		
Agricultural Costs	.290	to	.450
Processing Costs	.205	to	.280
Agricultural Profit (@ $30/acre)	.060	to	.060
Processing Profit (@ 13.5 percent)	.028	to	.038
Total Production Costs	.583	to	.828
Byproduct Credit	(.128)	to	(.213)
Net Production Costs	.455	to	.615*

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*It would seem more logical for the high range of production costs to correspond to the high range of byproduct credit, with inflation acting commensurately on both factors. However, if the least byproduct credit were deducted from the highest production costs, the net guayule rubber production costs could range as high as $.70 per pound. Conversely, deducting the highest byproduct value from the lowest production costs would yield a net guayule rubber production cost of $.37 per pound. Such a range, of nearly 100 percent, seems unrealistic, and is not projected in this report.

c. A degree of ambiguity is inherent in these production- cost estimates. Of the projected agricultural costs, the lowest figures are 1985 projections; the highest figures are based on 1979 costs. Processing costs projections also are based on 1985 economics. In the interest of offering a reasonably conservative estimate of guayule rubber production costs, these costs are assumed to apply to the year 1979 and are then projected to increase from 5 percent to 7 percent annually, similar to projected natural rubber price increases. Guayule production costs will be influenced indirectly by rising oil prices, principally through rising costs of energy, and by the general economic inflationary pressures within the U.S. economy. However, domestic guayule growing and processing costs and resulting prices are at least potentially controllable within the U.S. economy and are relatively insulated against cartel pressures exerted by foreign countries. Due to these factors, there probably will be a differential between the growth rate of the costs to produce guayule and that of world natural rubber prices. Natural rubber price increases probably would approach more closely the 7 percent growth rate, and costs to produce guayule would approach the 5 percent growth rate.

At a 5 percent increase rate, the cost of producing a pound of guayule rubber, including profit and byproduct credits, is projected to be $.48 to $.66 in 1980, $.73 to $1.21 in 1990, and $.73 to $1.47 in 2000 (Table V-3 and Figure V-1). These costs reflect increasing harvest yields, beginning in 1990, that will tend to flatten the cost-inflation curve.

d. Existing guayule strains should produce 500 pounds per acre annually. Expected improvements from plant breeding, cultural practices and bioinduction are assumed to increase production to 1,000 pounds per acre annually by 2000. Although a three-year growing cycle shows strong potential for increasing annual yields, the four-year cycle is proven and considered safer for initial investment, particularly in the absence of governmental underwriting. Assuming a four-year growing cycle, a delay will occur between planting and harvesting. Thus for example, shrub harvested in the year 1995 would produce 700 pounds per acre annually instead of 833 pounds. Approximately six years (1980 to 1986) are assumed as a development period to begin significant yield increases; thus, new varieties established in 1986 would produce increased yields in 1990. Some yield increase factors could be implemented without this delay, such as applying bioinduction chemicals on established shrub; but, this may be offset by lower yields initially resulting from less-than-optimum agronomic practices. The various sources of potential yield increases interact and tend to mask possible step function increases. Thus, the cumulative yield increase is projected as a straight-line function (Figure V-2).

e. Assumed guayule development is shown in Figure V-3 and V-4 and incorporates several assumptions as follows:

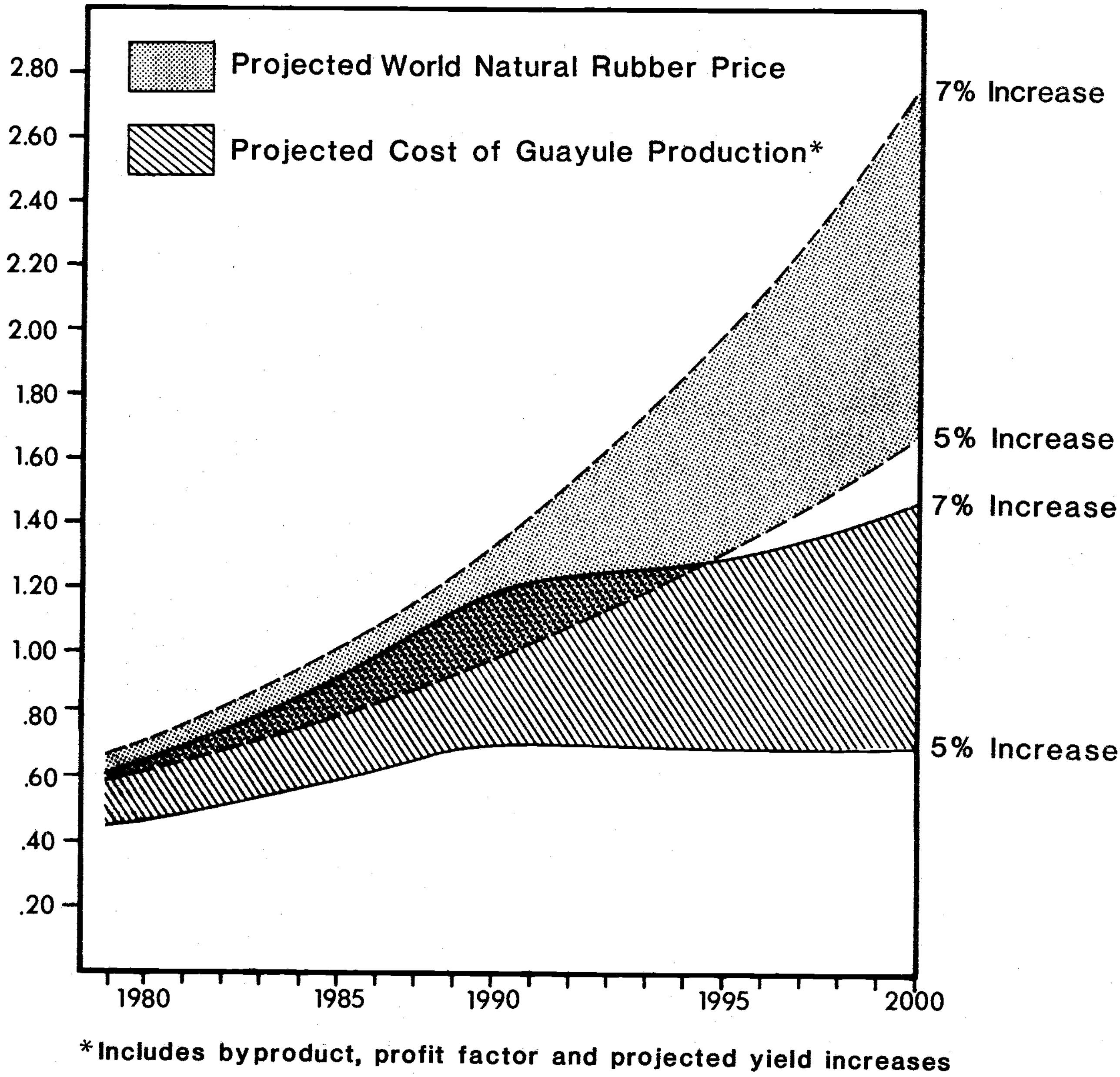


Figure V-1: PROJECTED WORLD NATURAL RUBBER PRICES AND COSTS TO PRODUCE GUAYULE RUBBER

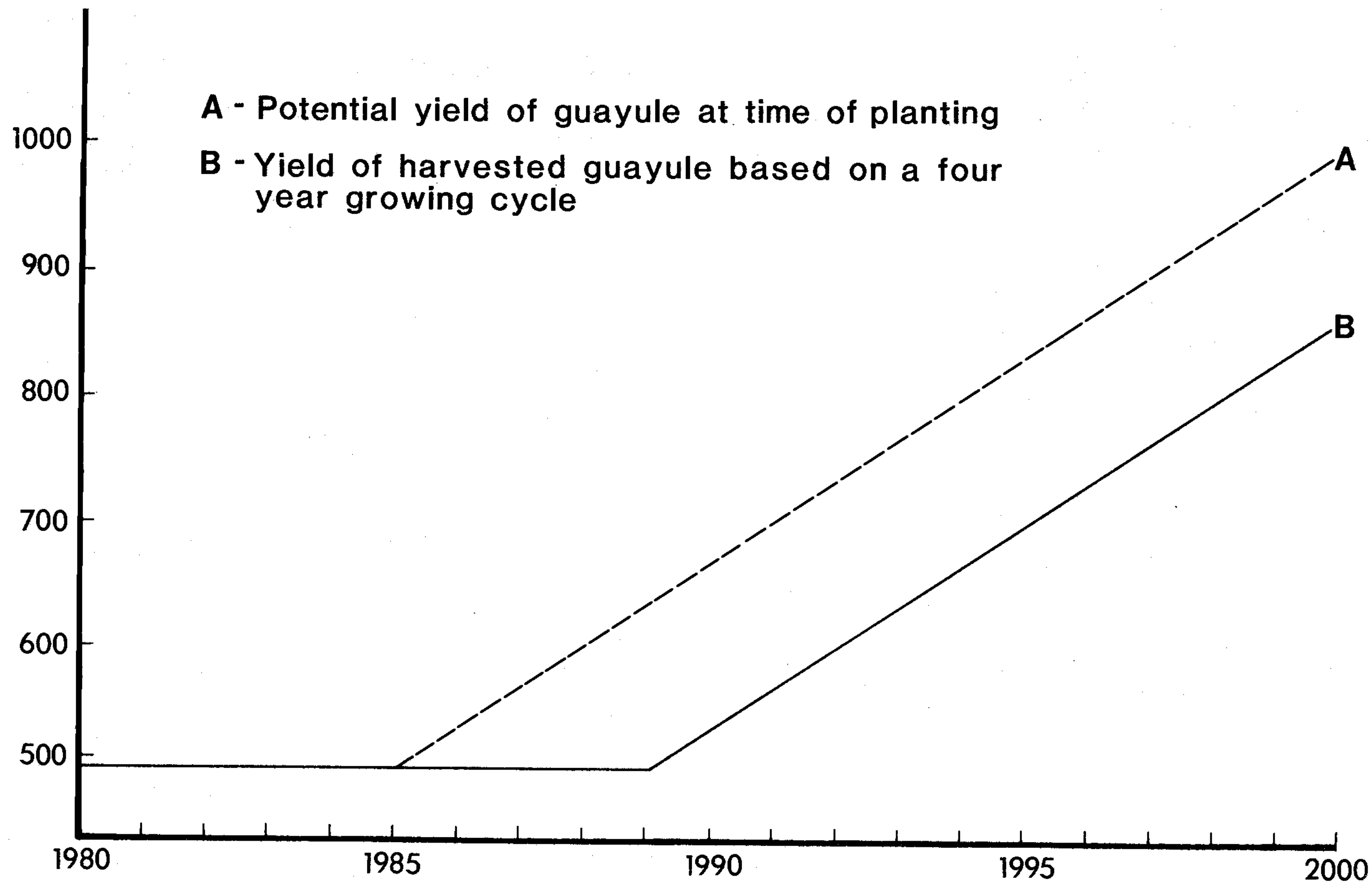


Figure V-2: PROJECTED GUAYULE RUBBER YIELDS, 1980 THROUGH 2000

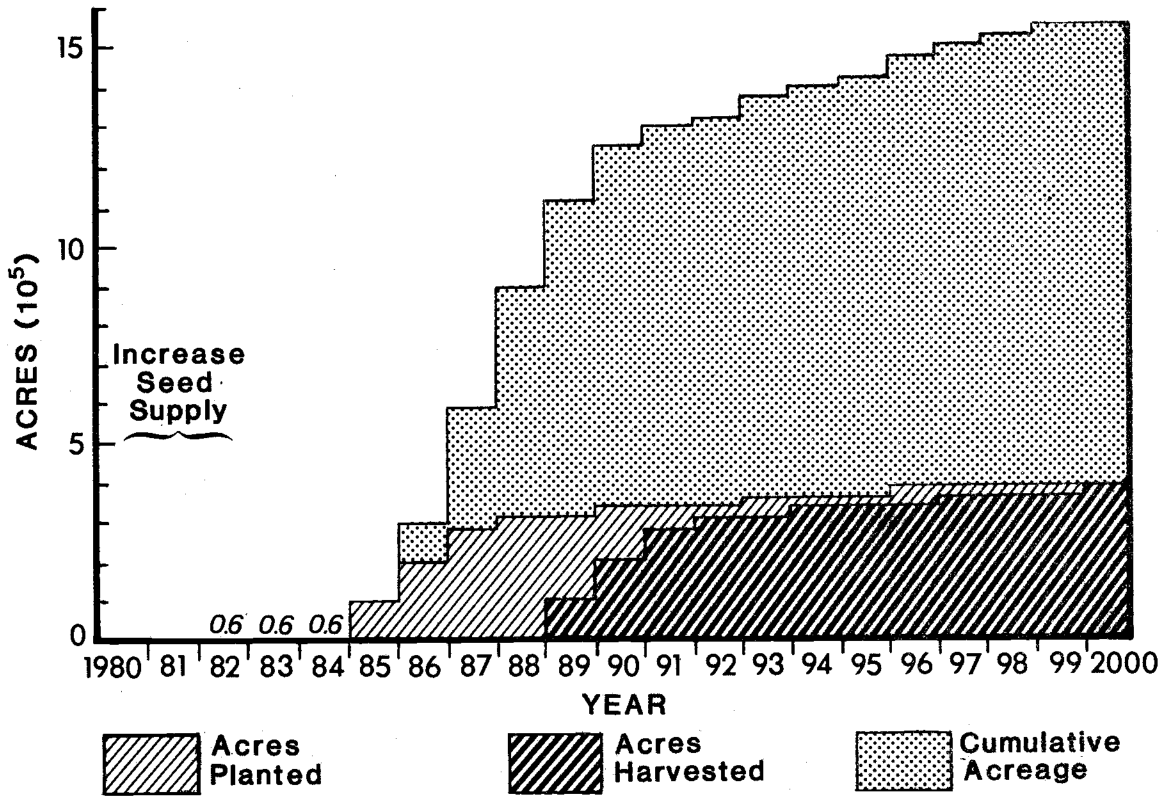


Figure V-3: DEVELOPMENT OF GUAYULE PRODUCTION, SCENARIO A

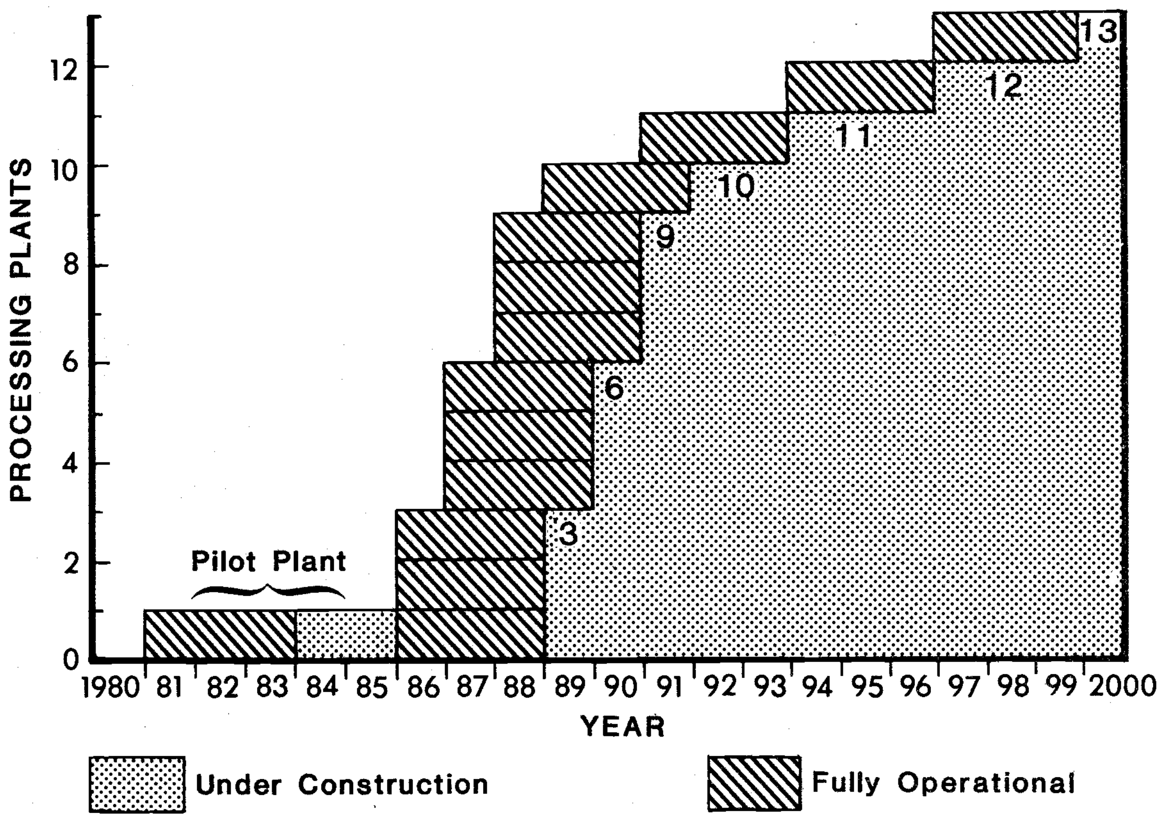


Figure V-4: DEVELOPMENT OF GUAYULE PROCESSING CAPACITY, SCENARIO A

i. An extremely limited seed supply (1979 conditions) will have a short-term effect on guayule production. ERP researchers reported seed yields of from 5 to 50 lbs per acre for first-year shrub and from 50 to 1000 pounds per acre for shrub 1-year-old or older. The State of California reports collection of 87 pounds of "raw" seed collected from the three-acrė experimental plot in San Diego County (California Department of Food and Agriculture, 1979). This represents a seed production rate reasonably similar to an averaged ERP first-year production of approximately 30 pounds per acre. Second-year-and-older shrub is assumed to produce seed at a rate that is an order at magnitude higher, or 300 pounds per acre per year.

ERP researchers conducted further investigations on the ratio of threshed seed to unthreshed seed, number of seeds per pound, and germination efficiencies (U.S. Forest Service, 1946b). For seed from first-year shrub, 0.29 pounds of threshed seed were obtainable per pound of unthreshed seed; and for subsequent-years' shrub this ratio was 0.40/1.0. Threshed seed averages 550,000 seeds per pound. ERP researchers were able to attain a 96 percent germination efficiency by planting four seeds-per-seedling plug in the nursery. Golden State Nurseries (California Department of Food and Agriculture, 1979) reports germination efficiencies ranging from 52 percent to 95 percent from planting two seeds- per-seedling plug in the greenhouse. Some of this seed was from old stock, however. This might account for the lower germination rates reported. Assuming utilization of fresh, threshed and treated seed, a 95 percent germination efficiency should be consistently attainable by using two seeds per seedling in greenhouse production and four seeds per seedling in nursery production. Based on these findings, the following formula is used to calculate acreage plantable per acre of seed production:

$$\frac{\dfrac{(\text{Pounds unthreshed seed per acre}) \times (\text{Threshed/un-threshed ratio}) \times (\text{Seeds per pound})}{} \times (\text{Germination ratio - \%})}{\dfrac{(\text{Seeds planted per seedling plug})}{(\text{Seedlings planted per field acre})}}$$

Based on these calculations, the following acreages should be plantable per acre of guayule seed production:

First-Year shrub		Subsequent-Year shrub	
Greenhouse Production	Nursery Production	Greenhouse Production	Nursery Production
200	100	2,800	1,400

Guayule seedling production during World War II was done primarily in nurseries, while present guayule studies have concentrated on greenhouse production. The means selected for seedling production, prior to such time as direct field seeding may become commercially viable, will depend on production efficiencies, costs per seedling and availability of facilities. For the purposes of scenario projection, a mix of 50 percent greenhouse and 50 percent nursery production is assumed.

Table V-6 projects guayule plantings and acreage plantable through 1982. Plantings for 1979 are based upon reports from guayule researchers, rubber companies and the State of California. Planting projections for 1980 are based on reported planting intentions of these same groups, and 1981 and 1982 plantings assume a doubling of guayule acreage planted per year in each state. Thus, seed supply is not viewed as a limiting factor beyond 1982. A two-to-three-year delay can be expected in putting newly developed varieties into full-scale production.

ii. Construction and testing of a pilot facility and construction of full-scale processing facilities will follow the construction schedule shown in V-3 and V-4. A two-year testing period should provide sufficient data with which to begin construction of full-scale processing facilities in 1986.

Two types of processing operations are assumed based on Saltillo technology and the proposed Firestone solvent extraction technique. For the purpose of this scenario, the Firestone technique is assumed to be perfected and that all rubber company installations are of this basic design.

iii. Glymph and Nivert (1978) estimate the optimum processing facility capacity at 50 million pounds of rubber annually. This capacity suggests a 100,000-acre guayule agriculture support base on a four-year growing cycle, with 25,000 acres harvested annually. Dryland guayule production for this scale of processing facility is expected to be 200,000 acres, with 50,000 acres harvested annually, since dryland yields are about half those of irrigated acreage. Processing facilities of this scale would require an $18 million to $20 million capital investment to construct. Recent breakthroughs in processing technology indicate that facilities of half this scale, or 25 million pounds per year, would be considered economically viable by the rubber industry (Nivert, 1979). Assuming that other interests (Farm cooperatives, Indian communities, private entrepreneurs) also would be motivated to engage in guayule processing and would be less likely to have access to investment capital of this magnitude; a range of processing facility scale is assumed, which is from 12.5 million to 50 million pounds of rubber produced annually. Thus, support acreage would range from 25,000 to 100,000 irrigated acres or 50,000 to 200,000 dryland acres of guayule. For simplicity, development schedules have been extrapolated in increments of the largest facility (See Figures V-3 and V-4). Some of these increments can be considered to be combinations of two to four smaller scale production units. Figure V-5 relates guayule production to natural rubber demand and shortfall.

TABLE V-6
GUAYULE SEED-SUPPLY DEVELOPMENT
SCENARIO A

Year	Location	First-Year Shrub	One-Year-or Older Shrub	Acres Plantable
1979	CA	27		
	AZ	6		
	NM	5		
	TX	7		
	(Total)	45		6,750
1980	CA	75	27	
	AZ	30	6	
	NM	10	5	
	TX	75	7	
	(Total)	190	45	123,000
1981	CA	150	102	
	AZ	60	36	
	NM	20	15	
	TX	150	82	
	(Total)	380	235	550,500
1982	CA	300	252	
	AZ	120	96	
	NM	40	35	
	TX	300	232	
	(Total)	760	615	1,405,500

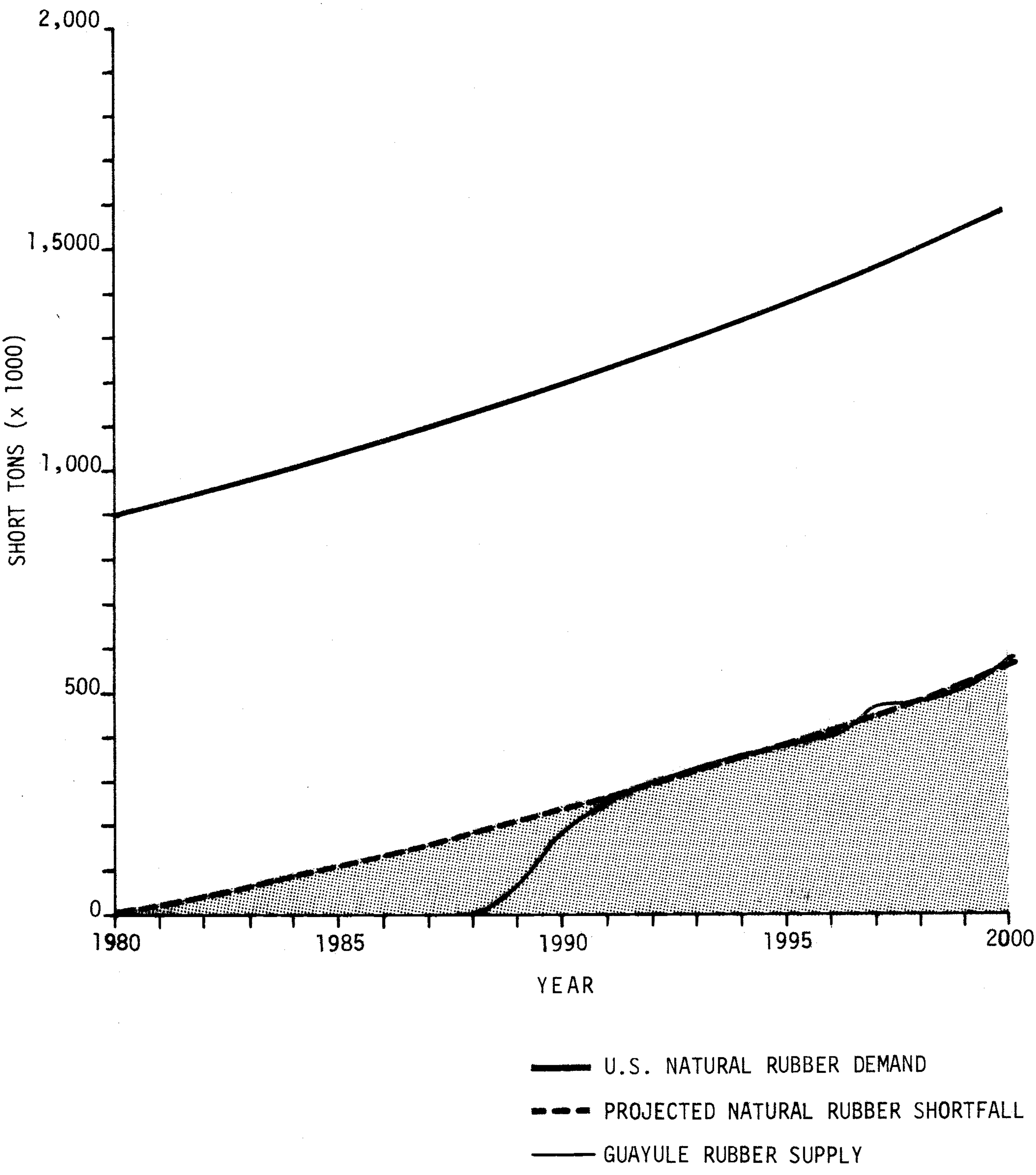


Figure V-5: RELATIONSHIP OF GUAYULE RUBBER PRODUCTION TO PROJECTED NATURAL RUBBER DEMAND

5. <u>Regional Sector Assumptions</u>: Locations of potential facilities are based upon the following agricultural considerations.

a. Temperatures for guayule should not go below 15 F and rainfall should not exceed 28 inches to 30 inches per year.

b. Soils must be deep, medium texture and well-drained.

c. Sufficient production areas must be available in a relatively contiguous area to support a processing facility.

d. Land-base competition with high-value crops such as orchards and vegetables will not occur.

e. The increasingly critical irrigation water shortage in Arizona, New Mexico and West Texas will continue to act as added incentive for guayule development.

Based on the above assumptions, Table V-7 lists the projected guayule acreage distribution for the year 2000. Locations of the projected guayule development centers are shown in Figure V-10. Appendix B contains a more detailed discussion of the areas considered favorable for guayule production.

6. <u>Infrastructure Alternatives</u>: Many participants could be involved in commercial guayule development, including tire and rubber companies; individual or corporate farmers or farmer cooperatives; greenhouses and nurseries; Indian communities; investment institutions; and a sizable number of federal, state and local government agencies. The positions within the commercialization structure that all of these parties-at-interest occupy greatly affect the way guayule is developed.

a. <u>Production</u>: Initiating guayule production could be accomplished by a mix of entrepreneurs:

i. Governmental entities to develop demonstration operations;

ii. Rubber companies to develop their own guayule land base;

iii. Farmers and/or Indian communities to grow guayule with private investment support; and/or

iv. Rubber companies to contract private farming land for guayule production.

b. <u>Propagation</u>: If direct seeding proves to be viable, nurseries and/or greenhouses will not be needed. As long as they are required, seedling nurseries or greenhouses could be developed as:

i. Adapted existing nursery companies;

ii. Grower cooperative enterprises; or as

iii. Rubber company enterprises.

TABLE V-7

PROJECTED GUAYULE ACREAGE DISTRIBUTION, 2000

SCENARIO A

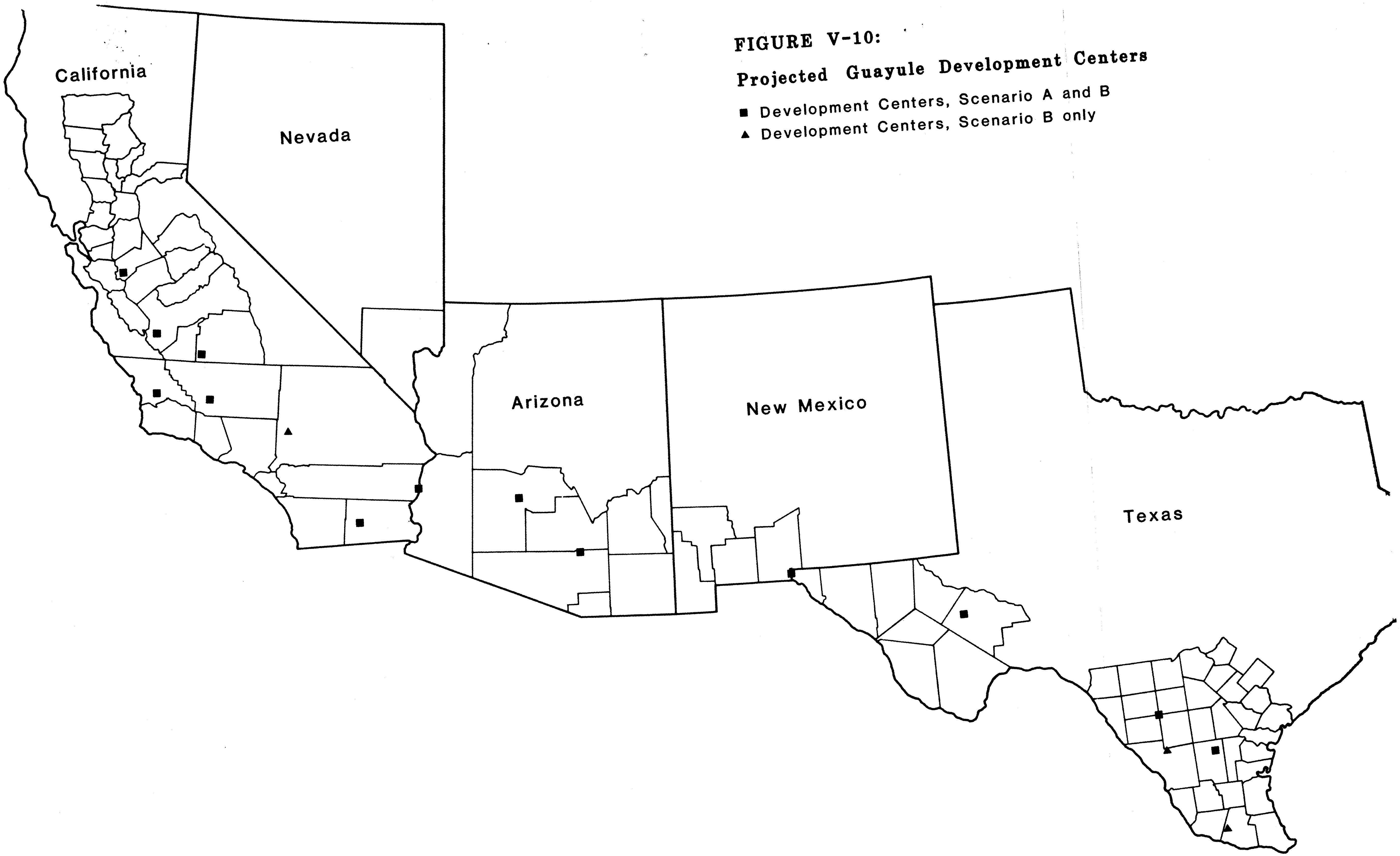
Location	Processing* Facilities	Acreage (1,000)	Percent of Total Guayule Acreage
Texas			
South Texas	2	400 - dryland	26
Trans-Pecos	1	100 - irrigated	6
			(32)
Texas-New Mexico			
El Paso-Mesilla Valleys	1	100 - irrigated	6
			(6)
Arizona			
Central Arizona	2	200 - irrigated	13
Colorado River Area	1	100 - irrigated	6
			(19)
California			
Colorado Desert Area	1	100 - irrigated	6
California Coast Area	1	150 - mixed	10
San Joaquin Valley	4	400 - irrigated	26
			(42)
TOTALS	13	1,550	100

*Based on largest production unit increments.

FIGURE V-10:

Projected Guayule Development Centers

■ Development Centers, Scenario A and B
▲ Development Centers, Scenario B only



c. <u>Processing</u>: Processing facilities might be developed by:

i. Private entrepreneurs;

ii. Grower cooperatives; or

iii. Rubber companies.

d. <u>Alternative guayule industry structures</u>: Under the surprise-free state-of-society and technology assumptions as discussed in the previous sections, four industry structures are considered. These alternative structures are depicted in Table V-8.

TABLE V-8

POSSIBLE INFRASTRUCTURES IN GUAYULE COMMERCIALIZATION
SCENARIO A

Structure*	Title	Comments
TVI (a,b,c)	Total Vertical Integration	All growing and processing activities carried out by rubber companies
PVI a(b,c)	Partial Vertical Integration	Growers sell guayule shrub to rubber companies that process
HC (a,b)c	Horizontal Coordination	Growing and processing activities by same group such as farmer cooperatives or Indian tribes that then market to any interested buyer
NI a,b,c	Non-integrated	Separate, coordinated activities by the three groups

* a= Producers of guayule shrubs
b= Processors of guayule shrubs
c= Buyers of guayule rubber

i. <u>Total vertical integration (TVI)</u>: TVI means that existing rubber companies will play the dominant role in growing and producing guayule rubber.

Under central management, these units will combine the following production states: seedling production; field planting and maintenance; harvesting; and processing and fabricating. Production facilities will be primarily on land owned by rubber companies.

ii. Partial vertical integration (PVI): PVI means that the guayule rubber industry will produce guayule rubber but under production contracts. The producers and the rubber company contractors will share the production risks, but the rubber companies will initiate production contracts. These contracts will set the prices of guayule shrub on a cost-plus-fee basis. The rubber companies will provide needed technology and capital for production.

iii. Horizontal coordination (HC): Grower organizations will dominate guayule rubber production. To help increase marketing power and to reduce costs, farm cooperatives and/or Indian communities will coordinate production and marketing. These associations would establish production quotas and quality standards, growers would purchase production inputs through them, and grower cooperative organizations would engage in processing.

iv. Non-integrated (NI): NI would mean that each phase of guayule production, processing and product fabrication would be conducted by separate, independent entities. Private nurseries or greenhouse companies would produce seedlings until direct seeding became viable. Private farmers, larger commercial farm enterprises and Indian communities would engage in guayule shrubs and would market rubber and byproducts. This infrastructure option might require some form of governmental coordination to ensure viable interaction among seedling producers, growers, processors and the guayule rubber and byproduct markets.

e. Infrastructure probabilities: The incentives for the rubber companies and farmers to grow guayule will differ. A mechanism to produce rubber at a more stable price will be provided if the rubber companies can grow and process guayule rubber at a cost commensurate with prevailing hevea rubber prices that are independent of foreign controls and that allow end-product profits.

Farmers must have a profit commensurate with other crops before guayule will be grown. This represents an add-on cost to the processor and, ultimately, the guayule rubber consumer. Thus, the incentive for rubber companies to enter into guayule production can be expected to develop before farmers, farmer cooperatives, Indian communities, or private entrepreneurs would find economic advantage in developing guayule nurseries, planting acreages or constructing processing facilities.

Initially, rubber companies are expected to dominate the guayule nursery and guayule processing industry with their own land resources and to contract with farmers as landholders for field production as rubber demands and prices increase. Within the hevea rubber production industry, a precedent exists for contracting with growers. As profitability increases, other parties could be expected to attempt entry into these enterprises. In time, both growers and regional entrepreneurs can be expected to see advantages in processing. This could expand the product market for regional interests from the closest processing facility to the world market for rubber and byproducts.

7. Overview: Table V-9 is a summary projection of guayule rubber yields, U.S. natural rubber shortfall, acreage needed to counter shortfall, acreage planted to counter shortfall, number of processing facilities required, guayule rubber production and projected natural rubber surplus or deficit for the years 1980 to 2000.

The projected natural rubber surplus or deficit beginning in 1989 is related to the timing and number of processing facilities being built and becoming operational in order to cope with an expanding guayule rubber demand. Production and processing are interactive in development. Growers cannot be expected to implement guayule production without adequate assurances of processing facilities becoming available. Processors should not be anticipated to begin constructing a facility without an assured guayule supply. Thus, guayule development would require close cooperation between the industrial and agricultural sectors.

B. Scenario B: Rapid Commercialization

The state-of-society, technological and sociopolitical assumptions inherent in developing guayule under a rapid "stimulated commercialization" are discussed in this section. This scenario assumes that world political events and world economic forces, including the activities of a moderately strong rubber cartel, have resulted in a 50 percent reduction in U.S. natural rubber imports.

The stimulated commercialization state assumes that substantial governmental involvement and assistance would occur in initiating and, when necessary, supporting guayule crop production and processing to meet the shortage. Intensive research and development activities would result in a series of technological advances to increase the rubber yield of guayule shrubs and to improve agricultural and processing techniques.

In this scenario, the overall result of the assumed domestic and international political and economic pressures is that by the year 1990 a portion of the total U.S. elastomer market, equivalent to 60 percent of the U.S. demand for natural rubber, would be met by large-scale guayule crop production in the U.S. Southwest. This represents an amount equal to the natural rubber shortfall projected in Scenario A plus the assumed 50 percent reduction of U.S. Hevea supply.

TABLE V-9

SUMMARY PROJECTIONS
SCENARIO A

Year	Projected U.S. Natural Rubber Shortfall (10^3 short tons)	Harvested Yield (Irrigated) (lbs/ac/yr)	Irrigated Acreage To Meet Shortfall (X 10^3)	Total Acreage Planted* (X 10^3)	Processing Facilities Required	Projected Facilities Operating	Rubber Produced (10^3 short tons)	Projected Natural Rubber Surplus (+) or Deficit (-) (10^3 short tons)
1980	---	500	---	0.6				
1981	23	500	92	1.2	1			
1982	46	500	184	1.8	2			
1983	69	500	278	2.4	3			
1984	93	500	372	3.0	4	1		
1985	120	500	480	100	5	(pilot)		
1986	145	500	580	300	6			
1987	170	500	680	587	7			
1988	200	500	800	900	8			
1989	227	500	908	1,112	9	3	75	152-
1990	256	533	961	1,250		6	160	96-
1991	284	567	1,002	1,300		9	225	29-
1992	308	600	1,027	1,325	10	10	300	81-
1993	337	633	1,065	1,375			317	20-
1994	368	667	1,103	1,400	11	11	367	1-
1995	396	700	1,131	1,425			385	11-
1996	424	733	1,157	1,475			403	21-
1997	455	767	1,186	1,500	12	12	460	5+
1998	489	800	1,223	1,525			480	9-
1999	514	833	1,234	1,550			500	14-
2000	559	867	1,289	1,550	13	13	564	5+

* Total mix of 1,050,000 irrigated and 500,000 dryland acres.

1. State-of-society assumptions: This scenario is developed from a set of state-of-society assumptions during a forecast period of 20 years, as partially indicated in Table V-10.

2. Rubber Market Assumptions:

a. World elastomer production and projected world and U.S. demands are forecast as follows:

i. World elastomer demand will increase 6 percent annually from 1980 to 2000.

ii. U.S. elastomer demand will increase 2.8 percent annually from 1980 to 2000 (See Table V-11).

iii. Natural rubber represents 30 percent of the world elastomer demand and 25 percent of he U.S. elastomer consumption as of 1980.

iv. In 1980, that portion of the total elastomer market that could be served by either natural rubber or synthetic rubber is held primarily by synthetic rubber. Natural rubber potentially could claim 50 percent or more of the elastomer market if prices are competitive and if supplies are sufficient.

b. More than 80 percent of the world supply of hevea rubber will continue to be produced in Southeast Asia. In 1978, the United States imported 758,172 metric tons of hevea rubber, and consumption was 764,645 metric tons; the difference was made up from company inventory.

c. U.S. supplies of both natural and synthetic rubber are extremely vulnerable to foreign political and economic pressures.

i. Political instability in Southeast Asia and changes in the balance of power will have an enormous effect on the availability of Hevea for U.S. consumption.

ii. Oil supplies from the Middle East are politically vulnerable and are subject to price and production control by OPEC. Rising oil prices and short supplies will cause general price increases and/or shortages in all primary petrochemicals and petrochemical products, including synthetic rubber, rubber products and rubber processing chemicals.

d. Hevea continues to be vulnerable to biological hazards, labor difficulties and competition from other crops.

e. For the purposes of this scenario, it is assumed that one or several of the possible crises or political developments that could affect world natural rubber prices and/or U.S. rubber supplies does occur. The result is a 50 percent reduction in U.S. hevea rubber imports beginning in 1980 and continuing through the year 2000.

TABLE V-10

STATE-OF-SOCIETY ASSUMPTIONS FOR SCENARIO B

- International tensions between major powers and big-vs.-small and small-vs.-small-country conflicts will increase. Political turmoil in Southeast Asia will continue.

- World population will continue to increase, but the rate will be slowed.

- The pressures of population growth and dwindling natural resources will continue to challenge capabilities; United States will remain a major food-stuffs exporter and net-energy importer.

- OPEC will continue to be a dominant factor in the world economic situation and as the price of crude oil continues to escalate, there will be fears of a worldwide recession. Global-growth forecasts will be scaled down.

- The Association of Natural Rubber Producing Countries (ANRPC) will become an increasingly dominant factor in the world rubber market and natural rubber prices will continue to escalate.

- The U.S. government and societal institutions will not change dramatically, but the country will experience a business recession due, in part, to curtailed oil and rubber supplies. GNP will be 1 percent to 2 percent less than had been projected, and inflation will increase by 1 percent to 2 percent.

- Developing nations will be running up huge debts as oil prices increase. Western banking institutions will fear loan defaults by these nations.

- Employment trends will continue; an increasing percentage of the work force will be in the information, service and governmental sectors, while the percentage in the industrial and agricultural sectors will decline slightly. The cost of labor and the rate of unemployment will increase as the economy slows, but inflation will continue to rise.

- Governmental and private research and development activities will increase substantially, particularly with respect to to alternate energy sources and alternatives to petrochemicals.

TABLE V-10 (Continued)

STATE-OF-SOCIETY ASSUMPTIONS FOR SCENARIO B

- The costs of minerals, materials, chemicals and equipment and the costs of food and fiber products will increase. The cost of energy will increase substantially, as well as costs of all products derived from petrochemicals.

- The population growth rate of United States will be slow. Average age of the population will increase greatly. Shifts to "sunbelt" states will continue, and urban to rural shifts will become exaggerated due to recession conditions.

- Concern about occupational public health and safety, and environmental hazards will remain high; but emphasis will increase on the economic and social costs, with much debate on priorities.

- Concern about adequate water supplies, particularly in the U.S. Southwest will increase.

- The U.S. government will become committed to new energy-source development, transportation-system upgrading, and serious conservation efforts.

- U.S.-Mexican relations wll become increasingly important to the United States because of the increased production of Mexican oil and natural gas. Cooperation between the two countries will increase.

TABLE V-11

UNITED STATES RUBBER PROJECTIONS
SCENARIO B

Year	U.S. Natural Rubber Demand (1,000 short tons)	U.S. Natural Rubber Shortfall 1/ (1,000 short tons)	U.S. Demand for Guayule Rubber 2/ (1,000 short tons)	"Guayule Share" of Natural Rubber Demand (Percentage)
1980	913	---	457	50
1981	938	23	481	51
1982	964	46	505	52
1983	991	69	530	53
1984	1019	93	556	55
1985	1048	120	584	56
1986	1077	145	611	57
1987	1107	170	639	58
1988	1138	200	669	59
1989	1170	227	699	60
1990	1203	256	730	61
1991	1236	284	760	61
1992	1271	308	790	62
1993	1307	337	822	63
1994	1343	368	856	64
1995	1381	396	889	64
1996	1419	424	922	65
1997	1459	455	957	66
1998	1500	489	995	66
1999	1542	514	1,028	67
2000	1585	559	1,072	68

1/ U.S. portion of projected world natural rubber shortfall as estimated in Scenario A.
2/ Projected shortfall plus half of U.S. projected natural rubber imports, 1980 through 2000.
Calculated as: U.S. Natural Rubber Demand - Shortfall + Shortfall (Guayule production is not projected to meet demands fully until 1990).

f. Following the drastic change in hevea rubber prices and/or supply, there will be an immediate demand for alternative rubber sources.

i. A target will be set to produce 730,000 short tons of guayule rubber by 1990, to replace the 50 percent reduction in imports and the shortfall projected for 1990 in Scenario A. Contingency planning to supply 100 percent of the U.S. natural rubber demand, if necessary, would be begun.

ii. Research and testing programs will be developed to improve methods of reclaiming scrap rubber and used tires. The rubber reclamation industry will be revived as a stopgap measure between 1980 and 1990, and programs to collect used tires will be initiated. Reclaimed rubber production will be boosted from a 1977 level of 94,000 short tons to a 1990 level of 287,000 short tons. However, this will represent only 5 percent of new rubber replacement by 1990.

g. The cumulative U.S. shortage of natural rubber before U.S. entry of guayule into the rubber market in 1985 will be about 2.5 million short tons, and about 4.5 million tons until 1990 when guayule rubber will first meet the U.S. need for supplemental natural rubber production. To make up this shortage the following is assumed.

i. The United States will import a higher proportion of the existing world cis-1,4 polyisoprene supply than the 1977 import level of 3,314 metric tons (3,653 short tons). Most of this increase would have to come from the Soviet Union, which is producing 0.5 million metric tons of cis-1,4 polyisoprene annually and has set a production target of 1 million metric tons by 1985. This supply of cis-1,4 polyisoprene would be vulnerable to political and economic pressures.

ii. Current U.S. domestic cis-1,4 polyisoprene manufacture will increase as rapidly as possible, from the 1977, 80 percent production level of 67,000 metric tons annually to the full production capacity of approximately 80,000 metric tons. A second cis-1,4 polyisoprene production plant, closed when production was not economically viable, again will be placed in operation to produce an additional 85,000 metric tons annually. Combined cis-1,4 polyisoprene production, at approximately 165,000 metric tons, would provide 20 percent of the U.S. peacetime requirements in 1980.

iii. Domestic cis-1,4 polyisoprene production facilities will be expanded through federal suport to increase the U.S. production capacity. However, production increase of cis-1,4 polyisoprene will be limited by the escalating demand for crude oil in energy applications and by the corresponding price inflation of crude oil as a petrochemical feedstock. This limitation could be somewhat eased by substituting coal as a stock supply for isoprene monomers.

h. Hevea-producing countries will have organized into a moderately strong cartel in an effort to control the world price of natural rubber. This cartel will become somewhat weakened as guayule rubber begins to assume a strong market position.

3. Sociopolitical Assumptions:

a. Guayule research, development and demonstration under the Native Latex Commercialization Act of 1978 will be increased drastically as a result of expanded congressional appropriations.

b. Federal legislation will be passed to provide a variety of government loans, guarantees and grants to stimulate guayule crop production and guayule processing facility construction.

c. Guayule rubber will be defined in technical terms based on physical and chemical tests. The federal government and the rubber-consuming and -producing industry jointly will develop the standards.

d. In response to unsettled world political and economic forces and to cuts in imports of natural rubber, the U.S. government will plan a national rubber program to establish a domestic natural rubber supply to become less dependent on foreign rubber sources. Goals will be established and guayule markets guaranteed. Legislation will be enacted to authorize establishment of a quasi-government corporation to implement and control the guayule development. Representatives will include the rubber industry, government and agricultural interests.

i. Government members will include the U.S. departments of Agriculture, Commerce, and Defense; the Agricultural Stabilization and Conservation Service; the Commodity Credit Corporation; the Bureau of Indian Affairs; and appropriate state-agency representives.

ii. Rubber industry members will include representatives of major tire manufacturers, the Rubber Manufacturers Association and Rubber Trade Association.

iii. Representatives of agricultural interests will include the Farm, Bureau, agricultural agents, farmer cooperatives, private farmers, farmers unions and representatives of appropriate Indian communities.

4. Guayule Technology Assumptions:

a. Seed supply: Initially, start-up of guayule development will be restricted by seed supply. Initial 1980 guayule growing activities by the State of California and researchers in Arizona, New Mexico and Texas are assumed to be approximately double those projected for Scenario A. Firestone's operations are assumed to start by 1981, developing 500 acres annually. It is assumed that given a situation of relative emergency, the quasi-government guayule corporation would negotiate the purchasing of existing stocks of guayule seed. The agency would determine distribution of seed purchased to ensure rapid and efficient production development. The seed supply held by private industry is estimated to be approximately 3,000 pounds.

The ratio of "acres plantable per acre of seed-producing shrub" is the same as discussed under Scenario A for the years 1979 and 1980. This ratio is reduced to 50 acres per acre for first-year shrub and 700 acres per acre for one-year-or-older shrub when planting densities are tripled starting in 1981, as discussed below.

An estimated 45 acres of guayule will have been planted in field or experimental plots in Texas, New Mexico, Nevada, Arizona and California by 1979. Initial plantings in 1979 and 1980 would be geared primarily toward seed production; they are expected to be planted at the ERP approximate planting density of 10,000 to 17,000 plants per acre.

Beginning in 1981, fields would be planted for maximum rubber production as well as seed production. Fields are expected to be planted at aproximately three times the density of the 1980 plantings.

The accelerated seed-supply development schedule is outlined in Table V-12.

By 1982, more than enough seed could be in storage to plant the entire projected acreage needed by 1990. The first seeds available will be from a number of different varieties. Existing higher-seed-producing strains will not be available in sufficient quantities for extensive planting until 1983.

b. Agronomic assumptions: Scenario B assumes immediate field application of experimental agronomic practices. Although agronomic practices have been shown to enhance yields greatly in controlled plot experiments, they have not been demonstrated previously in field practice. This scenario assumes that government underwrites the risk to the farmer of implementing these new practices.

i. Planting under controlled irrigation could have an increased spacing density of 14 inch by 10 inch or closer. ERP experimental plots showed highest yield from greatest density plantings (Bullard, 1946 b and c; Tingey, 1952).

ii. Harvest would be after two to three years.

iii. Initially, this denser planting is assumed to be with seedlings from nursery or greenhouse stock; however, denser irrigated planting would be greatly enhanced by refining direct field seeding techniques. The latter is assumed to have been given high research priority and would be developed rapidly.

TABLE V-12

SEED-SUPPLY DEVELOPMENT

Year	Seed Contributors	First-Year Shrub (acres)	One-Year-or-Older Shrub (acres)	Seed 1/ Produced (pounds)	Acres Plantable
1979	State Programs	25	5	2,875	4,300
	Federal Funded Programs	18	5	2,770	4,150
	Rubber Companies	20		300	450
	Private Entrepreneurs	18	5	2,770	4,150
Year Total		80	10-20	8,700	13,050 2/
1990	State Programs	4,000	30	75,000	112,500
	Federal Funded Programs	4,000	23	71,500	107,250
	Rubber Companies	500	20	17,500	26,250
	Private Entrepreneurs	8,500	23	139,000	208,500
Year Total		17,000	96	303,000	454,500 2/
1981		454,500	17,100	15,367,500	7,683,750 3/

1/ At 11,000 plants per acre, assume average yields first-year shrub, 15 pounds/acre; 1-year-or-older shrubs, 500 pounds/acre.
2/ At 11,000 plants per acre.
3/ At 33,000 plants per acre.

iv. Harvest cycle will be designed to provide for year-round processing facility operation to avoid idle times and to avoid exaggerated facility capacities.

Immediately applying these agronomic practices, selecting best available strains and developing field-effective bioinduction techniques and improved varieties are assumed to give the rapid increase in annual yields per acre as shown in Figure V-6. The yield increases projected here, 100 percent between 1980 and 1990 and 50 percent from 1900 to 2000, are significantly higher than those projected for Scenario A, i.e., 1,500 pounds per acre annually vs. 867 pounds per acre annually by the year 2000. However, such rates of increase do not appear unrealistic when compared with the hevea rubber industry that has been achieving a 10-year doubling of production per unit area for the past several decades (Semegen, 1979). Under Scenario B, a greatly accelerated research and development program is assumed. The most rapid yield improvement is expected to be achieved during the 1986-1994 period.

c. Production targeting: The guayule development program is targeted to meet natural rubber shortages (shortfall projected for Scenario A plus a 50 percent reduction of U.S. natural rubber imports) by 1990.

Again, guayule production units are assumed from 25,000 to 100,000 acres, with a processing facility. The quasi-governmental guayule corporation will have to deal with potential conflicts between scales that are necessary to meet rubber production objectives rapidly. Some mix of processing facility size is assumed, although most probably this would be at the upper end of the range. For the sake of simplicity, the development schedule for both acreages and processing facilities projects guayule development in increments of 100,000 acres plus the processing facility (Figures V-7 and V-8).

Although 94 percent more guayule rubber is forecast to be produced in Scenario B than in Scenario A by the year 2000, it also assumes a 73 percent higher yield per acre. Therefore, only 26 percent more land would be required to produce nearly twice the amount of rubber.

d. "Over-production": Once financial and land commitments have been made for guayule development, acreages and facilities are assumed to be maintained in production. Subsequently, increasing yields would drive guayule rubber production above the Scenario B projected natural rubber shortage. It is assumed that the limitations to processing facility capacities relate to shrub volume, rather than rubber quantity; thus, increasing rubber yield per plant without an increase in shrub tonnage should allow increasing processing facility efficiency.

Once guayule rubber production passes projected natural rubber shortages, development of production units (a processing facility plus its supporting acreage) is assumed to operate according to economic demand (Figure V-9).

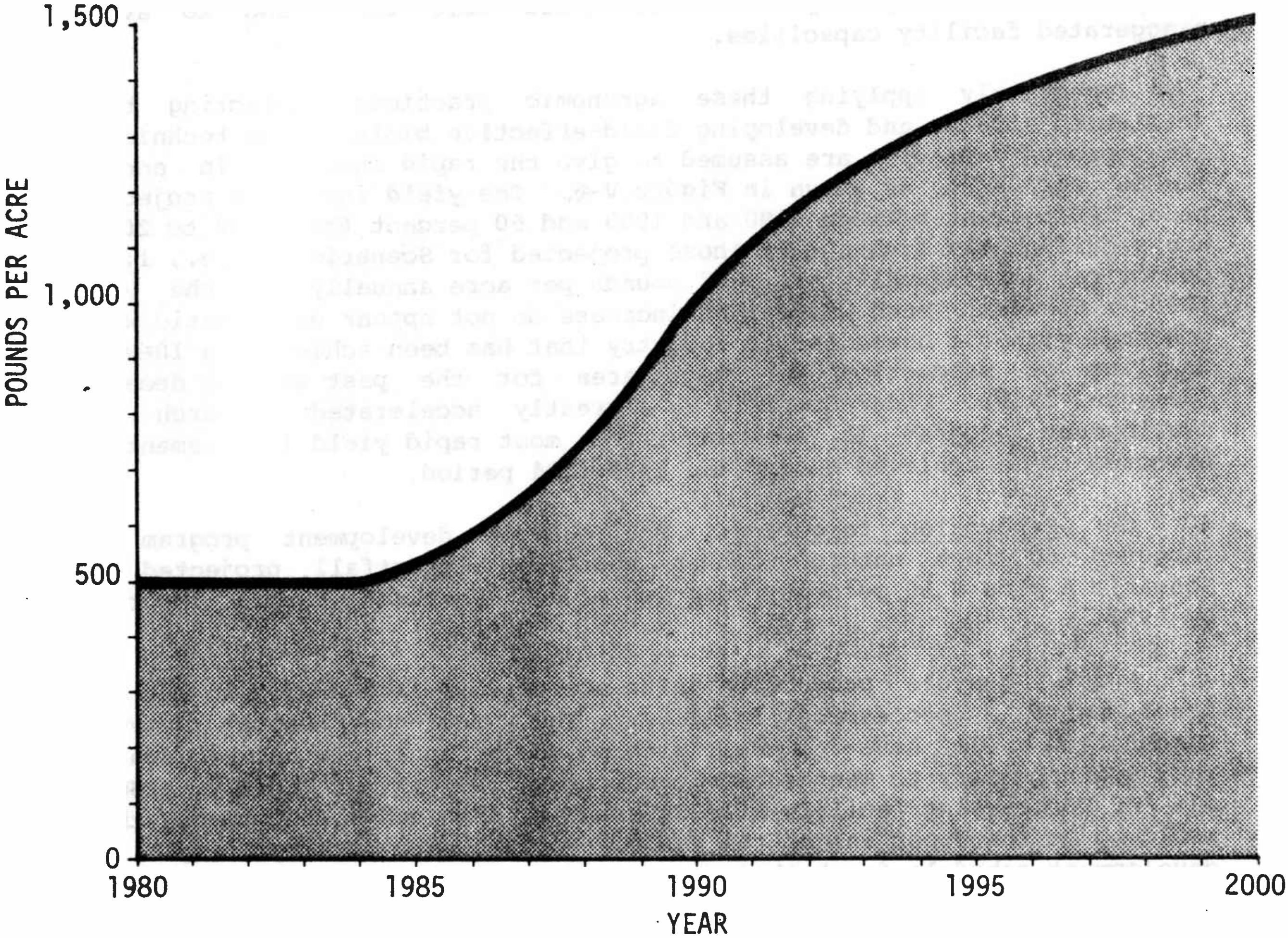


Figure V-6: PROJECTED GUAYULE RUBBER YIELD, 1980-2000

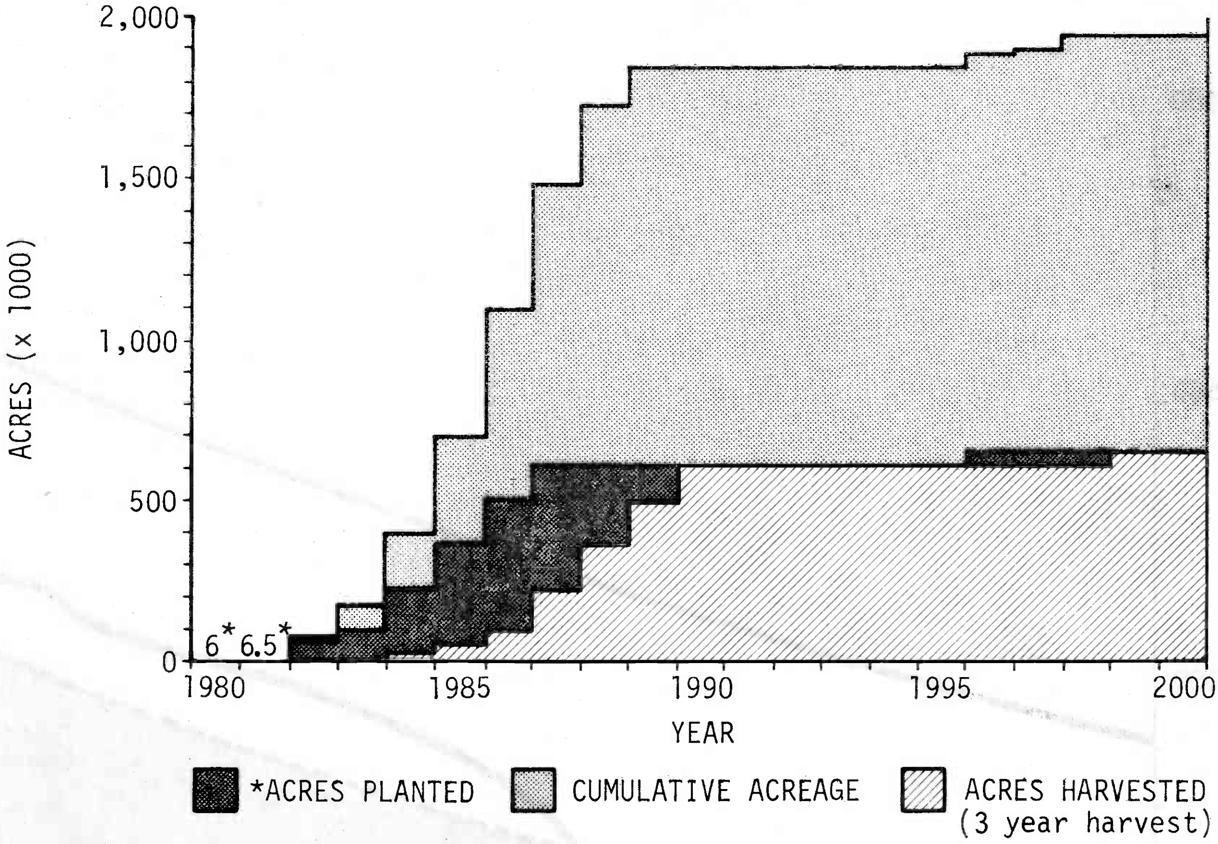


Figure V-7: DEVELOPMENT OF GUAYULE PRODUCTION, SCENARIO B

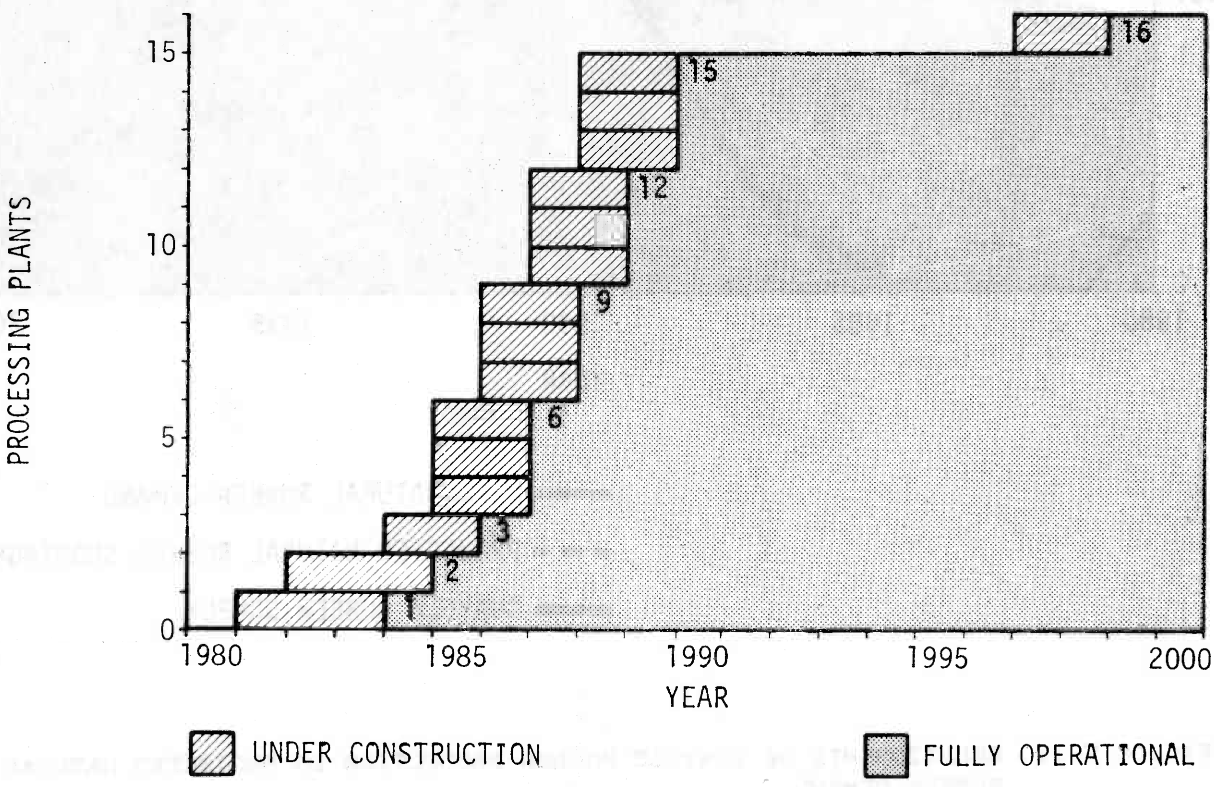


Figure V-8: DEVELOPMENT OF GUAYULE PROCESSING CAPACITY, SCENARIO B

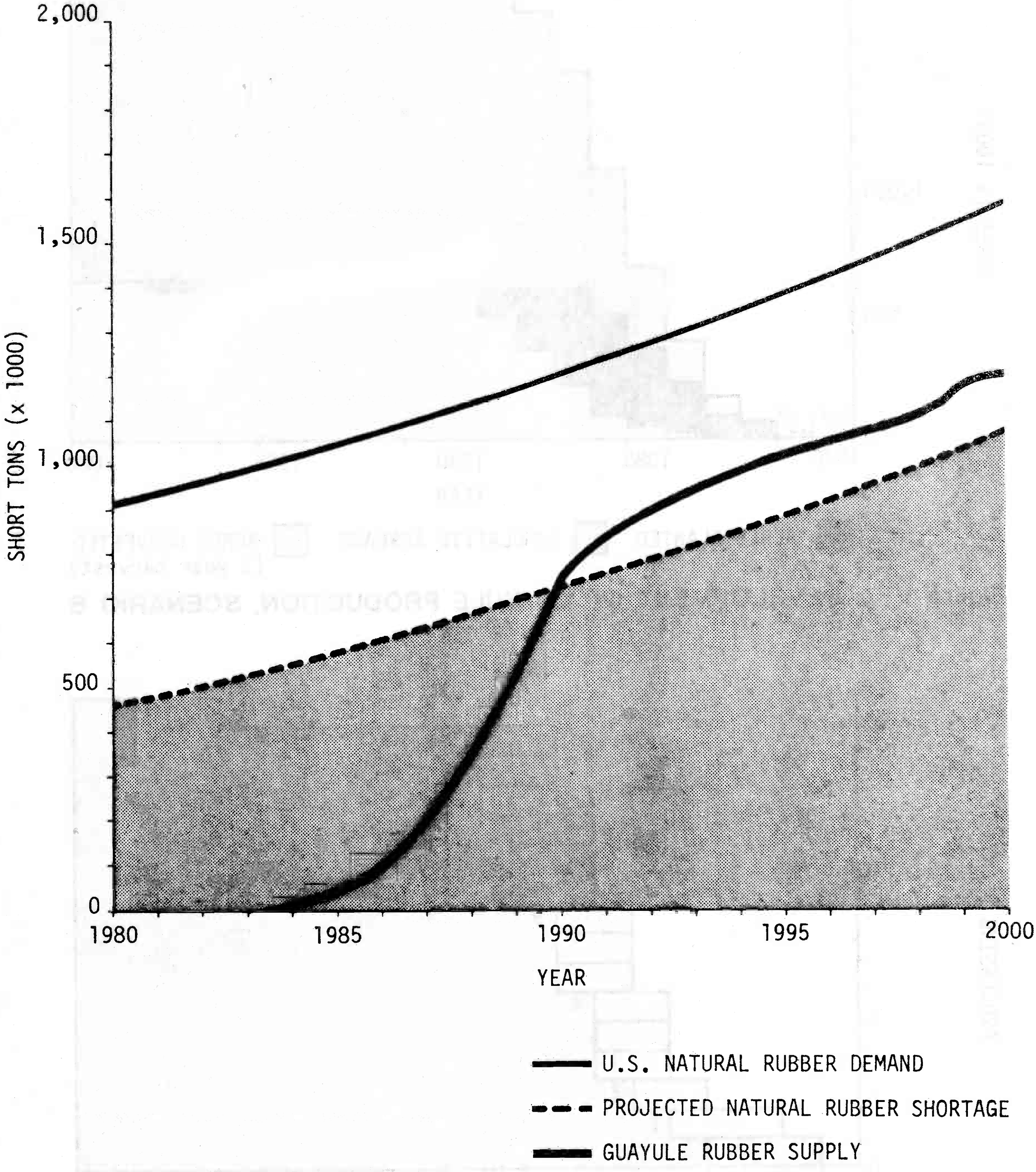


Figure V-9: RELATIONSHIP OF GUAYULE RUBBER PRODUCTION TO PROJECTED NATURAL RUBBER DEMAND

Rising crude oil costs are expected to continue to raise costs of synthetic rubber, and indirectly, the costs of hevea rubber. Competition with rapidly developing guayule rubber production should tend to depress somewhat increasing costs for hevea rubber. However, natural rubber might be expected to assume a greater proportion of the total elastomer market. Thus, a solid market is assumed for guayule rubber produced in excess of the Scenario B projected shortages. Once guayule has captured a portion of the rubber market, incentive is assumed to maintain a proportional level of production.

5. Regional Sector Assumptions: Sites of potential facilities again are based upon the agricultural considerations discussed in subsection V. A-5, a-e. Based upon those considerations, Table V-13 was developed to show the distribution of the projected 1.95 million acres of guayule for the year 2000. Figure V-10 shows the locations at projected guayule development centers.

A more detailed discussion of the areas considered favorable for guayule production is in Appendix B.

6. Infrastructure alternatives:

a. The guayule corporation: The nature of the natural rubber import reduction plus projected shortfall (from Scenario A) in Scenario B would require a concerted, coordinated effort to bring about sufficient guayule rubber production. However, this semiemergency situation would fall far short of the degree of urgency experienced during World War II that led to the creation of ERP. In recent years, programs that have met with most notable success have involved a close cooperation between government and private industry, for example, space programs such as COMSAT.

Therefore, it is projected for this scenario that guayule production would be coordinated by a quasi-governmental corporation authorized to provide management and a variety of economic incentives for developing an integrated program of farming, processing and marketing that would work when possible through already established agricultural and commercial organizations within the regional sectors. This "mixed guayule corporation" should be representative of all major parties-at-interest in guayule rubber production, with members as indicated under the sociopolitical assumptions (Section 3d).

The guayule corporation would need to coordinate the development of guayule production units, including a processing facility, the acreage necessary to support the processing plant and necessary nursery and/or greenhouse operations. Since venture capital could be expected to be in short supply for this relatively unproven industry, the guayule corporation might have to underwrite or directly finance the initial processing facilities. A guayule acreage allotment program could be used

TABLE V-13

PROJECTED GUAYULE ACREAGE DISTRIBUTION, 2000
SCENARIO B

Location	Processing * Facilities	Guayule Acreage (1,000)	Percent of Total Guayule Acreage (rounded)
Texas			
South Texas	4	100 - irrigated 600 - dryland	36
Trans-Pecos	1	100 - irrigated	5
			(41)
Texas-New Mexico			
El Paso-Mesilla Valleys	1	100 - irrigated	5
			(5)
Arizona			
Central Arizona	2	200 - irrigated	10
Colorado River Area	1	100 - irrigated	5
			(15)
California			
Colorado Desert Area	2	200 - irrigated	10
California Coast Area	1	150 - mixed	8
San Joaquin Valley	4	400 - irrigated	21
			(39)
TOTALS	16	1,950	100

* Based on largest scale increments, one processing facility served by 100,000 irrigated acres or 200,000 dryland.

to ensure development of sufficient support acreage with appropriate timing of harvest. Compensation to farmers would need to be made on some standardized basis. This would ensure a continuous harvest-to-supply year round processing facility operations rather than "batch loading" at times of highest rubber yield per acre.

The guayule corporation could be expected to operate at the forefront of research in plant variety development, bioinduction, optimum agronomic practices and guayule processing technology. The aspect would ensure against industry restrictions by private patent holders and would allow rapid, efficient dissemination of guayule production developments.

Finally, the mixed guayule corporation effectively could oversee final product distribution to satisfy both industrial and national security needs.

Conceptually, there could be a number of participants in each of the phases of guayule production.

b. Propagation: Until direct seeding proves to be viable, nursersies or greenhouses will be needed to produce guayule seedlings for transplanting to field plantations. These could be developed by the following:

i. The quasi-governmental guayule corporation;

ii. Rubber companies in conjunction with their plantation operations;

iii. Private nursery companies, under government contract;

iv. Farmer cooperatives, with governmental technical assistance and guaranteed markets and prices;

v. Other governmental entities; and/or

vi. Certain Arizona and California Indian tribes.

c. Production: Farm production of guayule could be accomplished by mix of the following:

i. The quasi-governmental guayule corporation;

ii. Rubber companies developing their own lands;

iii. Farmers and/or Indian communities developing guayule on their own lands; and/or

iv. Grower cooperatives developing a guayule land base in coordination with processing facility development.

d. Processing: Processing facilities could be constructed and operated by:

i. The quasigovernmental guayule corporation;

ii. Rubber companies;

iii. Private entrepreneurs, with government loans and technical assistance available and fair product price guarantees;

iv. Farmer cooperatives, with the same assistance and marketing guarantees;

v. Private companies and certain Indian tribes under government contract; and/or

vi. Other government entities.

e. Alternative guayule industry structures: Theoretically, under this rapid-commercialization scenario, a number of different guayule industry structures are possible. These are listed in Table V-14. Although it could be possible to achieve rapid commercialization without the formation of a quasi-governmental guayule corporation, this entity has been included in the alternative infrastructures to show how it might function in each instance.

f. Incentives: Incentives for specific components of this guayule development scenario are assumed to be provided by the quasi-governmental guayule corporation. Financing for this relatively untried industry through conventional sources can be expected to be slow at first. Furthermore, successfully coordinating the several interdependent subsystems--seedling production, field plantings, processing facility development and operation, and harvest timing--for a rapidly developing guayule industry would require close management, incentive, financing and direct involvement.

The guayule corporation is assumed to implement incentives and financial assistance to assure coordinated guayule development, and to undertake direct guayule production activities when these methods prove to be insufficient. The corporation also would directly support or undertake research identified as necessary to continue improving guayule development.

7. Overview: Table V-15 provides a summary of projected U.S. rubber shortages, guayule rubber yields, acreage to meet supply projections, guayule rubber production and projected natural rubber surplus or deficit for the years 1980 to 2000.

A dependable supply of natural rubber is vital to the interests of the U.S. economy as well as to the U.S. military. With hevea rubber in

TABLE V-14

POSSIBLE INFRASTRUCTURES IN GUAYULE COMMERCIALIZATION
SCENARIO B

Structure	Title	Comments
TVI (a,b,c)	Total Vertical Integration	All growing and processing activities carried out by the rubber industry or the guayule corporation.
PVI a (b,c)	Partial Vertical Integration	Processing and marketing by rubber industry or guayule corporation. Growing coordinated by contract.
HC (a,b) c	Horizontal Coordination	Growing and processing by farmer/Indian cooperatives in close coordination with guayule corporation.
NI a,b,c,	Non-Integrated	Production, processing and product fabrication each carried out by separate groups. Close supervision and coordination of all phases by the guayule corporation.

TABLE V-15

SCENARIO B: SUMMARY PROJECTIONS

Year	Projected U.S. Natural Rubber Shortage (10^3 short tons)	Expected Guayule Rubber Yield (lbs/acre/yr)	Acres Required 1/ to Meet Shortage (x 10^3)	Acreage 2/ Planted (Cumulative) (x 10^3)	Guayule Rubber Produced (10^3 short tons)	Projected Natural Rubber Surplus (+) or Deficit (-) (10^3 short tons)
1980	457	500	1,828	6	-0-	457-
1981	481	500	1,924	125	-0-	481-
1982	505	500	2,020	79	-0-	505-
1983	530	500	2,120	179	-0-	530-
1984	556	500	2,224	400	10	546-
1985	584	530	2,204	700	54	530-
1986	611	580	2,107	1,100	87	524-
1987	639	660	1,936	1,484	198	441-
1988	669	760	1,761	1,734	342	327-
1989	699	870	1,607	1,850	522	177-
1990	730	1,000	1,460	1,850	750	20+
1991	760	1,100	1,382	1,850	825	65+
1992	790	1,180	1,339	1,850	885	95+
1993	822	1,250	1,315	1,850	938	116+
1994	856	1,305	1,312	1,850	979	123+
1995	889	1,350	1,317	1,850	1,038	149+
1996	922	1,395	1,322	1,883	1,047	125+
1997	957	1,430	1,338	1,916	1,073	116+
1998	995	1,455	1,368	1,950	1,092	97+
1999	1,028	1,480	1,389	1,950	1,184	156+
2000	1,072	1,500	1,429	1,950	1,199	127+

1/ Assumes all irrigated acreage.

2/ Incorporates 1.25 million irrigated acres and 0.7 million dryland-farming acres.

short supply, the price of natural rubber will rise. A strong demand will exist for cis-1,4 polyisoprene, the only synthetic with properties similar to natural rubber. Imports and domestic production of this synthetic rubber can be expected to increase as rapidly as possible. However, production of this synthetic is vulnerable to the rising costs and potential shortages of the petrochemicals from which synthetics are made. Guayule rubber production would assure an alternative supply of rubber to the rubber market.

VI. IMPACTS OF GUAYULE COMMERCIALIZATION

A. Social Assessment

1. Introduction: The objective of a technology assessment is to enhance decision making by detemining a range of impacts of alternative courses of action. Guayule rubber technology was discussed in Chapter III. Potential growing regions were discussed in Chapter IV and Appendices B and C. Two scenarios for future guayule development in these regions were presented in Chapter V. These scenarios, building on technological data developed in Chapter III, identify the regions where guayule is most likely to be grown and processed. In this chapter the impacts of guayule commercialization under the two scenarios are discussed. A conceptual scheme of the generalized impacts of guayule development is presented in Figure VI-1.

All guayule growth regions were examined. However, because of current guayule activity and the contrast between the rural and urban areas of the regions, the Kern County, California, and Pecos County, Texas, areas were selected for intensive study. In these two areas present conditions were inventoried to describe social and economic bases. Less detailed inventories were conducted for the rest of the regions. Inventory data included the subjects below.

a. Demographic data: Includes current population characteristics, number, age, sex, distribution, the ethnic composition and other relevant census breakouts.

b. Community services: Focuses on health, education and other important services and facilities within the community.

c. Economic situation: Focuses on the size and general composition and characteristics of the labor force.

The inventory focused on the nature, size and production levels of industry, agriculture, commerce and services. The level of employment and types of jobs held and the level of unemployment and of subemployment or underemployment were examined as well. External factors influencing economics of the regions today also were analyzed. Current economic trends were identified as much as possible.

The inventory of present conditions was used as a basis to examine the impacts of guayule commercialization in terms of the two scenarios for future development.

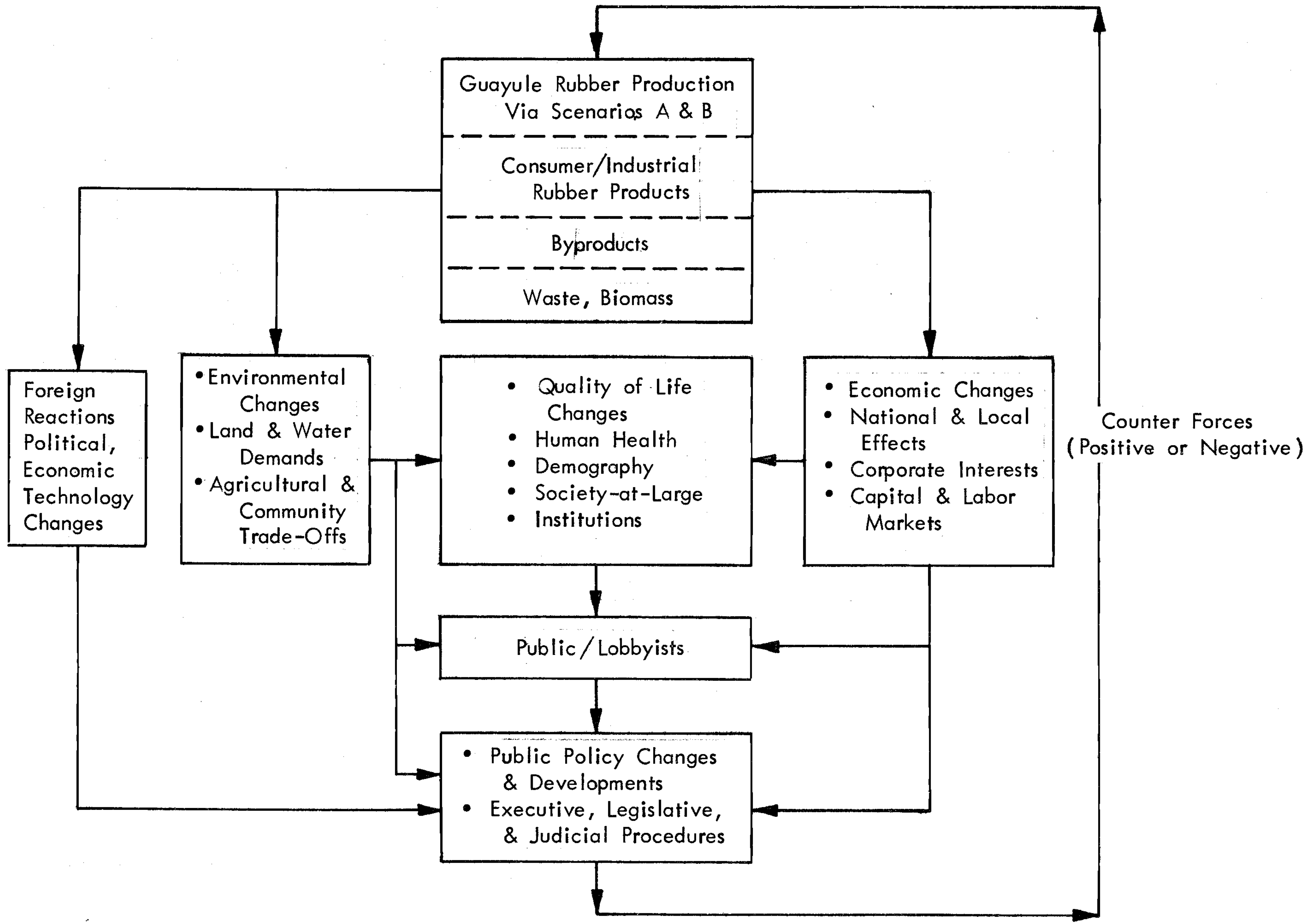


Figure VI-1: GENERALIZED IMPACTS OF GUAYULE DEVELOPMENT

The basic forecasts for the alternative futures in the potential guayule growing regions came from state and local planning offices, councils of governments and other agencies that are charged with long-range planning. The sources of these data are listed in Appendix C. Specific data were collected from Kern County, California, and Pecos County, Texas, by the authors of this report.

The relevant social impacts depend on economics and demographics. These two factors set the parameters of impacts on individual services, community services and area socioeconomic effects in the analyses.

Impacts were forecast by first projecting social variables if no guayule commercialization were to occur. The social variables forecast then were compared with those generated by projecting social variables that would occur under Scenario A and under Scenario B. By using this approach "net impacts" were forecast as illustrated in Figure VI-2.

The variables forecast were aggregated into three categories--demographics, economics and community services--because of the large geographical area involved and the limitations of data. Nevertheless, an analysis of impacts was possible in terms of the three aggregate variables. However, it was impossible to determine the magnitude of all impacts forecast, but they were identified in terms of being negative, neutral, or positive impacts, and in terms of being long-term or short-term impacts.

2. Regional Profile: The potential guayule production region is primarily rural with the exception of two counties in Arizona, parts of California, and the El Paso, Texas, area. Much of the region is characterized by low population density, substandard housing, low income and, while unemployment is not particularly high, employment opportunities are limited. Most of these factors are due to the isolation of this region from main transportation arteries and from other sections of the country. The mountainous and desert conditions that characterize the region isolate it.

Local highway systems link most of this region to the rest of the country, but many areas still have unpaved roads for access to state and federal highways. In most instances, financial services are adequate, however health services throughout the region are limited.

The economic base in the Southwest is derived mostly from tourism, recreation and retirement, agriculture, mining, trade and manufacturing. Tourism and recreation probably will continue to be the primary supports of the economy during the next several years, mostly because the climate is good and a variety of national parks exist in the region. The Spanish history and Indian heritage of the region also attracts tourists.

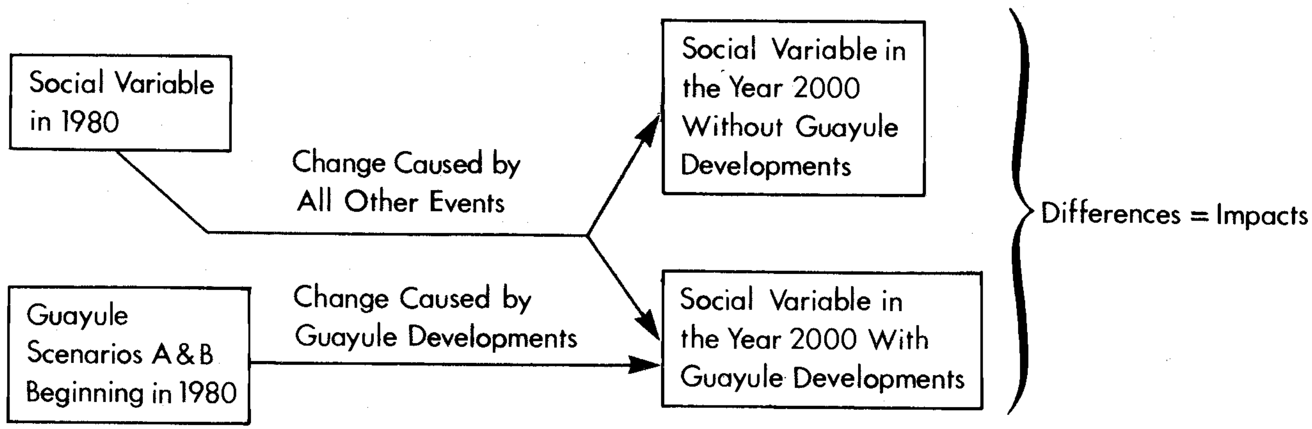


Figure VI-2: PROJECTING NET IMPACTS OF GUAYULE DEVELOPMENT

Agriculture will decline in economic importance from West Texas through New Mexico and Arizona and into some parts of California due to declining water supplies, increasing costs of irrigation, and increasing irrigation water salinity. Mining and oil production in the region may grow in importance however. In Texas, California, parts of New Mexico and parts of Arizona, exploratory drilling activities will increase. Copper, mercury and uranium mining will increase in parts of Arizona and New Mexico.

International trade with Mexico will increase, but it is unlikely that a significant amounts of international trade will take place in the potential guayule production region because most of it is rural. However, El Paso, Texas, and Tucson, Arizona, may become major centers of trade with Mexico. Potential exists to develop warehousing and distribution activities related to import- export activity in the region particularly between the United States and Mexico. Foreign trade zones also have potential in the region. The only established trade zone in the region is in Tucson, Arizona. These zones permit warehousing, distributing and manufacturing related to international commerce that are cost-effective for both importing and exporting goods.

Manufacturing activities in the guayule region are limited to the metropolitan areas, but additional manufacturing development likely will occur.

3. Alternative Futures: In examining impacts of growing and processing guayule, the focus is first on local and regional impacts and then on national and international impacts. The impacts at the local level on two diverse areas of the guayule growing region-- Kern County, California, a metropolitan area, and Pecos County, Texas, a rural agricultural county--are examined in detail to provide a range of potential impacts throughout the four-state area.

a. Kern County: Kern County, California, benefits from a long-entrenched State of California planning program. Following the state lead, Kern County has undertaken local comprehensive planning for the future, at least through 1985. Kern County population will grow to 437,000 by 1990 and to 476,000 by 2000. The County has a diversified economy. Most growth is expected to be in the industrial and commercial sectors. Mineral mining and processing will continue to play a major role until 2000.

Agricultural yields will continue to grow, but soil salinity, air pollution and the limited amounts of new irrigation water that will be available during the next several years will slow growth. Changes projected are in the cropping patterns that may change the nature of agriculture. Sugarbeets, alfalfa and potatoes may be replaced by other crops. The cotton base will not be altered because the cotton yield per acre is 250 percent higher than yields in other parts of the country.

Changing patterns of the agriculture will have no serious effect on the agricultural labor force, which is well established. One hundred forty-eight thousand persons were employed in the region in 1978. Agriculture accounted for 28,000 persons, or 19 percent of the labor force. Future growth in the labor force is expected among professional and technical workers who have mineral extraction and petroleum related experience.

The community service sector is anticipating the increase in population and expanding health care facilities, law enforcement, fire protection and related governmental activities. There will be new employment opportunities in each of these areas to meet the increased demands of the growing population.

Scenario A forecasts planting up to 200,000 acres of guayule in Kern County by 1990. It is estimated that growing guayule would require one full-time farmer per 700 acres (Lacewell, 1979). This assumes that rubber companies or other organizations would provide planting and harvesting crews, and that the farmer would be involved in crop maintenance. On a four-year growth cycle, 25 percent, or 50,000 acres, would be re-established annually. Since guayule likely would replace alfalfa, sugarbeet or potato crops in the Kern County area, this could mean that there would not be a significant change in the amount of agricultural labor required in the Kern County area due to guayule growing; however, 285 farmers would be needed to cultivate the 200,000 acres.

This production base would support at least two processing plants in the Kern County area. The cost of constructing a processing plant would be between $18 million and $20 million. It would require construction labor for a short to intermediate period. According to the best estimates by Firestone Tire and Rubber Company (Nivert, 1979), a processing plant capable of producing 50 million pounds of guayule rubber annually would require a staff of 120 to 130; 67 people in operation, 17 in maintenance, eight in the laboratory, and 30 to 40 personnel for supervision, management, secretarial and support positions. If the size of a plant were reduced to a 25 million pound processing facility, the number of people required would be reduced only by 15 to 20 persons. Approximately 100 to 115 persons per plant would be required at that production level. Guayule rubber production then would generate a minimum of 200 new jobs in the Kern County area. The local service sectors would require 300 additional personnel to support the plants. Total workers required to operate and support the industry would be 785, of which approximately 500 would represent new jobs.

It is not likely that a processing plant would create any major demands for energy services because bagasse, a byproduct of guayule processing, could be used to generate all the necessary energy to power a processing facility. Furthermore, it is expected that enough bagasse will be produced to generate electricity for sale after facility energy requirements are met.

In Scenario B guayule cultivating and processing would be accelerated greatly. It is likely, therefore, that some prime agricultural lands or marginal lands would be used for guayule production. Additional agricultural labor would be required in addition to full-time farmers because of the increased acreage. It is probable that at least two processing plants would be in close proximity of or within the County boundaries.

As in Scenario A, other industries probably will be developed to support guayule processing. Tire and rubber companies may establish plants near the growth areas rather than transport processed guayule rubber across the country.

In both Scenarios A and B, increased transportation will be required to move guayule rubber out of the area into plants where it can be converted into tires.

b. Pecos County: Rural Pecos County, Texas, does not have a planning-for-the-future program. It has a population of 14,300 persons. Population is expected to grow to approximately 19,000 persons by 1990 and to 22,112 persons by 2000. The current unemployment rate is less than 5 percent. Employment in the future will be primarily outside of the area of agriculture due to acreage declines caused by the high cost of natural gas to pump irrigation water. Much cotton cropland has been converted to rangeland as a result of these increased costs.

The growth of employment during the next 10 years probably will occur in the mineral extraction or petroleum development industries. A significant amount of oil exploration and drilling is occurring in the area and should increase during the next several years. Five thousand persons were employed in 1978. Agriculture accounted for 540 jobs, or 11 percent, of the labor force.

Under Scenario A up to 100,000 acres could be planted with guayule by 1990 to support one processing plant. To operate and support one processing plant 143 full-time farmers, 120 processing employees and 385 service sector employees will be required. These new jobs would represent a 12 percent increase in total employment and a 26 percent increase in the agricultural sector. About 650 new jobs will be required to operate and support the industry.

Under Scenario B forecasts for the Pecos County area, social impacts would not be much different from those forecast under Scenario A. It is not likely that more than one processing plant would be located in the area. The major difference would be how quickly the guayule rubber production system could be brought on line. More agricultural labor would be needed in the area, a requirement that could accelerate the use of undocumented workers to plant and harvest guayule.

4. Potential Impacts of Guayule Production: The impacts of producing and processing guayule in the Southwest depend mostly on where guayule would be grown. In the urbanized areas of California, in Phoenix and Tucson, Arizona, and in El Paso, Texas, the impacts would be relatively insignificant. In rural areas, however, there would be positive economic impacts, but negative community and social services impacts. Conflicts with cultural values and attitudes may occur. Figure VI-3 shows how guayule development could affect a rural community. It is impossible to quantify these impacts precisely. The discussion that follows, however, gives some indication of the potential positive and negative impacts of guayule commercialization on the local areas, the region and the nation, and on international relations.

a. Scenario A: The range of local impacts can be developed by comparing the forecast impacts on Kern county, California, and on Pecos County, Texas. The economic impacts would be relatively insignificant to slightly positive for Kern County, California. Economic impacts in Pecos County, Texas, would be positive but with certain negative short-run aspects.

i. Kern County: About 785 new jobs would be created by a guayule industry. Significant differences in the employment categories or oportunities are not anticipated, however, since guayule probably would displace other crops. Income earned by guayule processing plant workers would turn over approximately two and one-half times in the County to increase the tax base and the total buying power. Worker incomes, therefore, would have positive impacts on the tax base and economy of the County. In addition, the $18 million to $20 million spent to construct a processing plant would greatly enhance the short-term revenues in the County.

The impacts on the County government service and institution sectors would be relatively insignificant or at least minor. Costs of operating fire and police departments would rise due to increased population. Welfare and unemployment costs perhaps would increase. Providing adequate housing for an increased population would create stresses. However, because Kern County personnel are planning for a substantial population growth and because they have planned for a diversified economy, these impacts will be minimal. The health and education sectors in the County appear to have adequate personnel reserves to respond to forecast growth. Planning for growth in the school systems has been careful in considering the diversified nature of growth in the County economy. Finally, the tax base increase from guayule rubber production should offset the cost of providing more services in Kern County.

LOCALIZED VIEWPOINT OF GUAYULE AGRIBUSINESS AND COMMUNITY RELATIONSHIPS

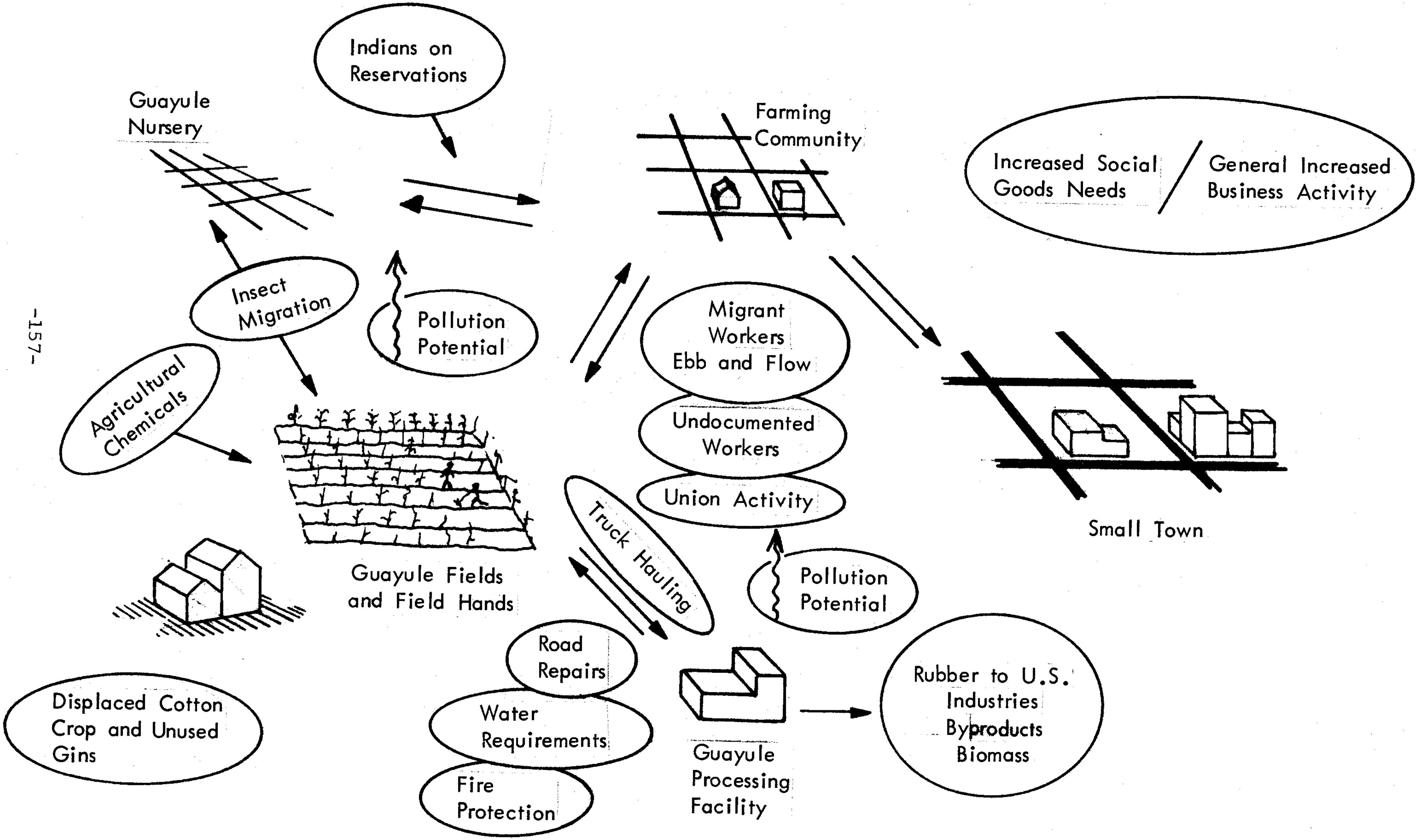


Figure VI-3

ii. Pecos County: The economic impacts would be somewhat different for this rural County. Guayule rubber production would increase the demand for agricultural labor because abandoned farmlands would be brought back into production. About 650 new jobs would be created, more than 140 of which would be in agriculture. This would represent a 20 percent increase in agricultural employment and a 13 percent general employment increase in the County. The potential new agricultural jobs may be filled by migratory or undocumented labor since prevailing agricultural wages do not compete with wages and benefits in the oil industry. Short-term jobs will be created to plant and harvest the guayule. However, direct seeding would eliminate those jobs associated with planting guayule.

The costs of constructing a processing plant would be $18 million to $20 million. Constructing a plant would require skilled labor not available in the County. The imported laborers would require housing, and community services, and would have a potentially disruptive effect on community life for a short period of time. Personnel planning processing plant construction should coordinate with the County communities planning staffs to provide adequate housing for construction workers and to minimize the impacts on the community services. Community development planning throughout the County should ensure that the short-term developments could be converted into long-term use for the County.

The establishment of a processing plant in Pecos County, Texas, would directly increase the job force by at least 100 people. At least two-thirds of the people could be from the County. However, professional backgrounds and skills required to fill particular jobs in the processing plant would have to be imported. Guayule processing also probably would increase employment in the transportation sector of the economy. The overall job impact in the County would be positive. The tax base and the total expendable income would be increased. The income of the processing plant workers would be turned over approximately two and one-half times in the County to increase retail trade and contribute to net benefits in terms of taxes and public and private revenues.

Other economic benefits would include guayule nurseries. If transplanting seedlings continues to be the dominant technology to establish plantations, additional people in the area would be employed. Abundant natural gas is available for greenhouse heating, but the high intrastate cost would be a constraint. In addition, rubber companies might find it profitable to establish tire manufacturing plants in close proximity to guayule processing plants to minimize crude rubber transportation costs.

Overall long-term impacts would be positive, but short-term impacts would be negative since present transportation facilities are minimal.

Increased expenditures in fire protection would occur in Pecos County because volunteer fire departments would not be able to handle the increased fire potential that dry crops such as guayule would create. It is unlikely that increased welfare costs would occur in Pecos County because the number of new jobs created would offset existing unemployment. This is especially true in the agricultural sector where unemployment is about 15 percent.

Housing would be the most difficult problem to face Pecos County. Housing developed for the short-term construction workers, however, later could meet the housing needs of the long-term guayule processing plant workers.

Additional demands on the Extension Service and the USDA would occur. Extension Service personnel must develop continuing education programs to deal with constituents who would be considering guayule as an income crop.

iii. General region: Impacts in the remainder of the guayule production region would be similar to those that would be experienced in Kern and Pecos counties. The urbanized areas of Phoenix, Tucson and El Paso would absorb the impacts of regional guayule production without any serious consequences under either Scenario A or B. On the other hand, the rural counties would experience impacts from some initial demands and perhaps some longer- term difficulties would occur. This would be especially true in those counties that have strong cultural modes where residents are suspicious of newcomers. The basic social fabric could be so disrupted that many cultural and social traditions would be destroyed.

There is another potential short-term negative impact, but one that would have positive long-term impacts in the rural areas in the region. Under both Scenarios A and B production, the transportation and communication networks would have to be upgraded. Connecting roads between communities would have to be improved to facilitate workers and product transportation. These transportation and communication improvements would require expenditures of state, federal and local funds. Short-term inconveniences would occur but both access to and from major county centers and transmission of information would be improved over the long term.

b. Scenario B: Scenario B calls for the rapid development of guayule growing and processing in the United States to ensure a supply of natural rubber in the event of a disruption in natural rubber imports. Under Scenario B it is likely that some traditional crops would be displaced and that some marginal lands would be used for guayule growth. In addition, three more processing plants would be brought into production.

The economic impacts of guayule commercialization under Scenario B would not be significantly different from those that would occur under Scenario A. The basic difference in economic impacts between Scenario A and Scenario B is that the federal government probably would provide economic subsidies to begin guayule production under Scenario B. Government subsidies and guaranteed loans would serve as incentives to farmers to begin guayule production.

Rubber companies probably also would receive federal subsidies to ensure the timely construction and strategic location of plants within the guayule growing region. Guaranteed markets and prices are other governmental options.

More land would be under cultivation and more labor would be required under Scenario B to maintain crops, assuming that the farmers would manage their own land instead of leasing it to the government as was done during the ERP.

The major impact under Scenario B would be development of a secure source of natural rubber that would be available during a crisis. This availability of domestic natural rubber would guarantee that tires and other necessary rubber products would be available and that rationing would be less likely, or less severe.

In order to examine the full range of impacts across the growing region, Kern County, California, and Pecos County, Texas, were examined again. The impacts on government and service sectors were not significantly different under Scenario B from those forecast in Scenario A. Rural communities would have to provide additional services and housing for persons involved in construction of processing plants, in production and later in processing. The cost of these services probably would be mitigated by federal government investment to facilitate enhancement of local services. Employment in the region would be stimulated because increased fire, criminal justice, health, education and other social services would be needed. In addition, guayule commercialization would increase monies available for educational opportunities and perhaps enhance the quality of education in the region.

Kern County, California, and the other urban counties probably would experience less impact than rural counties such as Pecos County, Texas. Kern County has an adequate labor force and is close enough to other metropolitan areas so that labor can be imported without undue difficulty.

In the rural counties agricultural supply firms probably would experience major impacts. They would have to make the changes required to meet the product demand of growing guayule. In the urban counties these impacts would be less severe because of the diversified economics that exist.

B. Environmental Assessment

Commercial guayule development in the U.S. Southwest can be expected to impact, both positively and negatively, the local environment, occupational safety and health and regional natural resources such as land, water and energy.

1. Environmental Effects of Guayule Development: Environmental impacts of guayule rubber production can be surmised from the findings of recent processing research in Mexico, from the growing and processing experiences from the World War II ERP and from earlier guayule production activities.

The guayule plant does not have any peculiar characteristics that would produce unusual impacts. Under cultivation it is a gray-leaved, semiwoody shrub reaching a maximum height of 30 inches. It branches profusely and if not crowded is about equal in height and diameter. It has unusually deep roots that can reach a depth of 20 feet under favorable soil conditions. Also, it is a profuse seed producer from wind- and insect-pollinated flowers.

In general, the environmental impacts are those of a row crop with a life cycle of up to four years. Under irrigation plants do not develop during the first year; but, the space between plants within rows will be closed by the end of the second year, and the space between rows will be closed during the second or third growing season. Under rainfall farming spacings will take a longer time to close.

The first impacts occur during field establishment. Land preparation needs to be thorough and up to usual standards for planting row crops. Direct seeding requires careful leveling to provide uniform moisture throughout the planting area. If establishment is by transplanting seedlings, leveling does not need to be as precise, but major irregularities and irrigation ponding must be avoided.

During the establishment period the soil may be subject to wind erosion that will become less of a hazard as the growing season progresses. If the land is prepared improperly there is also the danger of erosion by water. Dangers of these impacts would occur during three or four years.

Weed control during the establishment period also creates problems related to herbicides and the loosened soil caused by cultivation.

During the major period of growth, two to four years, guayule represents a stable plant community that experiences minor wind and water erosion hazards. During this period little cultivation is needed.

The mature shrubs are harvested by undercutting, windrowing and baling. These operations leave the soil uncovered, but because of roughness due to digging, erosion hazards are low.

Processing usually involves storage that should be under cover because rubber deteriorates when the harvested shrubs are exposed to sunlight.

The effluents and gases produced by various extraction operations could have important health impacts.

The environmental impacts of guayule as a crop have broad implications. Guayule probably will be grown in large tracts, perhaps up to 640 acres. On this scale it will have definite ecological cause-and-effect relationships. As a replacement for other crops it will become a major influence in its biome. Aside from special situations such as those involved in establishment, its influence will be on general host-predator situations involving birds, smaller vertebrates, a variety of invertebrates and various plant species.

Massive tilling of lands not now under cultivation could disrupt local ecological balances. Removing the present ground cover that serves as potential food sources and shelters for insects and small animals may result in guayule plants becoming substitutes for these purposes. Removing trees and large shrubs used by birds for nesting, shelter and food would cause bird migrations to forests, other agricultural areas and surrounding communities. Precise cultivation impacts are not predictable because of a lack of historical data. However, there is enough general knowledge to make some overall forecasts.

On the negative side, it is known that guayule is subject to most common plant diseases and to infestation by a limited number of insects. It is unknown whether growing guayule on a four-year cycle will increase or decrease plant diseases and insect infestations. Using good farming practices, including disease and insect controls, infestations should not increase and may even decrease. The same thing can be said for weed invasions.

It is assumed that guayule cultivation will require some fertilizer, pesticides, growth regulants and soil conditioner applications. Runoff and contamination, however, are potential problems associated with such applications. Current experimental guayule agricultural practices do not employ these techniques and thus provide no evidence up on which to base judgments.

There are no herbicides or insecticides registered or granted temporary application permits for guayule and there is no data base with which to render decisions with respect to their use. The major concerns regarding pesticide applications to non-food crops are the safety and health of applicators and field workers, and the residue and drift problems that potentially could contaminate nearby fields, worker housing and surrounding communities.

Fields of mature guayule plants may represent a significant fire hazard. Guayule must be considered a "hydrocarbon crop." Although young or mature plants may not be particularly flammable by themselves, they can be burned easily with the aid of flammable solvents or oils. This potential fire hazard would assume even greater importance during times of social or national emergency. Fields of hydrocarbon crops might be subject to vandalism, sabotage, or other acts of overt behavior, e.g. labor strike- related incidents. Establishing an adequate fire protection infrastructure is essential.

Guayule culture could improve the agricultural environment. Guayule's extensive root system, combined with a relatively low water requirement and moderate salt tolerance, could help to flush salts downward to reduce salt accumulation in the surface soils. These same characteristics would promote efficient water use, especially in areas where moisture may be left 5 feet below the soil surface by previous, shallow-rooted crop plants.

In a broader sense, guayule may have many impacts on the environment. Guayule will increase total crop acreages when grown on previously undeveloped land. This would be true also where it is grown on abandoned farmland to replace crops with higher water requirements and to keep the land in production.

Guayule can have a major impact on water supplies because it can be grown with significantly less water than most conventional field crops. In a cropping system under limited water supplies it may become possible to average out total water allocation by growing high-water-use plants on one portion of the farming enterprise and growing guayule on other portions.

In a four-year cycle, only 25 percent of the guayule acreage would require planting and harvesting equipment and labor inputs per year.

Nursery operations require intensive land use and would multiply impacts many times those listed above. One acre of nursery would provide enough seedlings to plant 30 to 40 field acres. Thus, a 100,000-acre production unit of guayule would require approximately 700 acres of nursery to plant 25 percent of the field acreage annually.

Greenhouse seedling production requires less space but adds the impacts of buildings. Also, research indicates that greenhouse seedlings would have to be hardened outside before transplanting. Impacts from the outside hardening of greenhouse seedlings would be similar to those of nurseries.

Rubber extraction and processing impacts would be mostly related to human health. They include the production of dust, various airborne particulates, liquid effluents and solid waste materials.

2. Occupational Safety and Health Concerns: Mears (1979, 1980) cautions that wild stands of uncharacterized guayule and other Parthenium species may contain sesquiterpene lactones that can cause contact dermititus or respiratory problems. Parthenium hysterophorus (congress grass or carrot weed) plants in India contain oleoresinous material that can cause severe dermal problems (Ranade, 1971; and Lonkar, et al, 1974). New strains or hybrids of guayule could be crossed with sesquiterpene lactone producers to increase rubber content or disease resistance. Precautions should be taken in this process because the new strains also could produce toxic materials. Harvesting and baling mature, pollen-bearing plants theoretically could cause respiratory problems for field workers or handlers.

Rodriguez and Sternburg (1979) reported on their research into the toxicology of guayule and guayule F_1 hybrids. One compound contained in guayule leaf extracts, believed to be terpenoid, has been found to be a potent sensitizer with laboratory guinea pigs. Studies of F_1 hybrids indicate the presence of numerous compounds not present in the two parents. These researchers conclude, "The significance of preliminary findings suggest that further studies are needed with human patients in order to determine the occupational hazard of guayule and measures needed to be taken by employers to minimize the effect."

The pilot processing facility in Saltillo, Coahuila, Mexico, employs the same personnel for harvesting, handling and processing wild guayule. In the experience of this program, in operation since 1976, there have been no reported respiratory, dermatological or allergenicity problems (Neavez-Camacho, 1979).

Once the mature guayule plants arrive at the processing facility, the concerns of hazard to, and safety of, the worker change drastically. Storage of dry guayule plants in closed sheds may result in relatively high concentrations of volatile materials and pollen. Workers breaking bales of dry guayule may require respirators and goggles.

Technological options for processing guayule plants are generally semicontinuous operations involving many stages that have potential to generate emissions and effluent, including parboiling (volatile losses); water jet defoliation (effluents); hammermill, crushing (particle generation); pulping (with caustic soda additions); washing and chemical treatment (detergents and effluents); chemical solvent extraction (acetone, hexane and other volatiles with associated effluents); antioxidant sprays (volatiles and effluents); and drying operations (volatiles).

None of these stages have been characterized fully and assessed for worker safety and health hazards. Mexican sources do not indicate significant hazards arising from current processing technology at the Saltillo facility. New processing technology designed by Firestone Tire and Rubber Company will rely heavily on solvent extraction and washing techniques using acetone, hexane and water (Nivert, et al, 1978).

Volatile losses of acetone and/or hexane would require development of safety procedures that address toxicity and flammability. For both economic and safety reasons effluents that consist of water and acetone or hexane are expected to be recovered for recycling.

Large amounts of bagasse will be generated during processing. Storing bagasse that contains water and traces of acetone may be a safety hazard. The bagasse may be subject to spontaneous combustion if temporarily stored in compacted form before being disposed of or used as a biomass energy source in the processing facility.

In summary, guayule commercialization suggests potential adverse environmental and occupational safety and health effects due to extensive agricultural practices; transportation of harvested plants; and construction and operation of processing facilities that would generate potential emissions, effluents and solid waste. If guayule development involves critical governmental decisions, environmental impact statements will be required for those activities that could affect environmental quality significantly. Thus, both agricultural and processing activities could involve environmental impact statement development.

3. Natural Resource Factors

a. Land use: The major impact of guayule production on land use in the U.S. Southwest may be to keep agricultural land in production that might otherwise be phased out due to dwindling water supplies or increased energy costs. This could have a profound effect on the stability of many rural communities, particularly those in water-short areas of Texas, New Mexico and Arizona. Sustaining the integrity of existing farms also slows "leap-frog" development in areas that have rapidly increasing populations, thus avoiding the problems inherent in disorderly urban expansion.

Sustaining agricultural acreage now in production by displacing higher water using crops with guayule is more probable than extensively reclaiming abandoned farmland for guayule production. The high renovation costs for neglected irrigation systems and abandoned fields may make using operational farmland a more economically attractive alternative.

New irrigated agricultural production probably will be limited to those Indian reservation lands in Arizona and California that have guaranteed surface and/or groundwater supplies. Developing marginal lands for guayule production, although considered highly desirable by governmental and private interests, probably will be minimal. Throughout most of the potential guayule growth region irrigation would be necessary for guayule production. A dependable water supply, not land, is the primary constraining factor on agricultural development. The exception to this rule is possible dryland farming of guayule in certain areas of southern Texas and California.

Under Scenario A, 1.5 million acres are projected for guayule production by the year 2000. Under the rapid stimulated commercialization of guayule projected in Scenario B, 1.9 million to 2.1 million acres would be used for growing guayule crops. In both scenarios, most of the guayule production is projected to occur in California and South Texas; Arizona, New Mexico and West Texas are severely restricted by limited agricultural water supplies.

i. California: The 100,000 acres of projected guayule production in the Colorado Desert region of California lie in an area with Colorado River water rights. It is possible that new lands would be brought into guayule production there.

The San Joaquin Valley and Tulare Lake region are areas of extensive agriculture and of groundwater overdraft. High value crops are grown in the areas. Land is expensive. For that region, 400,000 acres to 500,000 acres of guayule production are projected. But, guayule would have to be quite a profitable enterprise to compete successfully for land. Water is a somewhat limiting factor to agricultural expansion in the San Joaquin Valley--a factor that might favor introducing guayule. As a deep-rooted, low-water-use crop, guayule could help decrease soil salinization, a growing problem in those areas. In addition, guayule could be cultivated on some lands that less salt-tolerant crops could not.

One hundred and fifty thousand acres of potential guayule production land lie in the California coastal region. In some of that area, guayule could be cultivated under dryland conditions. However, the impacts of expanded urbanization and high land costs may constrain guayule growth.

ii Arizona: Temperature requirements would limit guayule production to the Basin and Range province in the southern and western portions of the State. Precipitation ranges would make irrigation necessary. Most of the non-Indian land portion of the 200,000 acres of potential guayule production projected for central Arizona lies in designated critical groundwater basins where additional irrigation or land use should not be expected for growing guayule.

Arizona is depleting its groundwater supplies. As water becomes more expensive or restricted in use, higher water- demanding crops will give way to more water-conserving crops. Overall, agricultural acreage in central Arizona is expected to decline by 42 percent to 43 percent from the nearly 900,000 acres in production in 1970. Guayule production could slow this decline by keeping existing farms commercially viable, by acting as an incentive for cultivating abandoned agricultural land, or by expanding agricultural potential on grazing ranges.

A public policy of purchasing agricultural lands in Arizona to conserve groundwater for future municipal and industrial use could severely constrain guayule crop production. However, land management problems and costs inherent in this policy could be mitigated by using guayule as a ground cover to control erosion and to prevent encroachment by noxious weeds.

A change in Arizona water laws to allow splitting water rights with part retained on the land for low-water-use crop production and part exported for municipal or industrial use would stimulate guayule development greatly in central Arizona.

In the Colorado River area where 100,000 acres of guayule production is projected, dependable surface water supplies are guaranteed on Indian lands. Some new agricultural land could be used in that area for guayule production, including areas with saline soils unsuitable for most other crops but within the limits of guayule salt tolerance.

iii. New Mexico: Potential guayule production areas lie in the southwestern corner of the State. Virtually all agriculture in this area is irrigated. A total cropland acreage of almost 210,000 acres was in production in 1975. New Mexico has been operating under strict groundwater controls for several decades. An adequate water supply exists for present agricultural usage. It is unlikely that much new land would be used for guayule crop production. Projected average is 100,000 acres in the El Paso-Mesilla Valleys of Texas and New Mexico. Considerable crop displacement could occur as guayule becomes a more profitable crop.

In accordance with State law, it is assumed that New Mexico will continue to operate within the constraints of its existing water supply, that water rights will continue to be available through the marketplace, and that the economic value of water for various purposes will determine its application. It is expected that water demand for increased urban and industrial needs in New Mexico eventually will result in a decline in irrigated agricultural acreage, but probably by no more than 5 percent to 10 percent before the year 2000.

iv. Texas: The greatest impact on land use from guayule commercialization would occur in southern Texas. Under Scenario A, 400,000 acres of dryland guayule production is projected; under Scenario B, 600,000 to 800,000 acres is projected. Most of the land under consideration in that area is brushland used for livestock grazing and leased for hunting use. Thus, developing guayule would represent a significant displacement of these two land uses, particularly under rapid commercialization forecast in Scenario B. Guayule development also could come into direct competition with other new crops proposed for this area, for example, with energy biomass crops such sugarbeets.

Because of the limited rainfall in the Trans Pecos region of Texas, guayule production in that area necessarily would be irrigated. Irrigated agriculture there is expected to decrease from 250,000 acres in 1974 to less than 150,000 acres by 2020 due to a declining water table and rising pumping costs. The 100,000 acres of irrigated guayule production projected for the area would involve considerable displacement of existing crops. Guayule's lower water use could result in more acreage remaining in agricultural production in Texas than would have been possible otherwise.

b. Water use: As indicated above, many of the areas in the U.S. Southwest suitable for guayule production, because of climate and soils, have dwindling water resources and rising energy costs. For these reasons there is considerable interest in guayule as a crop that could serve as an alternative by prolonging water supplies in Arizona, New Mexico and West Texas. Guayule may become one commercially viable alternative for agricultural interests in many areas of the U.S. Southwest as groundwater becomes more costly to pump from increasingly greater depths.

i. California: Most guayule production in California would require irrigation. Water will be a constraining factor to increased agricultural production in the southern part of the State according to the California Department of Water Resources. Commercial guayule production on developed agricultural lands would have to be competitive with other crops. In areas that have groundwater overdraft such as the San Joaquin Valley and Tulare Lake region where overdraft is more than 1 million acre-feet per year, using guayule as an alternative crop would serve as a conservation measure.

Urban water demands in the area are expected nearly to triple by 2020, but these demands will represent only 7 percent of the total water demand that will continue to be used primarily by agriculture.

Developing additional water sources for this area is only a remote possibility. Such development would require importing water from the northern coastal regions of California, an action which could be expected to meet significant environmental and economic opposition.

The California-Colorado Desert area is considered a prime area for guayule production and includes lands with Colorado River rights. Agriculture production is expected to increase in this area. Guayule production would not have significant impact on water depletion.

ii. Arizona: Water supplies in Arizona are being depleted by approximately 3 million acre-feet per year. In 1970 the Arizona Water Commission estimated that 89 percent of the State's total water depletion was attributable to irrigated agriculture. For the first time in its history, Arizona is approaching effective groundwater-withdrawal regulation.

Guayule can not be grown commercially in Arizona as a dryland crop; supplemental irrigation water would be needed. The bulk of potential guayule cropland in central Arizona lies in areas designated as critical groundwater basins. Using guayule as an alternative crop for this area would decrease the rate of groundwater depletion and would aid water conservation efforts. Due to population growth pressures, urban water-use demands are increasing and will compete strongly with future agricultural water needs. Water rights for irrigation on Indian lands are subject to the Winters Doctrine. Determining the water quantity available to central Arizona Indian lands is undergoing extensive negotiation.

A different set of circumstances applies to potential guayule production in Yuma and Mohave counties. Here, irrigated agriculture water supplies are more stable. In addition, Indian lands near the Colorado River have guaranteed surface-water supplies. Increased agricultural development is anticipated. Guayule production would have a less significant impact on water resources in this area of Arizona.

iii. New Mexico: Guayule production in New Mexico could be achieved only with irrigation. New Mexico is operating within the constraints of its existing groundwater supplies. Surface water use in the State is subject to provisions of compacts between New Mexico and several other states. No significant future increases in New Mexico water supplies are expected since these compacts are based on present dependable water supplies.

All irrigation water that could be applied to guayule production is subject to the New Mexico State Engineer permit system. Introducing irrigated guayule crop production probably would occur on existing farmland and would impose no additional burden on New Mexico water supplies. It is assumed that the economic value of water for various purposes will determine its application. A low-water-use crop such as guayule could provide one mechanism for reducing agricultural water withdrawals without significantly reducing agricultural acreage.

iv. Texas: Declining irrigation water supplies in West Texas are expected to reduce agriculture, particularly in the Trans Pecos area where deregulated natural gas prices have increased pumping costs significantly. Introducing guayule as a low-water-use crop might enable continued viability of agriculture by reducing water pumping costs to the farmer. This positive effect, however, may be overshadowed by the poor quality of groundwater in the area that might limit guayule production.

Significant development of guayule dryland farming in southern Texas could occur without appreciable reductions or diversions of available water supplies. Citrus farming and high-value vegetable crops will continue on irrigated acreages in that area.

Impact on water use by the increased acreage projected in Scenario B in the southern Texas guayule production area would be from water used in guayule processing facilities and from increased household and community water needs of the growing rural communities.

c. Energy use: Regional demands for electric power will increase as population growth trends continue in the Sun Belt states of the U.S. Southwest. The Colorado River desalinization plant under construction on the California-Arizona border will be a high energy user. Energy costs to farmers who rely on electric power or natural gas will escalate in response to increased regional power demands and the expiration of rates established during the 1950s.

Guayule commercialization would require energy for crop production. The highest net energy use for guayule production would be in areas where irrigation and pumping to deliver water to the fields are necessary. Energy use would increase wherever guayule production is an additional agricultural enterprise. Where it serves as an alternative for higher water-use crops, guayule could be viewed as an energy saver. Guayule dryland farming would require energy only for farm-equipment operation.

The price of electricity in areas of California and Arizona along the Colorado River is expected to rise when existing rates are renegotiated during the early 1980s. Energy costs in Texas are high due to unregulated natural gas costs. These high gas costs have been a major factor in the decline of irrigated agriculture in the Trans Pecos area. Energy costs will be a significant factor in establishing the commercial viability of guayule production in various areas of the U.S. Southwest.

Net energy use by guayule processing facilities may be negligible. Guayule bagasse can be burned as fuel to supply the energy required by guayule processing facilities as was demonstrated by ERP. Findings of research by the Firestone Tire and Rubber Company personnel indicate that a bagasse-fired cogeneration facility that would produce high-pressure steam for electricity generation and low-pressure steam for direct-processing use can supply all the energy required in processing and can produce additional electricity for sale as well. How much this additional energy production would offset energy demands by increased population attracted to the area by employment opportunities is difficult to determine.

C. Additional Consequences

Impacts that are outside the central thrust of guayule development Scenarios A and B in Chapter V are discussed in this section. Included are two general areas of impact: issues in guayule development identified by parties-at-interest, and tangential impacts that can be identified, but are outside the bounds of the TA.

1. Issues Perceived by Parties-at-Interest: The impacts that result from any technological development can be placed into two categories: impacts that proceed from the physical implementation of the technology, and impacts that are perceived by parties-at interest as resulting from the technology. In either case, the consequence is equally real. Therefore, the ways in which the issues identified by parties-at-interest are resolved can have a profound effect on guayule commercialization.

a. Issues in California guayule development:

i. Marginal land vs agricultural land development:

Marginal land proponents: the California State Legislature, much like the U.S. Congress, had economic benefit for the underprivileged through development of agriculture on marginal lands as one of the primary incentives to pass State guayule legislation. The California Department of Conservation views guayule development as occurring on marginal lands that, in turn, push agriculture into more marginal land development. The California Energy Commission study (1979) included guayule cultivation potential in the California desert region and assumed marginal land development. This assumption is based on their objective of assessing desert lands for biofuel potentials in such a way as to not disrupt existing agriculture.

Agriculture land proponents: The California Department of Water Resources views guayule as replacing "low payment-capacity," high-water-demand crops such as irrigated pasture, alfalfa, corn and possibly some grains and milo. This perception results from the perspective that water, not land, will be the limiting factor in Southern California agriculture. The Department does express interest in developing some guayule on valley slopes, but not from the perspective of intensive agriculture to produce a rubber crop efficiently. Such marginal land development could provide some economic return perhaps during a 10-year period on lands that presently yield virtually no economic return at all. In addition, some benefits for wildlife could accrue. The Department of Food and Agriculture does not view guayule as displacing other crops, "unless water becomes a serious limiting factor." It does view water as being a somewhat limiting factor in the San Joaquin Valley in the 1980s and 1990s. Whether or not additional water is supplied to Southern California agriculture is interpreted within the State as a highly political question. A change in administration could reverse present policy. Whether or not it displaces other crops depends primarily on the water-supply situation. The California Office of Planning and Research views the principal opportunities for guayule development as being on "set aside lands" legally taken out of other crop production. The Office is interested in the potentials of marginal-land development as well. The California Office of Appropriate Technology is interested primarily in the potential of developing Indian lands that may or may not be classified as marginal.

ii. Scale of development: The California Department of Food and Agriculture is in charge of the State guayule demonstration project. The Department sees its role as demonstrating production in coordination with the market development of guayule agriculture and processing. The Department envisions guayule commercialization as occurring at a slow pace and then "scaling up" once momentum is gained. The Department is interested in having part of the demonstration research acreage on an Indian reservation, but its primary orientation is toward funding guayule demonstration work until such time as normal market factors take over. To what degree scaling up is envisioned is not clear, but many existing California agricultural processing enterprises are quite large. Vertical agricultural system integration is firmly established in California agriculture (as stated by the Water Resources Department), and countermovements to promote large-scale horizontal coordination through co-ops such as Sunkist, Sunsweet, Diamond and Blue Diamond nuts, and the Tri-Valley Co-op also are strongly entrenched.

The State Office of Appropriate Technology views large-scale commercial enterprises as having little to do with local economic development for underprivileged communities or Indian reservations. Large-scale processing development is perceived to serve the interest of the tire and rubber companies, not the local economic needs.

The California Office of Planning and Research also views guayule development as most appropriate for individual farming enterprises rather than for corporate farm enterprises.

The California Assembly Committee on Agriculture consulting staff, recognizing the Legislature's desire for guayule to benefit the underprivileged, sees a number of existing legal pathways available to control the scale of guayule development. Incentive programs could be engineered so that they would benefit only the target population; small, high-risk business loans could be offered; tax incentives or backup funding could be provided for co-ops or processing facilities operated by co-ops.

iii. Additional water supplies for Southern California agriculture: Much of the difference in opinion about whether guayule will be developed on marginal or established agricultural lands stems from differing views of the probability of new water sources being developed for Southern California.

Estimates of irrigation costs for Southern California range from $5 to $7.50 per acre-foot. The Department of Food and Agriculture projects these costs to rise from $8 to $9 per acre-foot between 1980 and 1990. These delivered water costs are highly subsidized. Estimates of "public costs" range as high as $100 per acre-foot for this irrigation water. Costs of developing new water sources would be much higher. The source of new water would have to be the California north coastal region. Department of Water Resources estimates $150 to $200 per acre-foot just to secure new water to transport to the southern part of the State. The Assembly Committee on Agriculture estimates public costs of from $200 to $300 per acre-foot for new development irrigation water delivered in the south of California. A $7 billion "Peripheral Canal Bill" recently was defeated in the California Legislature. It met serious opposition based on both economic and environmental factors.

Nevertheless, Food and Agriculture believes that some possiblility of such development exists if the political climate changes in California. Some agricultural interests in Southern California seem to believe that such a water development may occur especially since some Southern California agricultural interests, particularly in the San Joaquin Valley, have strong and effective lobbying in the Legislature.

b. Issues in Arizona guayule development:

i. Governmental involvement vs. laissez faire: The clearest point of contention in commercializing guayule in Arizona is the question of whether federal or state government should be substantially involved.

Standing in favor of strong involvement by government are groups that traditionally have been "squeezed out" of much of the economic activity in the State: the Indian communities. They tend to favor involvement, particularly with respect to coordination of growing and processing on the reservations. They tend to see the reservations as traditionally receiving the least benefit from resource development, agricultural or other, and are seeking more complete development of resources on the reservation so that the whole value of the resource -- basic value, process added value, jobs inherent in all steps -- is realized by the recipient tribes.

Standing in opposition to government involvement, or at least in favor of the "least possible intervention," are the groups that traditionally, tend to realize the greatest benefits of resource development: the tire and rubber companies and the private farmers. Farmers view government regulation, even in terms of subsidization or incentive programs, as tending to minimize crop profitability. Acreage allotments, for example, are viewed as giving product buyers a "too-clear-view" of how much commodity will reach the market, and how little the farmer can accept and still make a marginal profit.

Federal involvement in guayule to promote reservation development and scarce-water use in competition with non-reservation farmers would be viewed as an threat to the non-Indian agricultural sector.

Governmental agencies tend to view involvement as legitimate up to the point of demonstrating the feasibiligy of guayule commercialization. Several agency representives stated that a "comsat-type" organization would be most likely to succeed. However, these agencies do not see legitimate involvement beyond the point of program initiation.

All parties-at-interest tend to see some governmental involvement as inevitable, but timing of this involvement could be critical in terms of local support or resistance.

ii. Irrigation water shortage: The combined effects of rising energy costs and lack of a dependable water supply are on the verge of making much traditional crop agriculture non-viable in Arizona. One farmer interviewed showed water costs to irrigate cotton as having risen by a factor of 10 over a five-year period. This situation, from the farmer's perspective, is exacerbated by impending State groundwater legislation that may put maximum groundwater withdrawal limits below traditional uses. Further complicating the issue is the allocation of federally subsidized project water in the State for irrigated agriculture on Indian reservations.

If water conservation alternatives are not found soon, the private agricultural industry sees agriculture as disappearing from Arizona, except on reservations where federally guaranteed water supply exists. This situation would carry with it the concomitant decline of rural communities throughout the State along with an array of sociodemographic disruptions.

Reservation agriculturalists have expressed the same concern about the future of rural communities and share the sense of urgency for low-water use crop development.

c. Issues in Texas guayule development:

i. Uncertainties of guayule technology: Uncertainties identified by Texas parties-at-interest include lack of adequate seed supply with proven yields, lack of processing facility development, and the unknowns inherent in dealing with a four-year crop rotation.

ii. Risk capital: These issues concern scarcity of locally available investment capital, high interest on agricultural loans exaggerated by a four-year delay on investment return and insufficient farmer cash flow.

iii. Land and water considerations: Re-introducing groundwater depletion on currently idled farmland, declining water quality in West Texas, converting brush or rangelands in South Texas to guayule field cropping, and the rapid and continuing demise of the cotton industry in West Texas resulting from dramatic increases in costs for natural gas used to power irrigation pumps are local concerns.

iv. Labor concerns: The need for alternative agricultural employment for those presently displaced was stressed. Conversely, others emphasized the difficulty of attracting farm workers (in competition with oil and gas field jobs) from the U.S. labor market as opposed to the relative ease of attracting Mexican farm labor. The latter was cited as a need for coordination of U.S. and Mexican guayule development.

v. Beneficiaries: Conflicting concerns were expressed in Texas as to whether commercialization of guayule will benefit primarily the tire and rubber companies or the small farmer.

2. Consequences Beyond the Bounds of the TA: Two alternative means of achieving guayule commercialization have provided bounds to this study: Scenario A, wherein commercialization is achieved through the relatively undisturbed marketplaces for rubber and U.S. Southwest agriculture; and Scenario B, wherein the federal government assumes a central, active role in rapidly stimulating guayule development. Superimposed upon this structure for the purpose of policy analysis is the federal decision option of whether guayule development is considered a strategic need. Discussion of consequences and policy implications are based upon the guayule commercialization system thus defined and bounded.

At the same time, it is recognized that many other potential or "hidden" impacts that may have a bearing on or may be affected by guayule commercialization lie beyond the main thrust of guayule commercialization including various factors that relate to Mexico and other countries where guayule might be grown, to American Indians and other minorities, to byproduct development and to world energy supplies.

Table VI-1 presents important economic sectors and parties-at-interest that may impact upon or may be impacted upon by guayule commercialization. Several areas require further investigation as guayule commercialization continues. The text that follows highlights these factors.

a. Local focus: Benefits to unemployed agricultural or unskilled workers from newly created jobs would be highly localized, having the greatest impact in the more remote rural guayule development areas. The labor requirements for guayule cultivation and processing appear to be minimal under the capital intensive approach assumed for Scenarios A and B.

Environmental concerns and issues related to worker safety and health are important to federal and state agencies. If guayule commercialization is established on existing or retired agricultural lands and not on previously undisturbed arid lands, environmental impacts should be minimal.

Major safety and health issues are unlikely to develop in harvesting, transporting, or processing guayule, including bagasse disposal Government regulations would require U.S. processing facilities to be designed to maximize safety in all chemical engineering operations and to protect the health of the worker and the environment-at-large. If the bagasse were incinerated for energy values, pollution control devices would be installed. These issues could be settled to the satisfaction of all groups concerned.

The general business community will benefit from increased farming and processing revenues and an expanding tax base. Under Scenarios A and B projections, positive multiplier effects that would be significant in the more rural guayule development areas should result from construction and operation of guayule processing facilities. Significant community benefits would result if a radial-tire fabrication plant were to be placed in the guayule growth region. Differentials between natural crude rubber, class tariffs, and finished rubber product commodity tariffs, however would tend to work against relocation of fabrication plants away from the final-product market and toward the raw-material source. Other factors such as the "Snow Belt to Sun Belt shift" would have to act as the primary driving forces to draw new tire manufacturing facilities to the rural guayule production areas.

Manufacturing facilities for other rubber products designed to serve a more localized market might have greater probability of becoming established in the guayule growth region of the U.S. Southwest.

b. Regional focus: Potential benefits and adverse effects accruing to American Indians, Hispanic Americans, and other minorities are unknown

TABLE VI-1
SECTORS AND PARTIES IMPACTED BY GUAYULE COMMERCIALIZATION

Economic Sectors, Including Parties-at-Interest	Impact or Consequence: Scenario A	Impact or Consequence: Scenario B
Local Focus		
Unemployed agricultural workers	Localized benefits from newly created jobs	Same
Unemployed semiskilled workers	Very limited benefits from newly created processing jobs	Same
Environmental, safety and health effects	Limited impacts	Potential adverse effects in the short term
General business community	Benefit from increased farming and processing revenues and tax base, multiple effects	Potential construction of tire or other rubber-product fabrication facilities in Southwest, multiplier effects
Regional Focus		
American Indian and other minorities	Limited positive effects	Probable economic gains for Indians through lease of land and water
Undocumented farm workers	Limited effects	Probable increased migration patterns
Marginal farm operations and economically displaced farmers	Benefit by shifting to less water-demanding crop	Benefit from SBA assistance and risk absorption
Banking and financial institutions	Uncertainty related to financing a four-year crop	Moderate impacts regarding risk absorption, loans to small holders, probable futures market
Communities-at-large	Increased needs for social goods including housing, health, roads, police, fire protection	Same

TABLE VI-1 (Continued)

National Focus	Impact or Consequence Scenario A	Scenario B
Environment-at-large	Minimal impacts over near and middle term	Possible new patterns of insect infestation and other pests, moderate pollution potential at processing facilities, moderate fire hazard
Guayule black market	Probable, especially for seeds and unprocessed shrub	Same
U.S. tire and rubber companies	Slight gain in supply stability, little effect on prices	Gain in control of supply and counterforce to cartel activity
Guayule research and development efforts	Minimal budgets and expenditures by research groups including industry and academia	Maximum budgets
Byproduct values including resins, wax, etc.	Limited positive impacts	Large impacts due to research and development efforts, possible depressed older resin and wax markets
Fertilizer and pesticide manufacturers and sellers	Neutral to limited benefits	Same
Recycling-reclamation of rubber	Limited effect on/by guayule development	Same
U.S. rubber stockpile	Potential fulfillment in the long run, short-term market potential	Probable permanent short-fall

TABLE VI-1 (Continued)

National Focus	Scenario A	Scenario B
Various governmental and state agencies	Minimal potential conflicts of policy	Probable conflicts of individual policies regarding land and water use for agriculture, industry, and communities and environmental quality
International Focus		
Balance of trade for U.S. rubber imports and rubber	Minimal effects over near and middle term	Moderate effects over the middle-to long-term
Mexican-U.S. relations	Probable strains if black market appears	Improvement through greater research and trade agreement and cooperation
Mexican government	Benefits limited to land-base development and employment in rural, economically depressed communities	Benefits by shared technology and research-and-development advances
Hevea growers	No loss of U.S. markets for short term, some loss of U.S. markets over long term	Loss of U.S. markets, gain in other world markets
Relationship between U.S. rubber companies and Mexican government	Mexican land-ownership laws prohibit large-scale plantation ownership	Same

at present since these groups have not come forward with definite plans or suggested-action options regarding guayule commercialization. Job opportunities in the American Indian sector probably will be constrained by Congressional reluctance to invest in guayule technology for this group. American Indians may participate more fully through tribally funded programs: land and water leases to growers; supplying seed; operating nurseries growing guayule or investing in capital equipment for processing facilities. These and other minority groups generally have limited capital for investment. The Bureau of Indian Affairs (BIA) or Small Business Administration (SBA) may play a major role in influencing the degree of American Indian involvement in guayule commercialization.

Undocumented farm workers and their regional migration patterns probably will not be affected by guayule commercialization under either scenario because few new job opportunities for them will be created.*

Agricultural crops identified for possible displacement by guayule in the U.S. Southwest include alfalfa, sugarbeets, sorghum, wheat and barley. For example, alfalfa acreage may decline regardless of guayule demand. Alfalfa farmers are expected to switch to other crops, including guayule, in response to rising irrigation costs. Losses of alfalfa for cattle feed may cause a rise in the consumption of other sources of cattle feed that could change crop acreage and prices, as well as dairy and meat prices.

Sugarbeet acreage has been declining and processing facilities have been idled due to the depressed U.S. sugar market. This trend could reverse, however, since sugarbeets can be used to produce alcohol. Sugarbeets can be grown under dryland conditions in South Texas, thus competing for the same land base. Currently the declining sugarbeet industry appears to be making a comeback as the gasohol demand and federal subsidies provide a market.

Land and water use laws and policies may limit the extent of conversion of marginal lands to guayule cultivation as tradeoffs are made between demands by municipalities, industry and agriculture. As the end of this century nears, the United States is experiencing loss of prime agricultural land by encroachment of communities and industry. Those entities that are best able to pay for increasingly more expensive land and water will have the greatest control of these resources. Guayule commercialization will have to compete against other crops that also have relatively low water demands, and in time probably will have to compete

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*The guayule job market probably will be characterized by replacement of one agricultural job by another, and by hiring more skilled labor for processing facility positions.

with energy crops in the U.S. Southwest. The Sociotechnical Survey of Guayule Rubber Commercialization (1979) treats land and water use laws and policies at length as well as water demand for several crops.

Banking and financial institutions could assist small land holders by offering loans, crop insurance and other forms of risk absorption. At present, most financial intermediaries are reluctant to consider these possibilities since guayule may be a three or four year crop. Certain technology gaps in commercializing guayule also must be addressed.

The creation of a guayule future market to foster growth of this agricultural industry could occur under both Scenario A and B (see Appendix E).

Another potential impact could occur if a major portion of a guayule agribusiness established in the future were shut down. For example, a guayule agribusiness belt in California or in West Texas may be shut down permanently because of political or economic decisions. If this happened in California, there would be likely to be only minor economic disruptions because the growers very quickly could revert to other crops in accordance with water-supply limitations.

In West Texas the effects would be more dramatic because growers might not be able to select another cash crop that has low-water-use demands. The idled lands might be converted to grazing operations or might be agriculturally abandoned once again. Jobs and revenues lost would represent economic losses of considerable magnitude in West Texas.

In both cases, the idled processing facilities would represent loss of productive capital.

Other potential socioeconomic impacts may result if a guayule black market were established along the border for seeds, shrubs and guayule rubber. The present price of guayule seeds in the United States may be near $100 per pound, which makes a black market for seeds potentially attractive. Furthermore, due to local economic differences in bordering communities and the presumed single price for all natural rubber (hevea or guayule), the establishment of a guayule black market seems quite probable.

The control of guayule black market activities would be difficult. Seeds are likely to be the most active black market during the early stages of guayule commercialization. It probably will be impossible to determine whether guayule rubber was grown or processed in Mexico or in the United States. Any distinctions in physical appearance of the rubber could be nullified by simple blending operations.

c. National focus: U.S. tire and rubber companies may gain some control over rubber supply and price stability if guayule is commercialized. Fertilizer, pesticide manufacturers, retailers and fuel distributors, likewise may benefit from guayule commercialization.

The economic value of guayule hinges upon the presumed value of rubber extracted from the plant, the technical interchangeability of guayule with hevea rubber, and the acceptance of guayule rubber by government, industry, and consumers of rubber products. Of equal importance are the byproducts (e.g., soluble resins, volatile essential oils and fatty acids) that may be useful as the result of research and development efforts.

The distribution of benefits will depend highly on the level of integration built into guayule commercialization. If rubber companies grow and process guayule, then the region will receive only the benefits of increased business activity and some marginal increase in wage labor. If farmer organizations or Indian communities are able to grow guayule, and particularly if they are able to process it, the economic benefits that accrue to the region should be significantly greater.

Sufficient byproducts credits are assumed to offset the costs of processing guayule. As of late 1979, byproduct research and development programs have identified a number of chemical substances of economic value (Soltes, 1979). Many of these, e.g., drying resins and terpenes, are similar to those common to the Southern pine. Guayule resins now appear to have promise for use as a component of rubber -- as a peptizing agent, pigment disperser, filler and/or tackifier.

Recycling and reclaiming rubber probably will not be significant in the near future unless world events lead to a rubber-crisis condition. Guayule commercialization should have little effect on rubber recycling-reclamation efforts.

The U.S. rubber stockpile shortfall of 400,000 metric tons may be partially made up under Scenario A as combined Hevea and guayule rubber production ease the shortfall market. Whether the stockpile would be filled by stocking with guayule or hevea rubber would depend upon guayule meeting stockpile specifications. Under Scenario B conditions, it is probable that the shortfall would persist.

Various governmental and state agencies may find policy conflicts regarding the application of land and water use statutes and regulations as well as in food-fiber tradeoffs, particularly under Scenario B. Discussion of these topics is contained in Chapter VII, "Public Policy Analysis."

d. International focus: Bilateral-science-and-technology cooperation is viewed as a positive step for both Mexico and the United States. Research institutions in both countries are proposing cooperative guayule research, which should aid in concurrent development, thus allaying potential border guayule problems such as black markets along the international boundary.

Hevea rubber growers may receive benefits even if U.S. guayule commercialization becomes a reality. Natural rubber occupies a depressed position in the total elastomer market. Significant guayule rubber production more likely would displace a portion of the synthetic rubber market, in turn easing somewhat the demand for non-energy applications of petroleum. In addition, the hevea producers loss of U.S. markets under Scenario B. would likely be made up by expanding Third World markets or by diversification by growers to more profitable cash crops such as palm oil, cocoa or cashews.

An additional factor that would undoubtedly be significantly affected by commercialization of guayule rubber in the United States is the development of guayule in other nations, Australia in particular. Israel and certain northern African nations also have expressed interest in the potentials of guayule development. Guayule commercialization in these nations, in turn, could be expected to affect the U.S. guayule development system.

VII. PUBLIC POLICY ANALYSIS

The technoeconomic and sociopolitical potentials for development and commercialization of the guayule agribusiness were described in the preceding chapters of this TA. This chapter focuses on the public policy issues that might accompany guayule commercialization and the policy options that are available to government decision makers.

A. Approach

Preliminary considerations of the policy aspects of guayule commercialization accompanied preceding portions of this study, i.e., the forecast technological developments and analyses of consequences. Project team members evaluated the several perspectives from which policy goals, issues and options could be viewed. Two public participation meetings further sharpened analyses of impacts and policy questions. A series of interviews specifically focused on sociopolitical aspects then were held with identified parties-at-interest including authorities from federal and state government agencies, officials of major rubber corporations and spokespersons of other private sector groups. The interview information then was analyzed in terms of public policy pertaining to certain societal goals and in terms of the issues, conflicts and institutional problems that might arise. The approach to the policy analysis is depicted in Figure VII-1 and amplified in the following subsections.

1. Perspectives for analysis: Two scenarios have been postulated in the preceding chapters of this TA: Scenario A assumes that current trends in guayule commercialization continue, while Scenario B assumes that half the U.S. need for natural rubber no longer can be obtained under politically and economically acceptable conditions from countries where it is produced presently (i.e., imports are reduced by 50 percent), and guayule rubber becomes the primary replacement. Under these scenarios and the analyses of consequences forecast therefrom, policy alternatives may be identified for three rather distinct sets of societal goals: a. policies to stimulate or encourage guayule development and commercialization; b. policies to control or regulate guayule development and commercialization; and c. policies to mitigate adverse side effects or otherwise accommodate guayule development and commercialization.

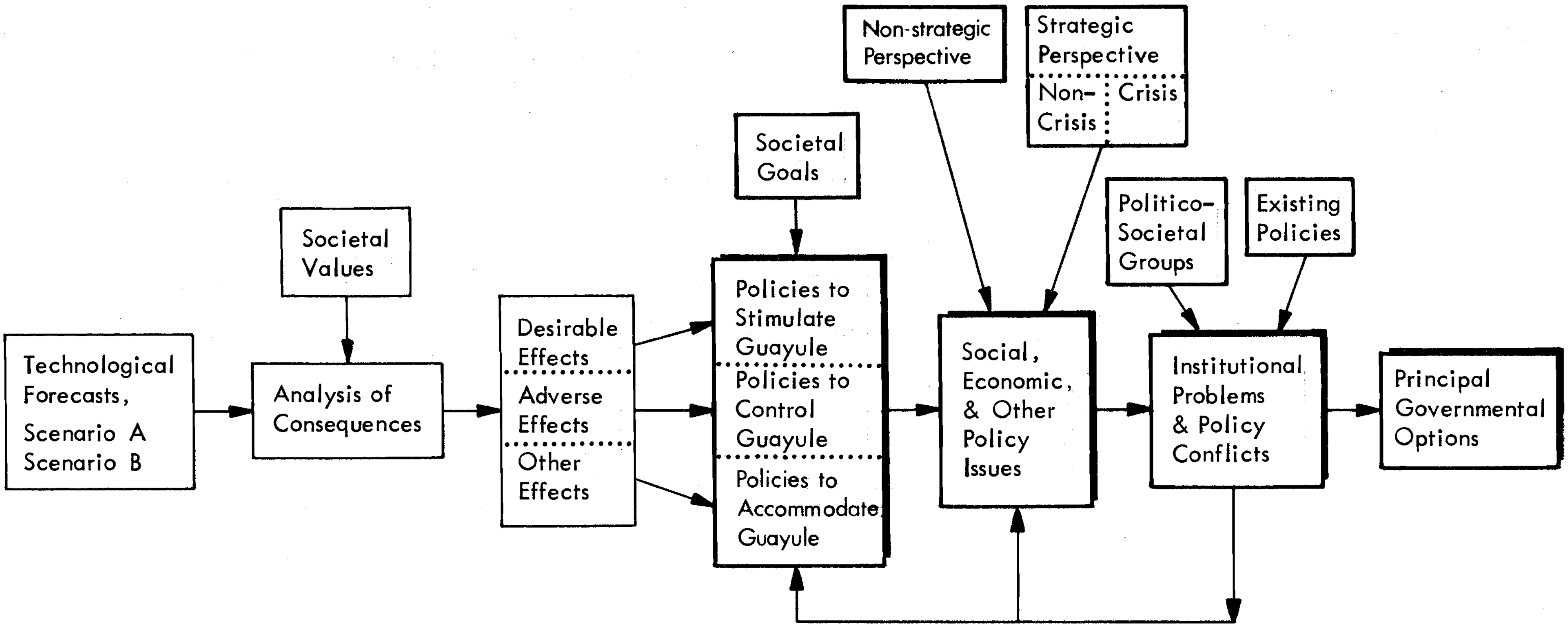

Figure VII-1: APPROACH TO PUBLIC POLICY ANALYSIS FOR GUAYULE COMMERCIALIZATION

For public policy considerations, however, two further perspectives somewhat different from the scenarios are helpful. These two perspectives develop naturally from the key question, "Should guayule development be viewed as of strategic value for the United States?"

The answer to this question is clearly "yes" under Scenario B because of the "crisis conditions" created by the loss of critical material (alternative sources of rubber or alternative approaches to relieve the crisis also may well be sought). The answer also may be "yes" under Scenario A, i.e., the government concludes that sufficient social, economic or other benefits may flow to identified sectors of the national economy; to selected regional, state or local areas; to target populations or groups; or to serve other national interests that "non-crisis," federal stimulation of guayule commercialization is warranted. The legislative history of the Native Latex Commercialization Act suggests that development would be desirable under both levels of consideration.

The answer, however, may be "no" under Scenario A. The recent modest level of governmental support for research and development of guayule more nearly fits this "non-strategic perspective" than it does the "strategic perspective" indicated in the preceding subset of Scenario A or under Scenario B.

Under the non-strategic perspective, commercialization would occur primarily as a result of private sector investment that may be vigorous. Governmental policies would be developed from time to time as needed to control or regulate this commercialization or to mitigate or accommodate side effects.

Under the strategic perspective, government would take an active role in stimulating guayule commercialization under Scenario A and possibly the dominant role in developing guayule to its maximum potential under Scenario B. Under Scenario A and a strategic perspective, the government may be willing to accept trade-offs of some adverse effects that would not be desirable under a non-strategic perspective to gain the anticipated benefits. Under Scenario B, the government's strategic perspective would permit it to accept substantial adverse effects (e.g., environmental damage or local socioeconomic disruptions) to gain the paramount benefit of obtaining a dependable domestic supply of natural rubber.

The roles of the private and governmental sectors developed from these two perspectives for the two scenarios are summarized in Table VII-1.

TABLE VII-1

COMPARISON OF GOVERNMENT'S ROLES UNDER DIFFERENT SCENARIOS AND PERSPECTIVES

	Non-Strategic Perspective	Stratetic Perspective
Scenario A (Present Trends Continue)	Development in private sector; government incentives minimal; government regulations firm	Development in private sector; government incentives under non-crisis atmosphere; government accepts some trade-offs
Scenario B (Rapid Commercialization)	Not Applicable	Development strongly stimulated or led by government under crisis atmosphere; government prepared to accept increased adverse effects

In addition to the perspectives of the proposed scenarios and strategic goals examined during the policy analysis, guayule commercialization was examined also in terms of the three arenas in which policy decisions arise and the analagous levels in which their impacts may be felt, i.e., the international scene, national domestic affairs, and state and local matters.

2. Presentation of results: The policy analysis was approached according to three major value areas: a. social policy issues; b. economic policy issues; and c. other policy issues (e.g., research and development support; water, land, and energy use; environmental policy and foreign relations). Each value area then was analyzed first from the non-strategic perspective, and secondly from the strategic perspective. To systematize the results of these analyses, a set of five topic areas was used for each value area: a. critical questions regarding guayule commercialization; b. identifiable issues; c. existing policy; d. potential policy needs/conflicts; and e. policy instrument.

The results of policy analyses are presented in the following three sections of this chapter according to the three major value areas noted above. Two additional sections summarize the potential institutional problems (policy conflicts and alleviating mechanisms) and the principal governmental options.

B. Social Policy Issues

Following is a discussion of social policy issues in guayule commercialization from non-strategic and strategic perspectives. The policy analysis begins by formulating certain critical questions from each perspective and flows to identifiable issues, to existing policies, to potential policy needs/conflicts, and finally to policy instruments for each critical question. In this manner, many potential direct and indirect (spillover) policy effects such as benefits, costs, risks, needs and conflicts are identified. The analysis is not exhaustive but will serve as a platform for informed discussion of guayule commercialization.

1. Non-strategic perspective: Table VII-2 is a summary of the social policy issues in guayule commercialization from the non-strategic perspective. Seven critical questions or value judgments have been formulated that need to be discussed in any policy debate. In general, all of these questions deal with social groups or geographic regions that anticipate benefits, costs, risks, needs and conflicts from this effort.

The first question focuses on the potential beneficial as well as adverse effects on American Indians, Hispanics, small-scale farmers, migrant agricultural workers, and the communities in the U.S. Southwest that may be too dependent on a limited crop mix. The second question concerns the employment requirements related to the guayule industry, and how it will affect the potential job growth within certain economically depressed areas. The third question addresses social impacts, and the flow of costs and benefits to targeted groups. The fourth question examines risk. Federal support could be justified when the risks are too great for private investment. The fifth question examines individual and community safety and health. The sixth question is concerned with the general issue of social welfare, and the seventh question concerns itself with a problem of substantial proportion in this country, that of illegal immigration.

Although a number of federal agencies have policies to deal with these issues, a number of potential policy needs or conflicts remain.

Potential conflicts about how best to examine guayule development are foreseen between the Bureau of Indian Affairs (BIA), the tribal councils, the Small Business Administration (SBA), and the Bureau of Land Management (BLM). In addition, state agencies and farm agencies and farm organizations will closely watch federal efforts developed to assist these targeted groups.

On the question of labor intensity or capital intensity, the base of this conflict is a new crop development for the area that would potentially generate impacts or alter current crop production

TABLE VII-2

POLICY ANALYSIS IN SOCIAL POLICY TERMS: NON-STRATEGIC PERSPECTIVE

A. Critical Questions Regarding Guayule Commercialization

1. What social groups or regions may benefit or suffer adverse effects?
2. Should this development be predominantly labor- or capital-intensive, or a mix?
3. Do potential benefits flow to targeted groups and communities as the result of minimum federal investment?
4. What are costs/benefits/risks to the public and private sector as the results of capital-intensive development?
5. What work practices and standards will be required?
6. What additional social goods will be required?
7. How may illegal immigration patterns be affected?

B. Identifiable Issues

1. Benefits and possible adverse effects on American Indians, Hispanics, small-scale farmers, unemployed agricultural workers, economically depressed southwestern communities.
2. Agricultural employment, including farm and processing operations, as function of costs and benefits.
3. Uneven flow of costs/benefits/risks to targeted groups and communities.
4. Spillover effects (positive and negative).
5. Individual safety and health; community health.
6. Social welfare.
7. Illegal immigration.

C. Existing Policy

1. BIA, HEW, DOL, BLM, SBA, state agencies, Winters Doctrine.
2. USDA, DOC, DOL, HEW, SBA, state agencies banking and financial institutions.
3. Federal investment where risks are too great for private investment and substantial need exists.
4. Reduce adverse spillover effects by redistribution of resources.
5. OSHA, HEW.
6. HEW.
7. Immigration service.

D. Potential Policy Needs Conflicts

1. BIA, BLM, SBA, tribal councils, state agencies, farmer organizations, and other group interactions, needs and trade-offs.
2. USDA, DOE, SBA, farm workers organizations, etc., interactions, needs, and trade-offs; family farm vs. corporate farm.
3. Need for clearer articulation of federal investment policy for medium to high risk ventures related to social needs.
4. Policy conflict over competing technologies to meet same social goals.
5. Federal and state agencies interactions, etc.
6. HEW and state agencies interactions, etc.
7. Unknown, may need policy statement.

E. Policy Instrument

1. Native Latex Commercialization Act of 1978; Winters Doctrine
2. Development and demonstration acts for various technologies; range of financial measures, including tax relief, grants, contracts, loans, underwriting, insurance.
3. Range of financial measures.
4. Range of social goods measures.
5. Policy in place (?).
6. Policy in place (?).
7. Unknown.

patterns. For example, if cotton production is replaced by guayule production, how will that affect the total U.S. production of cotton? Will it simply mean a rise in the price of cotton goods, or are there more substantial impacts such as changing employment patterns, shifts in unionizing, etc. that would result from this displacement?

In summary, the potential conflict that would arise in this option would be the trade-off between cost-efficient production and attention to the social needs of the region. Cost-efficient production probably will not significantly change existing social conditions or job patterns in the region.

Some of the policy instruments necessary to implement this option will be tax relief price support, loan guarantees, market guarantees and crop insurance.

The greatest problem facing guayule development is the anticipated three- to four-year growth cycle. Existing financial institutions may not accommodate this type of risk on a relatively unproven crop without some form of government assistance. Precedents exist for investment in long-term crops such as fruits and nuts that have been developed primarily within the private sector. A federal investment policy for medium- to high-risk ventures related to meeting social goals needs to be developed. There also is a potential policy conflict with competing technologies that are capable of attaining the same goals as those articulated in the Native Latex Commercialization Act of 1978.

The policy instruments appropriate to this option primarily will be a range of financial measures available to the government. These would include tax relief in the form of write-offs, deferments, abatements, or depreciation allowance. Grants or contracts and loans, either guaranteed or direct, could be used. Various insurance mechanisms, including direct crop insurance and providing for a guaranteed market, could be used as incentives to private development.

2. <u>Strategic perspective</u>: Table VII-3 is a summary of social policy issues from the strategic perspective. The identifiable issues involve such concerns as equity requirements, interdependence vs. self-sufficiency, and social needs vs. strategic needs. A number of existing policies already relate in a general way to the values underlying the questions raised. But the policy focus primarily would be directed at minimizing the negative social consequences of the massive guayule development that would be needed to compensate for the loss of foreign supplies projected in Scenario B.

A national strategic materials policy is in force that addresses the current materials stockpile. However, the actual size of the stockpile is only 23 percent of the projected requirement.

TABLE VII-3

POLICY ANALYSIS IN SOCIAL POLICY TERMS: STRATEGIC PERSPECTIVE

A. Critical Questions Regarding Guayule Commercialization

1. Should the United States be dependent on foreign sources for meeting elastomer needs?
2. Who is displaced in the agricultural sector when guayule is commercialized?
3. Will nation's spcial needs constrain the development of a critical material need?
4. Will target groups and regional social needs be "lost" because of strategic material needs?
5. How much federal control is required to minimize perceived negative social consequences?

B. Identifiable Issues

1. Interdependence vs. self-sufficiency.
2. Equality.
3. Social needs vs. strategic needs.
4. Potential subservience of social needs.
5. Cost/benefit/risk analysis.

C. Existing Policy

1. No formal policy position.
2. Federal policies in place.
3. No formal policy position.
4. Federal and Regional Commission policies.
5. Federal policies in place.

D. Potential Policy Needs/Conflicts

1. Strategic materials policy needed.
2. None (?).
3. Policy development needed (?).
4. Policy development needed to minimize negative consequences, particularly for Scenario B.
5. Federal mechanism needed to examine consequences of change, particularly under Scenario B.

E. Policy Instrument

1. Articulation of national strategic materials policy (policy is under development).
2. Monitoring function needed.
3. Monitoring function needed.
4. Monitoring function needed.
5. Monitor changes and consequences. Research and development on social cost of such investment.

If guayule is developed under a strategic perspective some type of monitoring function may be desirable to determine what social changes occur.

In the last two questions of Table VII-3 the issues involve equity and the cost/benefit/risk analysis associated with governmental investment. Policies already in place address these concerns, but conflicts can arise among them that would involve national environmental policy, economic growth, and agricultural and national security. Few federal mechanisms are available to examine the consequences of change. An effective evaluation mechanism must be implemented before government investment is made policy. A policy-setting board should govern all actions taken. The critical policy instruments would be evaluation mechanisms that monitor the investments and the changes that these investments make on the targeted social groups.

C. Economic Policy Issues

The second general area for policy consideration in guayule develoment would be economics. The intent in this section is to examine governmental options in terms of existing economic policies announcements and to focus on the institutions that exist to deal with changes brought about by commercialization of guayule.

1. Non-strategic perspective: Table VII-4 is a summary of the economic policy issues in guayule commercialization from the non-strategic perspective. Twelve critical questions were identified that underlie economic policy.

The first six questions focus on the agricultural nature of the U.S. Southwest, economic oportunities for specific minorities, agribusiness diversification, and the potential for economic risk to small land holders, such as family-scale farmers.

Policy makers must proportion the rate, extent and nature of federal investment in guayule in accord with several practical private sector concerns. These concerns involve technical limitations and innovation; the need for adequate financial return on investment; and the possibility that the large-scale farm operators will be favored greatly because of inherent economies of scale in production.

Current agricultural policy favors food-crop development with the exceptions of traditional cotton and tobacco cropping. Guayule, however, is neither a traditional nor a food crop. Potential exists for creating conflicts between those interests that are concerned about the rights of particular target groups and the targeted groups themselves. Specifically, the entire issue of how the relationship between Indian tribes and the Bureau of Indian Affairs changes during the development of guayule appears to be critical.

TABLE VII-4

POLICY ANALYSIS IN ECONOMIC POLICY TERMS: NON-STRATEGIC PERSPECTIVE

A. Critical Questions Regarding Guayule Commercialization

1. Is guayule development a regional "pork barrel"?
2. Does guayule development represent a new or replacement crop for U. S. Southwest?
3. Do economic venefits flow to targeted groups and regions, e.g., substantial employment opportunities?
4. Will Indian tribes and landholdings specifically be involved?
5. Who, besides the industrial sector, benefits from guayule development?
6. Is any federal investment required/justified to offset perceived risks?
7. What is the appropriate scale for production/processing unit?
8. Is a centralized, large-scale operation desirable?
9. How do energy costs affect guayule development?
10. Is the four-year harvest cycle too risky for private investment and the small land-holder?
11. Do byproduct values significantly reduce investment risk?
12. Will U. S. guayule development foster a Mexican guayule black market?

B. Identifiable Issues

1. Political expediency; favored treatment accorded lobbyists.
2. Agribusiness diversification/conservation.
3. Income redistribution; favored treatment of minorities.
4. Economic opportunities for Indians.
5. Accrual and flow of economic opportunities and benefits.
6. Uncertainty/risk to small land holder (i.e., farmer) and to U. S. tire and rubber industry, private vs. federal investment.
7. Microeconomics; economies of scale; centralized vs. decentralized.
8. Economies of scale.
9. Energy conservation; biomass development.
10. Risk assessment of commercialization effort.
11. Maximization of return on investment.
12. Differences in local economies at the international border.

C. Existing Policy

1. None.
2. Agriculture, commerce policies.
3. SBA, HEW, BLM, agriculture, commerce policies.
4. BIA policies.
5. Benefits should flow to targeted groups and the nation.
6. Should federal government invest if private sector is willing and able?
7. None.
8. None.
9. DOE policy formulation.
10. SBA.
11. None.
12. Federal involvement should not encourage the formation of or enhance a black market.

D. Potential Policy Needs Conflicts

1. (?)
2. Agriculture policy favors food crop development; potential conflict with non-food crop development for self-sufficiency.
3. No needs/conflicts; Commerce has regional commissions to monitor; need to articulate intent to avoid conflicts.
4. Potential conflict between tribes and bureaucracy; need to articulate intent to avoid conflicts.
5. Benefits do not flow to targeted groups or are far less than anticipated.
6. Investment policy needed to analyze risk element; federal support will not assure economic development.
7. Potential conflict in terms of economies of scale.
8. Federal/private disagreement about scale of production.
9. Federal/private disagreement about energy costs.
10. Federal/private disagreement about degree of risk.
11. Federal/private disagreement about value of byproducts.
12. Coordination of U. S.-Mexican guayule development.

E. Policy Instrument

1. (?)
2. Research and development support; information dissemination.
3. None needed.
4. Information generation leading to policy coordination.
5. Federal role limited to determination of the concept.
6. Federal investment policy; risk absorption; time scale for declining federal investment.
7. Difficult to define without further data; monitor.
8. Production quotas.
9. Monitor energy costs as part of demonstration.
10. Federal government reduces risk and/or offers incentives.
11. Monitor market values for byproducts as part of demonstration.
12. Joint U. S.-Mexico agreement on cooperative research; specific coordination agreements on guayule research.

Substantial research and development support and information dissemination in terms of policy instruments will be required from the federal government as well as substantial policy coordination if this option is selected for implementation.

The last six questions concern economies of scale, energy alternatives, the accrual and flow of economic opportunity and benefit, the size of risk and the return required for commercialization and the problems caused by differences in community economics at the international border.

The federal government generally does not invest if the private sector is willing and able to do so. Government investment is based on potential benefits that will flow to targeted groups and regions. Federal involvement should not encourage formation of a black market for guayule materials.

Federal support does not assure in all cases economic development in terms of policy needs and conflicts. A substantial amount of disagreement also exists between federal and private sectors about the scale of production, land use for energy crops, degrees of risk and the value of the byproducts. In addition, consideration must be given to U.S.-Mexican relationships so that a black market for guayule materials is not encouraged. Under the non-strategic options, a time scale for declining federal investment could be developed to limit federal involvement; the federal role whould be limited to feasibility demonstrations; or the government could provide price support or a guaranteed market for guayule materials. Minimizing the black market might best be served through coordinated guayule development in the United States and Mexico.

2. Strategic perspective: Eleven questions related to economic policy are listed in Table VII-5. The issues of economic concern are self-sufficiency, national security, and foreign relations. The federal stockpiling policy is based upon anticipated materials needs, given a particular set of conditions. This set of conditions takes into account primarily the U.S. need for the material, and only secondarily, the foreign-relations aspects. In addition to this stockpiling policy, the United States does have bi- and multi- lateral trade agreements that, if in effect, supply domestic demand for natural rubber but which, in fact, may be of little use should the foundations of the stockpiling policy be undermined.

Potential conflicts exist between U.S. economic needs and foreign policy stances, the need to increase the U.S. natural rubber stockpile to capacity, and the need for a U.S. policy to address foreign strategic and critical materials cartels.

TABLE VII-5

POLICY ANALYSIS IN ECONOMIC POLICY TERMS: STRATEGIC PERSPECTIVE

A. Critical Questions Regarding Guayule Commercialization

1. Is it essential for the United States to establish a domestic rubber supply, and if so, in what time frame?
2. How would a 50 percent reduction in hevea rubber supply affect current demand for elastomers until guayule rubber is made available?
3. Will guayule rubber be used to bolster the natural rubber stockpile?
4. What is the impact of a "cartel" pricing policy?
5. How will foreign governments view U. S. guayule development; will United States be viewed as becoming isolationist?
6. How will guayule development affect U. S. Balance of trade?
7. What happens if the natural rubber stockpile is depleted in the absence of alternate plans and programs?
8. What incentives will be needed to move the private sector into a cooperative guayule development program with federal
9. Are Emergency Rubber Project or COMSAT viable routes to develop guayule?
10. Will guayule take priority over other agricultural commodities?
11. What happens if important food and fiber crops, e.g., grains, cotton, etc., are displaced?

B. Identifiable Issues

1. National security and self-sufficiency.
2. Consumer, industrial and military use patterns for natural and synthetic elastomers.
3. Technological acceptability of guayule rubber and products.
4. Loss of competitive pricing of elastomers.
5. U. S.-foreign relations.
6. Strength of U. S. dollar abroad.
7. National security and self-sufficiency.
8. Risk absorption.
9. Cooperative efforts by public and private interests.
10. Food and fiber production.
11. Relative economic importance of various crops.

C. Existing Policy

1. Federal preparedness policy in effect.
2. No policy.
3. Stockpile policy in effect.
4. No policy; United States is price taker in natural rubber market.
5. Bi- and multilateral trade, science and technology agreements; UNCTAD agreement.
6. Improve balance of trade.
7. None; devastating effects under Scenario B.
8. SBA.
9. SBA, precendence of ERP and COMSAT.
10. Agriculture, commerce.
11. None, USDA favors food production.

D. Potential Policy Needs Conflicts

1. Economic vs. foreign policy stance.
2. Need policy to deal with distribution of strategic and critical materials shortages.
3. Natural rubber stockpile not at capacity.
4. Need policy for dealing with cartels of strategic and critical materials.
5. Economic vs. foreign policy stance.
6. Economic vs. foreign policy stance.
7. Stockpile should not be depleted.
8. None (?).
9. Balancing public and private needs and interests.
10. Conflict between food and fiber production.
11. Interagency conflicts.

E. Policy Instrument

1. Interagency resolution of policy differences.
2. Rationing or quotas; taxation or surcharges.
3. Authorize guayule as acceptable substitute for hevea rubber; appropriate expenditures to fill natural rubber stockpile using guayule.
4. Unsure of policy instrument.
5. Interagency resolution and coordination of activities.
6. Interagency resolution and coordination.
7. Incentives for stockpiling by private interests.
8. Incentives for guayule development.
9. Enabling authorization and appropriation; monitoring function and venture evaluation as part of legislation.
10. Articulation of policy for renewable strategic raw materials.
11. Interagency resolution and coordination.

Rationing materials, establishing quotas, taxing, or adding surcharges to the use of strategic and critical matrials would reduce demands. Authorizing guayule as an acceptable substitute for hevea rubber would make it an allowable product to be included in the national stockpile and would give added impetus to guayule commercialization.

Federal policies already exist to encourage cooperative efforts by public and private interests to meet the need for natural rubber while minimizing the social impact of meeting that need and to determine the relative economic importance of guayule development primarily in GSA, USDA, SBA and Commerce. These agencies have relied heavily on the use of market mechanisms to attempt to ensure acquisition of adequate supplies to the needed materials stockpiles. GSA policy for stockpiling critical raw materials, however, may not be compatible with the USDA policy of promoting food and fiber development.

The government could offer incentives to private interests to produce guayule as a living stockpile, basically through financial incentives.

Any federal investment should be made only after a system of evaluation is in effect to monitor the changes inherent in this policy development, and to develop any modifications required to ensure that economic benefits flow in an equitable manner. Some interagency coordination as well as a system to resolve policy differences will have to be implemented.

D. Other Policy Issues

Policy issues are discussed in this section from the perspectives of research and development, foreign relations, energy, land use, water and environment. The discussion crosscuts the social and economic policy issues previously addressed and focuses more specifically on federal or state policies already in effect that likely are to be affected by guayule commercialization.

1. Non-strategic perspective: Table VII-6 is a summary of the analyses of "other" policy issues. Eight critical questions were identified.

The issues of concern here are the types of trade-offs, conflicts, agreements, gains, or losses that would occur. For example, in land use, guayule cultivation could mean new productivity for marginal lands or prolonged productivity for currently cultivated lands. Planting guayule could be a way to inhibit further desertification in the arid U.S. Southwest. Conversely, guayule could deplete the soil, thereby promoting desertification. Conflicts may develop about diversion of land with mineral or energy deposits to guayule production. Considering water resources, substantial conflicts already exist between interests that have maximized the use of water for municipal, industrial, or

TABLE VII-6

POLICY ANALYSIS IN "OTHER" POLICY ISSUES: NON-STRATEGIC PERSPECTIVE

A. Critical Questions Regarding Guayule Commercialization

1. Are low-level federal research and development programs needed?
2. How may U. S. relations with Mexico and other nations be affected?
3. How may land use policy be applied?
4. How may water policy be applied?
5. How may energy policy be applied?
6. What roles do synthetic elastomers play in meeting elastomer demand?
7. What adverse environmental impacts may occur?
8. What health and safety problems may occur?

B. Identifiable Issues

1. Types and levels of research and development funding.
2. Agreements/trade-offs/conflicts/gains/losses in U. S.-foreign relations, including undocumented workers.
3. Land trade-offs; new, prolonged productivity.
4. Water trade-offs; municipal/industry/agriculture.
5. Energy trade-offs.
6. Elastomer trade-offs; new technology.
7. Environmental risks and benefits.
8. Health and safety risks.

C. Existing Policy

1. Agriculture/commerce/NSF responsible.
2. Mexico-U. S. bilateral agreements, including science and technology; other international trade and policy agreements; Immigration Service.
3. Agriculture focus on food production, state responsibility.
4. State responsibility.
5. In process of articulation; DOE policy formation.
6. Industrial focus; limited federal role.
7. Agriculture, BLM, EPA.
8. Agriculture, Labor, HEW, OSHA.

D. Potential Policy Needs/Conflicts

1. Food vs. fiber vs. "other", e.g., biomass.
2. U. S. support of expanded trade and improved relations, specifically toward Mexico; science and technology agreements; Immigration Service conflicts.
3. Food vs. fiber vs. "other".
4. Substantial conflicts possible between federal and state levels.
5. Substantial conflicts possible.
6. None.
7. None.
8. None.

E. Policy Instrument

1. Articulation of policy; legislation, resolution, coordination; federal grants to states for research and development.
2. Coordination of policies; bilateral agreements.
3. Coordination of policies via Joint Guayule Commission.
4. Coordination and resolution.
5. Coordination and resolution.
6. Coordination of activities.
7. Coordination.
8. Coordination.

agricultural purposes, and those who would minimize such usages. In terms of energy, guayule commercialization would lower the demand for crude oil for synthetic rubber production if guayule rubber could penetrate a greater portion of the market. Competition for land between energy-producing crops and guayule will have to be considered.

The potential policy needs and conflicts in the development of guayule focus on the relations between federal, state and local governments, and between federal and foreign governments. But some agreement probably would be struck with respect to the need for a coordinated federal research and development program that considers domestic and international ramifications.

Legislation that would coordinate federal and state activities and that reflects any policy constraints appears to be the best approach to counter some of the issues raised in these critical questions.

Synthetic rubber technology would play an increasing role in elastomer production (including synthetic polyisoprene) should natural rubber imports decline.

The health and environmental risks and benefits of guayule must be thoroughly examined. A number of existing laws and policies will have to be adhered to under non-strategic guayule commercialization. Some of these policy conflicts appear to have substantial importance. These conflicts will be discussed in more detail in Section E.

2. Strategic perspective: Table VII-7 is a summary of "other" policy issues as they relate to the strategic option. The case of substantial federal investment in strategic guayule commercialization is based on the answers to five critical questions from the "other" policy perspective.

The issues focus on national security vs. domestic concerns, such as water. Policy under the strategic perspective must meet the strategic need for natural rubber while not violating other major policies.

Other issues include centralized vs. decentralized control and the degree of governmental control necessary to ensure a strategic supply of natural rubber. Current policies address the questions that are raised in this option; the issue is the degree to which those policies might be overridden because of the perceived need for natural rubber.

A major conflict may exist between the U.S. need for strategic materials and existing land, water, energy and environmental policies at the federal, state and local levels. Some compromise also must be struck between interdependence for raw materials through foreign trade and for partial self-sufficiency in critical materials. Because of the probability of substantial economies of scale in production, a conflict

TABLE VII-7

POLICY ANALYSIS IN "OTHER" POLICY ISSUES: STRATEGIC PERSPECTIVE

A. Critical Questions Regarding Guayule Commercialization

1. What strategic materials considerations override land/water energy/environmental policies?
2. Should the United States strive for self-sufficiency in renewable natural resources?
3. Will the federal or state government control the growing and processing stages?
4. How much government control will industry accept?
5. What organizational apparatus will allow the government to maintain minimal investment with maximum strategic control?

B. Identifiable Issues

1. National security vs. domestic concerns e.g. decrease in water levels.
2. Self-sufficiency; protection from controls.
3. Centralized vs. non-centralized control; degree of governmental control; potential loss of individual farmer control.
4. Government vs. private industry interests.
5. Degree of vertical integration accepted by government.

C. Existing Policy

1. Native Latex Commercialization Act of 1978 and related policies, e.g., EPA DOE, Agriculture, Commerce.
2. Self-sufficiency policy (?); no policy at present regarding rubber cartels.
3. No policy at present; agriculture promotes farmer control/ family farm; commerce assists through regional commission.
4. No policy at present.
5. Antitrust legislation; possible regulation.

D. Potential Policy Needs/Conflicts

1. U. S. need for strategic materials; potential conflict with existing policies at federal and state levels regarding land use, water, energy and the environment.
2. Conflict between policy of interdependence and self-sufficiency.
3. Conflict between family farm and corporate production.
4. Policy need (focus of this TA).
5. Antitrust legislation/regulation vs. strategic need.

E. Policy Instrument

1. Articulate resolved policy; coordinated between Congress, Agriculture, Commerce, other agencies, State; may need new water policy standards and federal guidelines.
2. Articulate resolved policy.
3. Not sure how to resolve.
4. Types of incentives (see Social Policy) will dictate acceptable policy.
5. Coordination of activities, monitor investment; regulate proactively.

exists between the articulated policy of supporting the family farm and the possibility that most guayule production will be captured by large corporate farms or government-run programs.

The pursuit of this strategic goal requires carefully articulated and agreed upon policies coordinated between Congress and the major agencies-at-interest (Agriculture, Commerce, Labor, OSHA, EPA, State, Interior, and the states). The government has a role to play by providing guidelines for land and water use. The incentives used to institute an effective guayule policy will dictate the degree of acceptability of strategic guayule commercialization.

E. Potential Institutional Problems

A TA focuses on the impacts of change and the potential policy needs and conflicts implied by those changes. These policy needs and conflicts reflect the potential problems and possible institutional failures that might accompany the development of a particular technology. When institutional problems occur, mechanisms to resolve the problems are suggested.

Obviously no preferable set of compatible, coherent policies for guayule commercialization exists. In all likelihood, the "policy" that is ultimately developed for guayule commercialization will be formed from a mix of the options suggested in this analysis. The path chosen will depend on how the critical questions are answered.

Table VII-8 lists potentially conflicting policies, the problems that they raise, associated institutional failures and potential mechanisms to resolve some of the issues. A discussion of the Table follows.

1. Policy conflicts:

a. Agriculture vs. industrial water use: The first potential conflict in policy exists between agricultural and industrial water users. The potential problem, from the policy perspective, is that the value for industrial water may be significantly higher than the value for irrigation agriculture. The first step in resolving this difficulty would be for the federal and state governments to set priorities by means of economic incentives to encourage, or deterrents to discourage, water end-uses, i.e., to have an effective water policy for each type of end use.

b. Land use conflicts: A potential for conflict also exists between land used for food, fiber or energy production. A subset of these problems would be the impacts of guayule development on alfalfa, sugarbeet, grain and cotton production. A second order of impacts would occur as a result of reduced production of these crops. The primary area

TABLE VII-8

POLICY CONFLICTS - POTENTIAL FAILURES

Conflicting Policies	Potential Problems	Potential Institutional Failures	Potential Resolution Mechanisms
a. Water for agricultural use; Water for municipal and industrial use.	Value of water for agricultural use. Value of water for municipal and industrial use.	Market may not allocate water in socially desired manner.	Governmental priority setting via economic incentives, disincentives to particular types of uses.
b. Land for food production; Land for "other" production.	Value of food production; value of fiber/material production; desertification.	Conflict in policy -- governmental failure to establish priorities.	Limited policy statement with evaluation program to measure effect/intent.
c. Government investment; Private investment.	Scale of venture and anticipated costs/revenue.	Each evaluating what others might do before making investment.	Joint U.S.-industrial guayule investment group.
d. Government risk; Private risk.	Perception of degree of risk.	Private risk structure (banks, other financial institutions) not capable of handling four-year risk project.	Use of government to guarantee market, guarantee loans and insure investment; establish guayule futures market.
e. Federal; State; Local agriculture policies.	Value of various crops produced.	Intergovernmental cooperation.	Joint Commission to oversee development.
f. Current crop patterns; New crop patterns.	Value of crops produced; alternative crop production.	Governmental monitoring/priority setting.	USDA/stockpiling agency/ states agreement.
g. Target Groups: Small business (farmers); American Indians.	If strategic need, then social equity concerns may be over ridden or ill considered.	Inability of government to assist groups in equitable way.	Use of lands/water as capital formation mechanism; use capital for other investment programs.
h. Strategic-materials policy Agricultural policy.	Food U.S. materials production.	Inability of government to agree on policy stance where conflicting outcomes are sought.*	May not be resolvable.
i. Strategic-materials policy. Land-use policy.	Alternative economic land use, e.g industrial development.	Inability of government to minimize interference in market mechanism where conflicting needs are expressed.	May not be resolvable.
j. Strategic-materials policy: Water policy.	Human consumption vs. agricultural vs. industrial water needs vs. strategic need.	Inability of government to minimize interference in market mechanism when conflicting needs are expressed.	Will not be easily resolved.
k. Strategic materials policy: Environmental policy.	Land, air, water, safety, health, aesthetics ignored because of stragegic need.	Inability of government to set criteria and limitations in policy conflicts.	Policy to minimize environmental impact.

TABLE VII-8

POLICY CONFLICTS - POTENTIAL FAILURES
(CONTINUED)

Conflicting Policies	Potential Problems	Potential Institutional Failures	Potential Resolution
l. Foreign policy: interpendence in world economy; Independence in critical materials.	United States vs. Hevea producing countries.	Inability of government to articulate single coherent policy.	May not be resolvable.
m. Farm policy: Family; Corporate.	Family farm vs. corporate production.	Inability of government to resolve basic policy conflict.	Does not appear to be resolvable.
n. Strategic-materials policy: Antitrust policy.	Degree of vertical integration or horizontal cooperation.	Government policy may inhibit efficient production method required to meet another governmental role.	Government monitored oligopolistic structure.

* Also market may not allocate resource use effectively, although it may do so efficiently.

of potential institutional failure would be governmental: the government would have to establish a set of relative priorities for food, fiber, and other commodity production. The potential resolution of this conflict would be a limited policy statement to establish production priorities and an evaluation program to measure the effect of that policy.

c. Government/private investment conflicts: Governmental investment policy may conflict with private investment in the areas of scale and cost. The institutional failure would come from the lack of an effective mechanism that allows both public and private interests to determine how to invest in guayule development. One way to resolve this dilemma would be for a joint U.S.-industrial guayule investment group to determine precisely who should make what types of investment in guayule commercialization.

d. Government/private risk conflicts: A potential conflict of policy exists between governmental and private perceptions of the degree of risks in guayule commercialization. In this case, the institutional problem is in the structure for risk underwriting in the private sector. Banks and other lending institutions are reluctant to finance a new, possibly risky agricultural crop that has a four-year production cycle and an evolving processing technology. The mechanism to resolve this problem would be the use of government investment funds to guarantee markets and loans or to insure the investment by other means. Alternately, the establishment of a guayule futures market with appropriate federal guidelines might reduce risk significantly.

e. Federal/state/local agricultural policy conflicts: Much potential conflict exists between federal, state and local agricultural policies. The potential problem is that the different levels of government may place different values on the alternative crops that could be grown. Institutional failure in the past often has resulted from a lack of intergovernmental cooperation, but this possibility might be countered by the establishment of a joint commission to review policies that would affect the development of guayule.

f. Current/new crop conflicts: Conflict exists between current and potentially new crop production patterns. The problem rests in the comparative values of the crops currently produced and a guayule or other alternative crop. Institutional failure would occur if priorities are not set by the government and if monitoring the diverse needs of different crop production areas is not implemented. Resolution will require agreements between the stockpiling agencies, USDA, and state government officials.

g. Target group conflicts: A resource conflict exists between farmers as small-business operators and Indians as land holders. The potential problem arises when guayule commercialization is viewed from the strategic perspective. If guayule development is viewed as a strategic need, social equity concerns may receive insufficient consideration or may even be disregarded by government, hence creating conflicts. The failure, then, is the inability of government to assist groups in an equitable way when it pursues strategic goals.

Potential mechanisms for surmounting this problem would be for farmers and Indians to use their land and water rights as mechanisms for capital formation, and then to use that capital for other investment.

h. Strategic material/domestic agriculture policy conflicts: A strategic materials policy may conflict with U.S. domestic agriculture policy. The problem is a food materials production issue. Institutional failure would be the inability of the government to agree on a policy stance through which conflicting values are reconciled. This problem may not be completely resolvable, however, and the policies may continue to exist in conflict.

i. Strategic material/land use policy conflicts: The strategic materials policy and land use policy apear to conflict. The problem arises from the alternative economic uses for the land; for example, industrial development or farming. In this case institutional failure is the inability of the government to minimize interference in market mechanisms when conflicting needs are expressed. This failure may not be resolvable.

j. Strategic material/water policy conflicts: The strategic materials policy also may conflict with water policy. The problem is based in competition for water among municipal, agricultural and industrial interests. The institutional failure would be the inability of government to minimize interference in the market mechanisms when conflicting needs are expressed. This specific problem may be resolvable, but not easily.

k. Strategic material/environmental policy conflicts: The strategic materials policy and environmental policy have the potential for a major conflict. Land, air, water, safety, health and aesthetics potentially could be ignored because of the strategic need for natural rubber. The institutional failure would be a government need to set criteria and limitations in policy conflicts: a very broad environmental policy established to address a long-term concern conflicts with a short-term policy directed at meeting strategic needs. The potential resolution mechanism is a policy directed at meeting strategic material needs and, at the same time, minimizing the environmental impacts of that change.

l. Interdependence/independence policy conflicts: In U.S. foreign policy a conflict exists between interdependence in the world economy and independence in meeting critical needs. The potential problem would be in changed relationships between the United States and Hevea producing countries. Institutional failure would be the inability of government to set a coherent policy that defines those topics wherein the United States needs to be independent and those wherein the United States should accept interdependence. This conflict may not be resolved for some time.

m. Family/corporate farm policy conflicts: Farm policy has been a consistent source of conflict for a number of years. The conflict in farm policy arises between the stated governmental support for family farms and the increasingly corporate nature of the production of food and fiber in the United States. The institutional failure lies in the inability of the government to resolve a basic policy conflict between efficiency and lifestyle. In the light of past history, it does not appear likely that this conflict ever will be resolved.

n. Strategic material/antitrust policy conflicts: Strategic materials policy has the potential to conflict with antitrust policy. This conflict will be heavily dependent on the degree of vertical integration that is allowed within the guayule industry. The institutional failure would rest upon government policy that inhibits the efficient production methods required to meet another governmental demand. The potential resolution mechanism would be a government-monitored oligopolistic structure for guayule production, harvesting and processing.

2. Alleviating mechanisms: A single or a simple mechanism for minimizing the potential conflicts outlined in Section E-1 does not exist. The major source of potential problems is governmental uncertainty about when to be involved in policy and how to balance protective policies with promotional policies. The market mechanism is, in a sense, an efficient allocator of value, but it is not necessarily the most equitable. Hence, there is a need for some governmental intervention in the system.

The commission concept strengthened by additional legislation and expanded to include subgroups such as a joint U.S.-private guayule investment group could become an effective mechanism for overseeing guayule commercialization.

A number of individuals have suggested the use of a system similar to the World War II ERP. The suggestion is worthwhile, but it has two inherent difficulties. One, the United States is not in a comparable crisis situation; and two, the structure of government has changed so dramatically and the number of public policies has increased so substantially since the 1940s that the system probably would be ineffective in meeting the current policy needs for guayule development and commercialization. Some other alternative that employs a number of the mechanisms suggested in this analysis will be required if guayule is to become a domestic crop under non-crisis situations.

F. Principal Governmental Options

The federal government can consider six basic options with respect to guayule commercialization under Scenarios A and B.

Given a perceived non strategic need for rubber the federal government can exercise those options as discussed in F-1 and F-2.

1. The federal government can allow gradual guayule development to continue, as described in Scenario A (present trends continue), and take no action other than that specified during 1979-1983 by the Native Latex Commercialization Act of 1978. Present guayule developments involve a complex set of driving forces including the Act itself, federal agencies and departments, state and regional commissions and corporate and private interests. Guayule commercialization will be based primarily on economic driving forces that are well understood in the market place. The necessary governmental apparatus and infrastructure are already in place to deal with social and economic impacts as they occur during the next three to five years.

2. The federal government can take a more active and involved role in guayule commercialization than that specified in the Act. Although guayule commercialization may occur slowly in a non-strategic situation and under customary market forces (Scenario A), benefits will not necessarily flow to targeted groups, and undue risks may be borne by small land holders. The federal government can assume a greater role in monitoring and overseeing to ensure that benefits flow to appropriate parties-at-interest and can assist in risk absorption through loans, grants, crop insurances and other methods. The government can encourage the establishment of a guayule futures market.

Given a perceived strategic need for rubber under Scenario A, the federal government can exercise the options discussed in F-3 and F-4.

3. The federal government can allow guayule commercialization to proceed as described in F-1 with minimal guidance and support as authorized by the Act. Concurrently, the government can take steps to complete stocking the rubber stockpile at the specified level with hevea rubber, while establishing military specifications for guayule rubber.

4. The federal government can take a more active role in guayule commercialization. It can emphasize monitoring and overseeing activities by federal agencies and work closely with state agencies and private interests to provide incentives. An important policy consideration is balancing land and water use practices for agriculture, including food and non-food trade-offs, and for strategic needs. The government can investigate and attempt to control any guayule black market activity that may occur.

The differences between Scenarios A and B are mostly a matter of timing (gradual vs. rapid) and level of effort (emphasis) by various agencies and parties-at-interest domestically, as well as being a matter of geopolitical forces (potential supply restrictions) and economics (including cartel activities) internationally.

Given a perceived strategic need for rubber under crisis conditions (Scenario B), the government can exercise the options discussed in F-5 and F-6.

5. The federal government can take an intermediate role in establishing, promoting, and otherwise assisting guayule development and commercialization. In particular, it can complete stocking the rubber stockpile with either hevea or guayule rubber. It can provide increased monitoring and overseeing activities of social and economic consequences of guayule commercialization, with increased emphasis on recognizing and controlling benefits and costs accruing to parties-at-interest as well as third parties (spillover effects). The government can establish closer cooperative scientific and technological agreements with the Mexican government regarding guayule development and commercialization.

6. The federal government can take the lead or play a dominant role in rapidly developing an extensive guayule agribusiness on massive scale that would involve perhaps 2 million acres or more of land in West Texas, New Mexico, Arizona and California. The government can provide ample incentives, including subsidies, if necessary, to parties-at-interest. It also can exercise full administrative control by setting prices, supply quotas, technical specifications, and distribution quotas between military and domestic market needs. Finally, the government can resolve policy conflicts and set priorities regarding land and water use, and municipal, industrial, agricultural and recreational needs.

VIII. SUMMARY

In this section brief summaries of the major findings of the technology assessment are presented. Some future research and development needs are suggested. Impacts and policy implications of alternative guayule commercialization pathways are indicated.

A. Findings

The major findings of this study are summarized and are presented according to the following categories: technology and agronomic practices; economics; environmental, ocupational safety and health concerns; sociocultural dynamics; public policy analysis; and legal issues.

1. Technology and agronomic practices: Table VIII-1 summarizes what is known and unknown in guayule technology. This tabulation is intended to overview the known and unknown aspects of the state-of-the-art of guayule development.

General production based on several harvesting experiences in Mexico and the United States has shown that guayule can be harvested from native stands. It is known that harvested stands will regenerate, but it is not known to what extent or what time period is needed for complete regeneration.

Based on experiences of the Intercontinental Rubber Company and the Emergency Rubber Project, guayule can be grown under suitable rainfall or irrigation farming conditions and will produce harvestable amounts of rubber. It is not known exactly under what conditions economic production will be obtained.

Seed from several available varieties can produce 20 percent rubber; there are genetic and physiological potentials for an even higher rubber percentage and production through increasing plant size. So far these higher yields have not been obtained under known production practices.

Irrigated shrub production has been obtained in excess of 10 tons in four years, with a rubber percentage of 10 percent to 12 percent yielding 400 pounds to 600 pounds of rubber per acre annually. The theoretical production of 1,000 pounds per acre annually with a 20 percent rubber content has not been obtained.

TABLE VIII-1

GUAYULE TECHNOLOGY: SUMMARY

Known	Unknown
Guayule can be harvested from native stands.	The amount of regeneration and time required is unknown.
Improved hybrids have been developed.	Field testing of hybrids is in initial stages.
Varieties with potential of 20 percent rubber exist.	Under field conditions 10 percent rubber in four years has been obtained.
Four-year-old harvest of 10 tons of shrub is possible under irrigation.	Rubber yield from this shrub of 400 pounds to 600 pounds per acre annually is below potential.
Stand establishment by direct seeding is possible.	Field applications are not yet known; costs and weed control may be limiting.
Nursery seedling production and field transplanting techniques have been developed.	Alternate greenhouse seedling production may prove to be satisfactory or superior.
Low-water-use irrigation regimes favor guayule to other cultivated crops.	Reduced water use resulting in stress may increase rubber production.
Maximum rubber production has been achieved experimentally with close spacing and early harvest.	Because of establishment costs it appears that wider spacing and longer growing cycles will be more profitable.
Irrigation farming produces the largest shrub and total rubber production.	Costs of dryland production are lower, but longer growing periods may be needed.
Diseases and insects require control.	No registered pesticides are available.
Bioinduction to increase rubber perentage is promising.	Field applications of bioinduction are in initial stages.

TABLE VIII-1 (CONTINUED)

Known	Unknown
Guayule rubber production is greatest on good crop producing soils.	Growth is restricted by poor internal drainage, impervious layers and high water tables.
Guayule has low fertility requirements and broad salt tolerance.	The effect of low fertility and high salt content on growth and rubber production needs further study.
Rubber determination methods have been developed.	Non-destructive assays or determinations based on small samples need to be developed.
Extraction methods have been worked out on mill scale and pilot plant scales.	New methods based on solvent extraction are still in laboratory stages.
Guayule rubber production will require relatively large acreage to support extraction facilities.	Unit sizes will be determined largely by economics of the extraction process.
Byproducts offer a source of income to offset extraction costs.	Recognizing specific products, their production, and possible uses and market capacities are not beyond laboratory stages.
Harmful environmental effects of guayule appear to be minimal.	Detailed determinations of harmful effects have not been made.
Harvesting methods have been developed.	Improved harvesting methods related to milling need to be worked out.
There is very little loss or deterioration of rubber during short storage periods.	Conditions and methods for satisfactory storage need to be developed.

Stand establishment by direct seeding is possible; however, direct seeding has not yet proved to be successful for commercial production. Improvements in planting methods and the refinement of seed and pesticide uses have great promise under irrigation.

Stand establishment using nursery grown seedlings has been successful, but the economic viability has not been determined in commercial enterprises.

Guayule is a low water user; but moisture promotes shrub growth while drying promotes rubber development. The optimum combination to produce maximum amounts of rubber per acre has not been determined.

Plant spacing has an influence on growth and on rubber production. Young plants under close spacing have produced the most rubber per acre annually; but wider spacing and longer growth periods may result in optimum economic production.

Diseases are not more of a problem for guayule than for other cultivated crops; but guayule is particularly susceptible to diseases enhanced by excessive moisture conditions.

Insects have not been a serious problem. Control methods for harmful insects have not been perfected and no pesticides have been registered by the EPA for use on guayule.

Weed control is a serious problem especially with direct seeding and in the early stages of field plantings. As the guayule canopy closes, weed control improves. No herbicides have been registered for guayule.

Harvesting by digging, which utilizes the rubber in the roots, has been successful. Baling the shrub reduces volume and decreases hauling and storing costs. Other methods such as chopping might decrease volume but have not been practical because of defoliation difficulties.

Successful processing methods, based on pebble mills or paper manufacture mills, have operated on a commercial scale. Solvent methods have been worked out on a laboratory scale, but remain to be developed commercially.

The development of intraspecific and extraspecific hybrids has been successful in increasing rubber yields, cold tolerance and disease and insect control. However, most studies are incomplete and results have not been widely available for commercial production.

The experimental use of bioinduction agents has shown great promise, but so far has not reached the stage where bioinduction has contributed to field production.

The broad limits of fertilization response and tolerances to harmful substances are known, but specific guidelines are based largely on empirical observations.

Physical soil conditions indicate guayule production is limited to soils with a moderate field capacity, good drainage capacity, and the absence of impervious layers or water tables within the root zone (5 feet).

The size of an economic production unit will depend largely on local processing capacities.

The present methods for determining shrub rubber content are satisfactory in terms of laboratory procedures, but are not adequate to meet needs of genetics and field operations when analyses need to be made without destroying the plant. Non-destructive methods currently provide qualitative rather than quantitative results.

Arbitrary values have been assigned to byproducts quantities based on the composition of non-rubber portions of the plant; but, methods of extraction, processing and marketing have not been developed beyond the laboratory stage.

2. Economics: World demand for natural rubber historically has exceeded supply. The average annual growth rates of natural rubber production and consumption during the last 30 years have been 3 percent to 4 percent. The comparable growth rates for synthetic rubber during the same period are 8 percent to 10 percent annually.

Recent conditions, such as the dramatic oil price increases and the stagnant economic conditions in the industrialized nations of the world, continue to slow the growth of elastomer demand. The high price of fuel and decreased use of, or demand for, vehicles have reduced the demand for tire rubber. The declining demand is affecting synthetic elastomers more than natural rubber. Rising oil prices are resulting in increased prices for synthetic rubber and feedstocks such as styrene and butadiene. Increasing radial tires use is resulting in a higher percentage of natural rubber in the manufacture of tires.

Projecting future demand for natural rubber is complicated by a number of factors:

a. the stability of world economy;

b. social or political changes that could change the world supply or demand for elastomers;

c. the availability and price of fuels to power vehicles requiring tires;

d. the availability and price of raw matrials for the production of synthetic rubber, natural rubber, and other yet undiscovered elastomers;

e. the rate at which tire rubber demand can be expected to grow in the developing nations; and

f. the forms of personal and commercial transportation which will dominate the future.

Although the factors that impact future elastomer demand are highly variable, some reasonable bounds can be placed on the system. Figure II-5 shows a potential range of total world elastomer demand through the year 2000 and a corresponding range of natural rubber shortfall implicit in these projections when they are coupled with available data on the expected future supply of hevea rubber.

Guayule rubber cultivation could benefit farmers and other small holders, including American Indians by providing an alternative cash crop. Guayule also could provide a domestic source of natural rubber to U.S. tire and rubber companies. Economic benefits would accrue to communities in the U.S. Southwest. Finally, guayule rubber cultivation would offset the current trade deficit in natural rubber.

3. Environmental, occupational safety and health concerns: Large-scale guayule cultivation and processing have not taken place and no significant body of data exists regarding environmental or occupational safety and health impacts. Limited data from Mexican and U.S. sources indicate few hazards arising from cultivating marginal agricultural lands. Cultivating previously undisturbed lands, as forecast in Scenarios A and B, would be minimal and would be restricted primarily to southern Texas.

Establishing large plantations of any field crop potentially could affect topsoil erosion; provide optimum environments for pests or disease organisms through monocropping; build chemical residues in the soil resulting from applications of fertilizers, biocides and bioinduction materials; and deplete groundwater or surface water supplies. Although any of these potential environmental impacts may result from large-scale guayule production, the impacts can be expected to be less in most instances than from cultivating more conventional field crops. It is anticipated that guayule will require less fertilizing than most other crops, and water consumption should be significantly lower. Deep rooted guayule theoretically could remove chemical or salt residues left in the soil by other crops.

Mature guayule plantations or the temporarily stored dry plants and bagasse may be fire hazards. Processing operations involve storing flammable solvents for extraction. In rural communities, volunteer firefighters may not be able to provide sufficient protection for a large-scale guayule agribusiness.

Harvesting, transporting, and processing of mature guayule plants pose no significant occupational safety and health problems, however potential respiratory hazards, due to pollen release or dust generation from bagasse exist.

Land and water use would be significantly affected. Crop displacement of such economically marginal field crops as wheat, barley, sorghum and sugarbeets is expected. However, some guayule agriculture is expected to be developed in southwestern Texas as a dryland crop where it would not displace other field crops. Water use would be reduced significantly as the result of crop displacement by guayule cultivation.

Guayule production should not create a major impact on regional energy requirements since processing plants can use bagasse to generate energy. Selling excess power to local utility companies would be a positive asset.

Appropriate future steps may require environmental impact statements regarding guayule cultivation and rubber processing as well as OSHA monitoring and surveillance.

4. Sociocultural dynamics: The methodology used for the sociocultural-dynamics analysis relies on published state and regional historical data and projections coupled with in-depth interviews with parties-at-interest. The data base was analyzed for direct, indirect and aggregate effects.

a. Direct effects: Land and water use would be affected. Also, production would have some effect on industrial siting, but would result in no significant damage to the quality of life. The initial negative effect of guayule commercialization would be the need to provide housing. Short-term housing would have to be provided for imported crews to construct processing facilities in rural areas. In addition, this would have some short-term effect on schools and on municipal and rural services such as law enforcement, fire protection and other services needed to provide an adequate quality of life. These impacts would not be felt as significantly in the urban areas where an adequate labor force and service sector already exists.

There would be few significant, direct negative effects in the long term. An adequate labor force already exists in most areas to deal with both growing and processing guayule. Increasing agriculture-related jobs in the rural areas would provide a positive employment effect. However, in urban areas there would be little change in the number of agricultural workers employed. The most important, direct economic effect is that guayule development would increase the tax base, enabling local communities to enhance public services. The increased tax base would upgrade service in the areas of education and police and fire protection. A multiplier effect would increase the total buying power and would impact wholesale and retail sales. Guayule commercialization should result in an increased economic viability for communities in the U.S. Southwest.

The major, direct, negative consequence of guayule production could be a disruption of the local cultural heritage that exists in parts of the region. Importing labor and increasing industrial activity could result in a change in the patterns of relationships that could have severe disruptive consequences for long-time residents, especially those of Hispanic heritage and American Indians.

b. Indirect effects: As guayule commercialization begins, the major indirect effects will result from providing rubber to ensure that there will not be a rubber-product supply shortage in the United States. Producing guayule under Scenario A or Scenario B should result in somewhat increased employment opportunities in the U.S. rubber industry.

Other product markets, relating to guayule byproducts, would be affected as well. These effects might include compensating for previous short supplies, or significant over-production. Market capacities for guayule byproducts are relatively unknown to date.

c. Aggregate effects: Guayule production would encourage self-sufficiency, and would enhance national security by providing a domestic supply of natural rubber. The United States could stockpile natural rubber without disrupting prices. Guayule production should: a) enhance capital supply; b) contribute effectively to the labor market; and c) enhance business opportunities related to growing, processing and selling rubber products. In addition, it could enable the United States to maintain a strong position in foreign policy and international trade and could help create a more favorable balance of payments.

5. Public policy analysis: Interviews were conducted with identified parties-at-interest. Interview data were matrixed with a series of public policy areas that were then analyzed to predict policy impacts and potential conflicts that might arise.

a. The key public policy issue: The question, "Should guayule development be viewed as a strategic need for the United States?" was the key policy issue assumed to underpin the policy analysis. This key issue allowed a broad discussion of the range of potential governmental and private options existing under a positive or negative response to the question.

b. Public policy perspectives: The two major policy options indicated above were analyzed in relation to three primary areas of concern: social policy; economic policy; and other policy, including research and development, land, water, energy and environmental policies. The critical questions discussed for each perspective are shown in Table VIII-2 by area of primary policy concern.

TABLE VIII - 2

SUMMARY OF CRITICAL QUESTIONS IN POLICY PERSPECTIVES UNDER CONSIDERATION BY AREA OF CONCERN

Non-strategic Perspective	Strategic Perspective
Social Policy	**Social Policy**
1. What social groups or regions may benefit or suffer adverse effects in this effort?	1. Should the United States be dependent on foreign sources for meeting elastomer needs?
2. Should this development be predominantly labor or capital intensive?	2. Who is displaced in the agricultural sector when guayule is commercialized?
3. Do potential benefits accrue to the targeted groups and communities as a result of minimal federal investment?	3. Will the nation's social needs constrain the development of a strategic-material need?
4. Are the costs, benefits and risks to both public and private sectors worth the investment?	4. Will target group and regional social needs be lost because of strategic-material need?
5. What work practices and standards will be required?	5. How much federal control is required to minimize perceived negative social consequences?
6. Will additional social goods be required?	
7. How may illegal immigration patterns be affected?	
Economic Policy	**Economic Policy**
1. Is guayule development a regional "pork barrel?"	1. Is is essential for the United States to establish a domestic rubber supply, and in what time frame?
2. Does guayule development represent a new or replacement crop for U.S. Southwest?	2. How would a 50 percent reduction in hevea rubber supply affect current demand for elastomers until guayule rubber is made available?
3. Do economic benefits flow to targeted groups and regions, e.g. substantial employment opportunities?	3. Will guayule rubber be used to bolster the natural rubber stockpile?
4. Will Indian tribes and landholdings specifically be involved?	4. What is the impact of "cartel" pricing policy?
5. Who, besides the industrial sector, benefits from guayule development?	5. How will foreign governments view U.S. guayule development; will the U.S. be viewed as becoming isolationist?

TABLE VIII - 2 (continued)

Non-strategic Perspective	Strategic Perspective
Economic Policy (continued)	**Economic Policy** (continued)
6. Is any federal investment justified to offset perceived risks?	6. How will guayule development affect U.S. balance of trade?
7. What is the appropriate scale of production/processing unit?	7. What happens if natural rubber stockpile depletes in the the absence of alternate plans and programs?
8. Is a centralized, large scale operation desirable?	8. What incentives will be needed to move the private sector into a cooperative guayule development program in conjunction with federal activities?
9. How do energy costs affect guayule development?	9. Are Emergency Rubber Project or COMSAT viable routes to development of guayule?
10. Is the four-year harvest cycle too risky for private investment and the smallholder?	10. Will guayule take priority over other agricultural commodities?
11. Do byproduct values significantly reduce investment risk?	11. What happens if important food and fiber crops e.g. grains, cotton, etc. are displaced?
12. Will U.S. guayule development foster a Mexican guayule black market?	
Other Policy	**Other Policy**
1. Are low level federal research and development programs needed?	1. Will strategic materials considerations override land/water/energy/environmental policies?
2. How may U.S. relations with Mexico and other nations be affected?	2. Should the United States strive for self-sufficiency in renewable natural resources?
3. How may land-use policy be applied?	3. Will the federal or state government control the growing and processing stages?
4. How may water policy be applied?	4. How much government control will industry accept?
5. How may energy policy be applied?	5. What organizational apparatus will allow the government to maintain minimal investment with maximum strategic control?
6. What roles do synthetic rubbers play in meeting elastomer demand?	
7. What adverse environmental impacts may occur?	
8. What safety and health problems may occur?	

c. Policy conflicts and institutional failures: On the basis of the public policy option analysis, Table VIII-3 details potential conflicts in policy, institutional failures, and resolution mechanisms.

6. Legal issues: Many federal and state laws relating to environmental quality, water conservation, industrial and farm worker safety, agricultural price support, production adjustment, local zoning regulations, trade agreements, and antitrust apply to guayule commercialization.

State water laws will directly affect new guayule plantations. Irrigation will be required for guayule production in southern California, Arizona, New Mexico, and western Texas, all of which are areas of dwindling irrigation water supplies. The varied water-use laws in these states will dictate whether guayule can be grown on retired agricultural land, or on undisturbed land, or as a crop replacement.

In Texas and Arizona, percolated groundwater belongs to the owner of the overlying land. This has resulted in an Arizona public policy to purchase agricultural land as a groundwater conservation measure. In Arizona most guayule production would be on land designated by the State Land Department as critical groundwater areas, where it is prohibited to drill wells to irrigate land not irrigated within the past five years. Pumping from existing wells in these areas is not controlled. But, Arizona groundwater laws are undergoing a state-legislature-commissioned study; additional control seems assured.

In New Mexico all water belongs to the public and is subject to appropriation for beneficial use. Application for use is made to the state engineer who determines if unappropriated water rights exist. California regards all water as belonging to the public and has assumed the right to apportion groundwater equitably and to limit or prevent groundwater overdraft.

Diffused surface water in Texas is regarded as the property of the landowner, but all other surface water is considered the property of the state and is subject to both riparian and appropriative use rights, which are at times conflicting. All Arizona flowing surface water is public and surface-water rights are obtained from the State Land Department.

According to the Winters Doctrine, the establishment of Indian reservations implies water rights that are sufficient to irrigate the irrigable portions of the reservations. The Law of the River, an aggregate of court decisions, interstate compacts, and treaties with Mexico governs Colorado River water use. The Law of the River allocates Colorado River water to Arizona through construction of the Central Arizona Project, but the only increase in irrigation that could result would be on Indian reservations.

TABLE VIII-3

POLICY CONFLICTS, INSTITUTIONAL FAILURES, AND RESOLUTION MECHANISMS

Conflicting Policies	Potential Problems	Potential Institutional Failures	Potential Resolution Mechanisms
a. Water for agricultural use; Water for municipal and industrial use.	Value of water for agricultural use. Value of water for municipal and industrial use.	Market may not allocate water in socially desired manner.	Governmental priority setting disincentives to particular types of uses via economic incentives.
b. Land for food production: Land for "other" production.	Value of food production; value of fiber/material production; desertification.	Conflict in policy - governmental failure to establish priorities.	Limited policy statement with evaluation program to measure effect/intent.
c. Government investment: Private investment.	Scale of venture and anticipated costs/revenue.	Each evaluating what others might do before making investment.	Joint U.S.-industrial guayule investment group.
d. Government risk: Private risk.	Perception of degree of risk.	Private risk structure (banks, other financial institutions) not capable of handling four-year risk project.	Use of government to guarantee market, guarantee loans and insure investment; establish guayule future market.
e. Federal: State: Local agriculture policies.	Value of various crops produced.	Intergovernmental coooperation.	Joint Commission to oversee development.
f. Current crop patterns: New crop patterns.	Value of crops produced; alternative crop production.	Governmental monitoring/priority setting.	USDA/stockpiling agency/ states agreement.
g. Target Groups: Small business (farmers) American Indians.	If strategic need, then social equity concerns may be over-ridden or considered.	Inability of government to assist groups in equitable way.	Use of lands/water as capital formation mechanism; use capital for other investment programs.
h. Strategic materials policy: Agricultural policy.	Food U.S. materials production.	Inability of government to agree on policy stance where conflicting outcomes are sought.*	May not be resolvable.
i. Strategic materials policy: Land use policy.	Alternative economic land use, e.g industrial development.	Inability of government to minimize interference in market mechanism where conflicting needs are expressed.	May not be resolvable.
j. Strategic materials policy: Water policy.	Human consumption vs. agricultural vs. industrial water needs vs. strategic need.	Inability of government to minimize interference in market mechanism when conflicting needs are expressed.	Will not be easily resolved.
k. Strategic materials policy: Environmental policy.	Land, air, water, safety, health, aesthetics ignored because of stragegic need.	Inability of government to set criteria and limitations in policy conflicts.	Policy to minimize environmental impact.

TABLE VIII-3

POLICY CONFLICTS - POTENTIAL FAILURES
(CONTINUED)

Conflicting Policies	Potential Problems	Potential Institutional Failures	Potential Resolution
l. Foreign policy: interpendence in world economy; Independence in critical materials.	United States vs. Hevea producing countries.	Inability of government to articulate single coherent policy.	May not be resolvable.
m. Farm policy: Family; Corporate.	Family farm vs. corporate production.	Inability of government to resolve basic policy conflict.	Does not appear to be resolvable.
n. Strategic-materials policy; Antitrust policy.	Degree of vertical integration or horizontal cooperation.	Government policy may inhibit efficient production method required to meet another governmental role.	Government monitored oligopolistic structure.

* Also market may not allocate resource use effectively, although it may do so efficiently.

Environmental legislation could constrain both guayule cultivation and shrub processing for rubber. The National Environmental Policy Act (NEPA) of 1969 would require impact statements for guayule processing plants constructed with federal funds or private projects involving federal permits, funds or other federal actions. Guayule processing facility construction on private land with non-federal funds would be exempt from NEPA requirements but would be subject to an environmental quality act in California. The required NEPA reports and public hearings could delay construction of processing facilities.

The Federal Water Pollution Control Act and Amendments set national effluent standards for all point sources of water pollution and will affect guayule processing facility siting, design, construction and operation. The Clean Air Act and Amendments set national primary and secondary ambient air quality standards. Specific air pollutant quantities that could be emitted from a commercial guayule processing plant are not known.

The Resource Conservation and Recovery Act of 1976 (RCRA) expands the solid Waste Disposal Act as amended in 1970. RCRA provides for a hazardous waste regulatory program; eliminates open dumping; provides financial and technical assistance for planning solid-waste management programs; provides grants to rural communities to improve solid-waste management systems; and directs the EPA to conduct and encourage studies and research related to solid waste, including marketing of recovered resources. In particular, the EPA has taken an active role in helping state and local governments find suitable methods of controlling and disposing of solid wastes. The major guayule waste will be the bagasse. If this is burned for fuel within the processing facility, there will be no bagasse disposal problems, but air pollution is possible.

Various pesticide and herbicide regulations require control and registration of chemicals used for that purpose. Chemical use and tolerance levels controls for pesticide chemical residues in raw agricultural products and laws regarding control and eradication of plant pests all would apply to guayule production. The Occupational Safety and Health Act of 1970 establishes health and safety standards for workers and will apply to agricultural field workers and processing facility operators.

The Native Latex Commercialization Act established a policy of federal government assistance in guayule research and development in order to convey "substantial economic benefits to peoples living in arid and semiarid regions of the United States."

Two types of guayule growers are foreseen: private farmers, possibly forming guayule production cooperatives; and the rubber companies. U.S. antitrust legislation (the Sherman and Clayton Acts) and the Federal Trade Commission are intended to prevent production and trade controls that would eliminate competition between entities in the guayule production industry, restrict production and product distribution, or exclude competing entities from a market. The farming industry is exempt under the Clayton Act when a cooperative is formed for mutual help; but farm cooperatives are regulated under the Cooper-Tolstead Cooperative Marketing and Agricultural Marketing Agreement Acts and may not enter transactions contrary to the antitrust laws.

The Strategic and Critical Materials Stockpiling Act of 1979 identifies natural (hevea) rubber as essential; a stockpile goal has been established. Stockpile requirements could be met by guayule rubber.

The United States is committed to promoting free trade and reducing worldwide protectionist pressures and is a major source of private investment in Malaysia and other rubber-producing countries. The U.S. government has negotiated a series of bilateral trade agreements, referred to as Economic and Technology Cooperation agreements, with each rubber-producing country in order to gain access to raw rubber supplies. This could inhibit U.S. guayule commercialization. In addition, the National Export Policy, in conjunction with the Mulitlateral Trade Negotiations, provides an environment of fair competition from imports.

Guayule is of interest to both Mexico and the United States. The Economic and Technology Agreement with Mexico, renewed in 1979, provides a strong bond for cooperation in developing guayule. Potential conflict exists between these two nations regarding illegal migration across the U.S./Mexican border. U.S. commercial guayule development is not expected to have any signigicant effect on this migration problem.

B. <u>Future Research and Development Needs</u>

Given guayule commercialization in the U.S. Southwest, the major future research and development topics regarding guayule rubber commercialization include the following.

1. <u>Technology and agronomic practices</u>: Table VIII-1 lists both known and unknown guayule technology and agronomic factors. The unknown factors listed in that Table indicate the areas of guayule research where further work is needed.

2. <u>Economics</u>: The need for aggregate elastomer economic research is not foreseen. Econometric modeling by U.S. agencies, by producing countries, and by independent study groups has ongoing programs to analyze elastomer supply and demand patterns and trends throughout the world. The aggregate studies by various groups do not always agree; but, on balance, a useful picture of world elastomer supply and demand emerges.

A need for further microeconomic studies of growing, harvesting, transporting, and processing guayule exists. Much research and development remains to be done on guayule byproducts and their potential micro- and macroeconomic effects on resin and naval stores markets.

3. Environmental and occupational safety and health concerns: Monitoring and surveillance by appropriate agencies and independent groups will supply information regarding environmental and worker safety and health concerns and will be forthcoming if and when guayule rubber is commercialized. The need for research and development in these areas is not foreseen at this time.

4. Social dynamics and policy development: The direct and indirect consequences arising from guayule commercialization have been presented earlier. The need for further inquiries in this area is not foreseen until guayule commercialization becomes a reality. In effect, guayule commercializaion must pass from an "in vitro" to an "in vivo" condition to justify further considerations of social dynamics and policy developments.

During a period of time, perhaps three to five years, existing technical, agronomic and social forces will gather strength slowly and their direct and indirect consequences will be recognizable. During that time, various agencies and independent groups will have ample opportunities to evaluate the social dynamics on local and regional scales; to formulate policies to reinforce positive effects and to alleviate negative effects; and to attempt to resolve policy conflicts arising from guayule commercialization.

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APPENDIX A

RESEARCH APPROACH TO THE GUAYULE TECHNOLOGY ASSESSMENT

Project Organization, Staff and Advisors

To perform a technology assessment (TA) of the commercialization of guayule, a combined program between two research organizations was proposed. The University of Arizona Office of Arid Lands Studies (OALS) has had extensive experience with a variety of potentially commercial, desert adapted plants. Through Dr. William G. McGinnies, Director Emeritus of OALS and formerly Chief of Surveys and Operational Studies, USDA Emergency Rubber Project during World War II, OALS has experience in guayule research extending back over more than 35 years. Midwest Research Institute in Kansas City, Missouri, has conducted several technology assessments of both agricultural and industrial systems.

The technology assessment team drew upon the expertise of the following Advisory Committee members.

- Dr. Andrew Cowan, U.S. Department of Agriculture, knowledgeable on guayule and USDA policy.
- Dr. Earl Gregg, B.F. Goodrich Company, expert on rubber industry.
- Dr. Harold Linstone, Department of Systems Science, Portland State University, expert on systems and futures research.
- Dr. David Rubis, Department of Plant Sciences, University of Arizona, expert on guayule plant breeding and genetics.
- Mr. Stephen T. Semegen, Malaysian Rubber Bureau, expert on world rubber market behavior.
- Mr. Marcelo Fontanoz Jr., Naval Air Rework Facility, San Diego, involved in U.S. Navy testing of guayule rubber for military applications.
- Ms. Kathryn T. Louka, Office of Technical Assistance, U.S. Department of Commerce, the Economic Development Administration, applications of arid-adapted plants, and EDA programs.

In addition, the guayule technology assessment drew upon the expertise of the following research consultants.

- Dr. George Hanson, Los Angeles State and County Arboretum, expert on guayule plant breeding and genetics.

Dr. Donald McIntyre, Institute of Polymer Science, University of Akron, expert on guayule rubber characterization and chemical properties.

Dr. Enrique Campos-Lopez, Director, Centro de Investigacion en Quimica Applicada, Saltillo, Mexico, expert on Mexican guayule and in charge of the only pilot guayule processing facility operating at the present time.

Daniel M. Bragg, Center for Strategic Technology, Texas A & M University, College Station, conducting NSF funded research on guayule within the world rubber market.

Ronald D. Lacewell, Agricultural Economics Department, Texas A & M University, conducting "break even" budgets for guayule production on Texas farms.

The Guayule Technology Assessment project was divided into the several work phases that are outlined below.

Phase I included a "walk-through TA session," chaired by Mr. Joe Coates of the Office of Technology Assessment, that involved 22 guayule, rubber industry and technology assessment experts. This phase included brainstorming potential guayule issues and conflicts, refining of the project tasks and developing the first final report outline. Phase I resulted in publication of the document Technology Assessment of the Commercialization of Guayule--Domestic Rubber Source of the Future: Orientation Report, December 1978. This document lists the system parameters discussed, the proposed outline format, and the participants in the walk-through TA session.

Phase II, the sociotechnical survey of guayule development, involved extensive review of the present state-of-the-art of agricultural and industrial aspects of guayule technology including chemical and physical properties of guayule rubber; production history and trends in research and development; discussion of the prospects for guayule commercialization, including national economic concerns, incentives for and constraints on guayule production; and identification of alternative technologies that may affect rubber supply or demand. This material was distributed extensively throughout the scientific and industrial community for review, commentary and updating. Corrections and new research developments subsequently were integrated into the review that was then published as A Sociotechnical Survey of Guayule Rubber Commercialization: A State-of-the-Art Report in April 1979. This report contains a comprehensive review of guayule technology including appropriate environmental conditions, plant modification research, agronomics and processing; prospects for commercialization of guayule, including both incentives and constraints; and assessment of alternate elastomer technologies. Appendix A of that report lists the persons who reviewed the state-of-the-art material.

The state-of-the-art report then served as the foundation from which two alternative commercialization scenarios were projected as Phase III of the guayule TA project, technology forecasting. Scenario A projects "present trends continue" whereby guayule development occurs in response to natural rubber demand and need for low-water-use crops in the arid Southwest. This scenario then was distributed for comment and revision to the same group of guayule experts that had reviewed the guayule technology material. Subsequent to this review and the outline development of Scenario B, "rapid commercialization" wherein government becomes deeply involved in guayule development in response to perturbations in the international rubber market, an advisory committe/consultant meeting was held in Tucson on June 15, 1979. At this meeting the state-of-the- art review, Scenario A and projections for Scenario B were discussed. Upon completion of Scenario B, this projection also was distributed to the group of reviewers indicated above, and both scenarios were revised according to review commentary.

The guayule TA team conducted two public meetings on guayule commercialization: one in Kansas City, August 20, 1979, and one in Tucson, August 28, 1979. These meetings were conducted for the dual purposes of informing the public concerning the state of guayule research and development and our scenario projections, and of receiving public input regarding impacts and policy implications of guayule development. As is true of many public meetings, the information gathering function proved to be only marginally successful. However, the meetings did serve the valuable function of informing the public as to the present state of guayule commercialization.

Phase IV, impact forecasting, is based on the scenarios developed in Phase III. Besides the two public meetings, information for this forecasting is drawn from extensive interviews of governmental personnel, parties-at-interest, and others who might be affected by guayule development in the U.S. Southwest. Persons interviewed included state government personnel agricultural extension agents, local government personnel, farmers, private entrepreneurs and Indian community representatives. Rather than to attempt an in-depth review of the entire potential guayule growth region, a detailed socioenvironmental assessment focused on two example areas intended to demonstrate the range of social and environmental conditions extant within the potential guayule growth region: Bakersfield, Kern County, California, and Fort Stockton, Pecos County, Texas.

Phase V of the guayule TA involved assessment of public policy issues. This phase also depended largely upon direct personal interviews with personnel of the federal government, state governments and the rubber industry. In addition to the two scenario projections, the policy analysis is keyed to the critical federal policy option of whether guayule rubber is viewed as a strategic commodity.

Coordination between the two research institutions involved in the guayule TA was accomplished through numerous joint meetings as well as the use of the TELENET Electronic Information Exchange System operated by the New Jersey Institute of Technology. Close contact also was maintained with the NSF-funded guayule economics project at Texas A & M University, and with Mexican guayule researchers at Saltillo as well as with other ongoing guayule research.

APPENDIX B

PHYSIOGRAPHIC PROFILES OF POTENTIAL GUAYULE GROWTH AREAS

The following discussions of potential growing areas and restricted areas are based upon agricultural and water use data from the 1970s. More complete descriptions are contained in the report A Sociotechnical Survey of Guayule Rubber Commercialization: A State-of-the-Art Report (Foster, et al, 1979). World War II Emergency Rubber Project (ERP) findings are reported herein as they support contemporary data.

Locations of the areas disucssed in the following sections are shown in Figure B-1. Letters refer to potential guayule growth areas. Numerals refer to areas not conducive to guayule development.

I. Potential Guayule Growth Areas

South Texas:

A. Star and Hidalgo counties are considered a "one-mill, dryland production" potential growth area (200,000 AC). This area averaged 418,000 harvested acres of field crops in 1975 to 1977, nearly all irrigated. Precipitation ranges from 17 to 25 inche annually. ERP reported some 560,000 suitable acres for dryland guayule, much of it in brushland. Guayule could act as insurance against drought-induced irrigation water interruption.

B. Duval, Jim Wells and portions of Live Oak, Webb and McMullen counties could serve as a one-mill dryland production guayule area (200,000 AC).

Rainfall (18-28 inches) could support guayule. An average of 240,000 acres were harvested in 1975 to 1977, about 10 percent of which were irrigated. ERP reported 540,000 potential acres for guayule production, much of it brushland.

C. Kinney, Uvalde, Zavala, Frio, Dimmit and LaSalle counties are considered sufficient to support one to two mills of dryland production. Rainfall ranges from 18 to 26 inches. Harvested areas in 1975 to 1977 averaged 270,000 90 percent of which was irrigated. This area includes the bulk of the Winter Garden Irrigation District, indicating serious competition from established crops. However, more than 1 million acres are considered irrigable in this region (ERP reported 1.18 million acres suitable), and water supplies at present cannot be expanded to these levels for irrigation.

D. The Trans-Pecos area of Reeves and Pecos counties are considered "marginal but probable." Although 95 percent of irrigated agriculture in the Trans-Pecos region was located in these two counties, only 130,000 acres were irrigated in 1974, and 1975 to 1977 harvested acreage averaged 51,000 acres. Escalating natural gas costs have contributed to the decline in irrigated agriculture in this area. However, the activities of Firestone Tire and Rubber Company in the Fort Stockton area indicate a strong likelihood of guayule development in this area.

Texas/New Mexico:

E. This Upper Rio Grande area includes the El Paso Valley in El Paso and Hudspeth counties, Texas, and the Mesilla Valley of the Rio Grande in Dona Ana County, New Mexico. Potential acreage in the Deming area of Luna County, New Mexico, also could serve this region. Guayule would be an irrigated crop in this area. In the mid-1970s, 378,000 acres were irrigated in this area, and 195,000 acres of field crops were harvested. Although irrigated acres are expected to decline by one-third in the El Paso Valley, New Mexico, acreage should remain relatively stable due to earlier application of irrigation water restrictions.

Arizona:

F. Pima and Pinal counties have nearly 300,000 acres of irrigated agriculture. Precipitation ranges from 6 to 10 inches annually in the farming areas. Declining water tables and increasing costs of irrigation water are expected to provide incentives for desert adapted crops. One mill served by 100,000 acres of irrigated guayule might be supported in this area, including potential Indian reservation cropland.

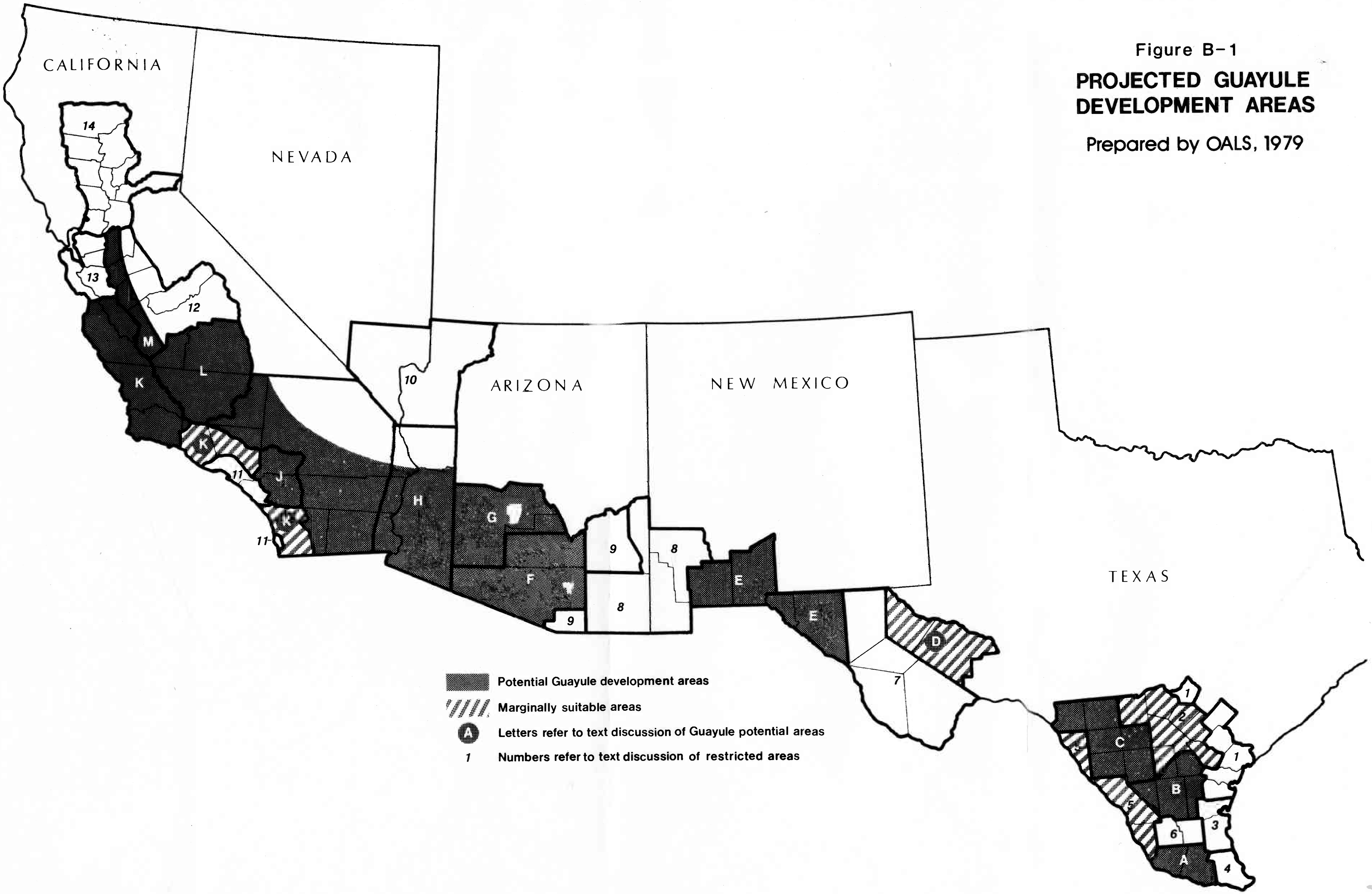
G. Maricopa and northern Pinal counties are considered to be a one-mill, irrigated-production possibility. In the mid-1970s 434,000 irrigated acres of field crops were harvested in Maricopa County. Although this is anticipated by the Arizona Water Commission to decline by nearly one-half by 2000, the agricultural water restrictions primarily bringing about this decline would serve as a stimulus for production of low-water-use crops. Some 80,000 acres or more of Indian agricultural land could help the area meet the production needs of a processing mill Agricultural reduction in the Phoenix area is expected due to urban expansion. Rainfall is from 6 to 8 inches annually in the farming areas.

H. Yuma and Mohave are the only counties in Arizona anticipating increasing irrigated agricultural development. Areas in California, adjacent to the lower Colorado River, also are included in this unit. Irrigated agriculture, including the Wellton-Mohawk area of the lower Gila and irrigated areas along the Colorado River, both Indian and privately owned, amounted to 350,000 acres in the mid-1970s. This is expected to increase to more than 400,000 acres by 2000. One mill is projected as possible for this area.

Figure B-1

PROJECTED GUAYULE DEVELOPMENT AREAS

Prepared by OALS, 1979



California:

I. The Colorado Desert hydrographic unit plus the southern portion of the South Lahontan unit are considered adequate support for at least one or two mills. More than 650,000 acres of irrigated field crops were harvested in this area from 1975 to 1977, with a potential for nearly 1.7 million acres in 2000, including lands with Colorado River water rights. Areas considered prime for guayule include the Imperial, Coachella and Antelope valleys.

J. Although the majority of the south coastal region experiences urban or other pressure restricting guayule potential, there is some possibility that the San Bernardino-Riverside area might support a processing mill, particularly if coupled with the Coachella or Antelope valley areas. Harvested acreage in this area was more than 200,000 acres from 1975 to 1977 and is anticipated to increase. Competition with high value crops, however, makes this area somewhat marginal for guayule development. Precipitation ranges from 10 to 30 inches annually, indicating a possible mix of irrigated and dryland guayule dvelopment.

K. The Central California Coast may have potential to support a guayule processing facility as it once did in the past. ERP researchers identified more than 100,000 acres of suitable guayule growing area based on climate and soils. More than 450,000 acres of field crops were harvested in this region until the mid-1970s. Although some high value vegetable crops are grown in this region, Central Coastal Valley agriculture is characterized by groundwater overdraft and poor potential for access to Central Valley development project water. These conditions may, in time, act as incentives for re-introducing guayule. The Salinas and Santa Maria valleys are considered best in this region for potential guayule development.

L. The Tulare Lake region, including Kings and Tulare counties and most of Kern County, offers very good guayule potential. The ERP classified more than 170,000 acres as appropriate in 1945. Irrigated field crops were harvested on approximately 1.5 million acres in the mid-1970s. This level of agricultural development results in groundwater overdraft of more than a million acre-feet annually under present conditions; and, although continued Central Valley Project expansion is expected to increase area water supplies, increasing irrigated agricultural development to as high as 3.5 million acres is expected to increase overdraft up to 2 million acre-feet annually by 2000. This combination of extensive agriculture and groundwater overdraft should affect guayule development positively; however, it would have to compete with some relatively high value crops. From two to five or more mills potentially could be supported in the Tulare Lake region.

5. The western side of the San Joaquin Valley, including portions of San Joaquin, Stanislaus, Merced and Fresno counties, shows, perhaps, the highest potential for guayule development in the entire guayule growth region. ERP research identified some 180,000 acres of suitable

land for irrigated guayule development. In the mid-1970s, 1.8 million irrigated acres of field crops were harvested, and these acreages may nearly double. Guayule development is encouraged by the need in this area for lower water-using crops to decrease water application and associated soil salinization; and the need for deep-rooted crops for reduction of suspended groundwater. Acting to inihibit guayule development are the high value crops and expensive land presently characterizing this area. Five or more guayule processing mills could be supported in this area.

II Areas Not Conducive to Guayule Development

A. South Texas

1. The Guadalupe Basin (Guadalupe and DeWitt counties) and Goliad, Refugio, San Patricio, Aransas and Nueces counties (Coastal Bend Irrigation Area) are considered unsuitable due to excessive precipitation (30 inches annually) coupled with consistent warm temperatures that do not allow stressing.

2. San Antonio Valley (Bexar, Wilson, Karnes and Bee counties) are considered questionable for guayule cultivation due to precipitation (26 to 32 inches annually) and lack of cold stressing periods. Medina and Atascosa counties are questionable due to rainfall and lack of appropriate soils in quantity.

3. Kleberg and Kennedy counties are discounted due to salt intrusion in coastal groundwater and the relatively low levels of field-crop agriculture.

4. The Lower Rio Grande Valley Irrigation Area portion in Willacy and Camerron counties are eliminated due to competition with high value citrus and vegetable crops.

5. The Middle Rio Grande Irrigation Area (including Maverick, Zapata and Western Webb counties) are considered questionable due to low relative concentration of field crop agriculture. Some incentive may exist for guayule, however, as an insurance against loss of Rio Grande irrigation water during drought periods. Although there is not enough compact acreage to support a mill here, guayule grown in this region might be transferred to mills in adjacent production areas.

6. Jim Hogg and Brooks counties are considered unsuitable for guayule due to poor soils and little field crop agriculture.

West Texas:

7. The area between the El Paso Valley and the Trans Pecos are considered insufficient in agriculture to support a processing facility. Rainfall is insufficient for dryland production (8 to 12 inches annually). Less than 15,000 acres were harvested in this area in the

mid-1970s. Escalating fuel costs are seriously impinging on irrigation. High irrigation costs might induce some farmers to switch to guayule for shipment to processing facilities in adjacent areas if transportation costs are not prohibitive.

New Mexico-Arizona:

8. Greenlee and Cochise counties, Arizona, and Grant and Hidalgo counties, New Mexico, are eliminated primarily due to cold temperatures in agricultural areas. Furthermore, Greenlee, Grant and Hidalgo counties have relatively little agriculture (34,000 harvested acres from 1975 to 1977).

9. Although Graham County, Arizona, has about 50,000 acres of irrigated agriculture as well as appropriate temperature ranges, it is physically isolated from nearby potential guayule growing areas. It is considered unlikely that 50 percent or more of the County's developed agriculture would be converted to guayule. Santa Cruz County has winter tempratures that are too low, and very little field-crop agriculture.

Arizona-Nevada:

10. Northern Mohave County, Arizona, as well as Clark County, Nevada, are restricted by both too low temperatures and very little agricultural development relative to the area necessary to support a guayule processing mill.

California:

11. The South Coast area is characterized by competition between urbanization and high value orchard crops, such as citrus and avocado, and vegetable crops, all of which tend to severely restrict the potential for guayule development.

12. Most suitable guayule growing areas in the San Joaquin Valley are in the western half of the valley. The eastern side has less suitable soil and is characterized by considerable acreages of orchards and vineyards.

13. Expanding urbanization is severely restricting agricultural acreage in the San Francisco Costal hydrographic unit. In the mid-1970s, 27,300 acres of field crops were harvested in this area, a reduction of some 84 percent since 1950. Agricultural acreage is expected to continue to decline.

14. The Sacramento Basin shows little likelihood of developing sufficient acreage of guayule to support a processing facility. There is more than sufficient field crop-acreage, more than 1.6 million field-crop acres were harvested in the mid-1970s, but much of this acreage is in high value field crops representative of conditions not conducive for

guayule development. For example, nearly 25 percent of field-crop production in the Sacramento Valley is rice. Rainfall for most of the agricultural areas in the Sacramento Valley is from 20 to 40 inches annually. High precipitation in the surrounding mountain areas (to 80 inches annually) make Sacramento Valley the greatest supplier of water to the California water distribution system, and subjects much of the Valley to periodic flooding. All of these conditions severely restrict the potential for guayule development.

APPENDIX C

SOCIOLOGICAL PROFILES OF POTENTIAL GUAYULE GROWTH AREAS

The guayule growing area is large and diverse. As a result, it is difficult to identify collectively the social impacts in the entire area. In order to get a picture of the range of impacts, two particular areas will be examined in depth: Kern County, California, and Pecos County, Texas. These two areas reflect the areas of greatest guayule growing potential. They also reflect the ares of greatest difference; Kern County is highly industrialized and is part of the urbanized area of Bakersfield; Pecos County is primarily rural and agricultural in nature.

The guayule areas with the greatest potential in Arizona and New Mexico will be examined in less depth. This is because only about 20 percent or less of the guayule grown and processed would come from these two states.

I. California

Kern County, California, is a relatively conservative county, both politically and economically. It was one of only two counties that voted against Proposition 13. The majority of the citizens also voted against the Brown administration in the 1978 election.

Economically, the County is the second leading agriculture-producing county in the United States. The principal crop is cotton with a dollar value of $228 million in the mid 1970s. The harvested field crop acres are in excess of 650,000. Other major crops include almonds barley, grapes ($526,556,000); hay, lettuce, oranges, peaches, rice strawberries, sugarbeets tomatoes, wheat, and tomatoes, wheat and nursery produce. In addition, Kern County ranks sixth in the United States in livestock production.

Kern County also is the leading oil-producing county in the United States. The largest amount of domestic petroleum exploration also is taking place in the County. The oil companies have an additional impact on the economy because several of them own large corporate farms in the County.

Kern County is a growing county. The population increased from 292,00 in 1960 to 362,000 in 1979. The majority of the County (74 percent) is white (non-minority). Only 5 percent is black. The largest minority concentration is Hispanic (17 percent).

Forty-nine percent of the populaion is male, a ratio that holds across all social subgroups.

The age composition of the population of Kern County is interesting. Approximately 8 percent of the population is 64 years of age or older. The two largest age group concentrations for both males and females are the 5-to-19 and 25-to-54 categories. These two categories contain 33 percent and 35 percent, respectively, of the males and 31 percent and 36 percent, respectively, of the females.

The rate of natural increase in the County has averaged 10 each year since 1970. The birth rate for each of the years 1970 through 1979 has ranged from 15.96 to 19.08. It has averaged 18.50 for each of the years 1976 through 1979. The death rate has ranged from 7.94 in 1976 to a high of 8.36 in 1970. The death rate usually is somewhere around 8.15.

The overwhelming majority of the population is married. Sixty-eight percent of the males over 14 years of age are married while 66 percent of the females are married. The marriage rate for the County is about 8.5 percent annually. Only 3.61 percent of the males who were ever married are divorced while 5 percent of the females are divorced.

Kern County is prosperous. Total retail sales totaled $1,289,311,000 in 1978. The total net effective buying income was $1,791,303,000. This represents a per capita buying income of $4,902 or an average effective buying income per household of $14,804.

The latest available statistics indicate that the per capita income for Kern County was $5,769. Since that is a 1975 figure, the per capita income has increased, but there is no recent update. In 1975 the total personal income increased, but there is no recent update. In 1975 the total income was $1,995,119. This represents approximately 1.4 percent of the total per capita income of the State. This is a decline from 1950 when the total personal income represented nearly 2 percent of the California total.

While Kern County is well off, 23,210 persons receive some type of public assistance. Of this total 15,095 receive food stamps, 7,396 receive general home relief, and funds are spent for placing 556 children with foster families and 80 children in institutions. The percentage of the Kern County population receiving public assistance is only 6 percent. Only 4 percent of the total population receives food stamps.

There are 51,324 persons below the poverty level in Kern County. Of this total, 31,718 are female, with the largest concentrations in the 22-to-4 and 60-to-64 age categories. The largest concentrations of males below the poverty level are in the age groups 14-to-21 (5,817) and 22-to-44 (5,811). There are 11,253 Hispanics that are classified as being below the poverty level. Of this number, 57 percent (6,3800) are female. In case of Hispanics the greatest concentration for both males and females is in the 14-to-21 and 22-to-44 age categories. The totals are 1,430 and 1,894 respectively, for males, and 2,003 and 2,929, respectively, for females.

Eighty-four percent of the population in Kern County lives in single family housing. Nearly 60 percent of the housing is owner- occupied. Only slightly more than 1 percent of the housing in the County lacks some or all plumbing. However, 18 percent have 1.01 or more persons per room as of June/July 1977. Housing has been expanding to keep up with the pace of populaion growth. The number of residential building permits issued in Kern County grew from 2,753 in 1970 to nearly 5,000 in 1976. The increase in building permits declined somewhat during the 1973 recession; however, it appears that that was not a significant or long-term ocurrence and that the mix of the economy in the County is sufficient to insulate it from serious economic repercussions.

The civilian labor force in Kern County for 1978 was 171,800 persons. However, 15,300 persons (9.1 percent of the labor force) are unemployed, although the total number of persons employed (156,000) is a record. While impressive gains have been made in employment, they were not sufficient to keep pace with the swelling labor force.

Looking at only wage and salary employment in 1978, Kern County registered a gain of 5.9 percent over 1977. The total wage and salary employment in all industries was 148,300. Of this total, agriculture accounted for only 27,8000 persons receiving a wage or salary. Non-agricultural wage and salary employment totaled 120,500, which breaks down as follows: mineral extraction, 10,000; construction, 6,800; manufacturing, 9,200 (durable goods, 4,600) (non-durable goods, 4,600); transportation and utilities, 7,200; trade, 30,800 (wholesale, 7,100) (retail, 23,700); finance, insurance, real estate, 4,400; services, 20,400; and government, 31,700.

An examination of the employment in agriculture indicates that nearly 75 percent are farmers and farm workers. Approximately 7 percent are clerical workers. Only 22 percent are professional, or technical workers, while only 1.1 percent are managers, officials, or proprietors. Sales and services collectively account for only 1.4 percent of the agriculture-related employment.

Nine percent of the farms in Kern County with sales of more than $2,500 are operated by corporations. The average size of all farms in the County is 1,873 acres. However, there are 141 farms of less than 10 acres, and 844 of less than 180 acres. There are 327 farms that are in excess of 100 acres.

Politically, Kern County is rather conservative. The County voted Republican in both the 1972 and 1976 presidential elections.

About 60 percent of the votes cast were for the Republican candidates.

Kern County had 110,876 students enrolled in school in grades kindergarten through 12 in 1977. Of this number, 79,810 were enrolled in public schools; 24,741 were in grades 9 through 12. Private school enrollment accounted for 3,356 students, of which 625 were in grades 9 through 12.

In Kern County there are 147 elementary schools, 31 high schools, four community colleges and one four-year state college.

Health care is currently adequate in Kern County. There is a rate of one physician for every 117 persons in the County. There are currently 16 hospitals in the County with a total of 1,373 beds, or a range of one bed for every 392 persons. Several hospitals have begun expansion programs to accommodate the expanding population of the county.

The number of police officers in the County is relatively low for the size of the population. There are 551 police officers. The latest crime information indicates that there are annually 26,264 serious crimes known to the police. Of this number, 8,364 were rapes, 8,588 were burglaries, 1,825 were motor vehicle thefts, 975 were aggravated assaults, 901 were robberies and 5,611 were other crimes.

II. Arizona

It has been estimated that less than 20 percent of the guayule produced would come from Arizona. As a result, the detail on the demographic, economic and community characteristics of Arizona are less detailed than for Kern County, California, and Pecos County, Texas.

There are nine counties in Arizona that have been identified as potential guayule growth counties; however, because of the constraints identified earlier, only four, Maricopa, Pima, Pinal and Yuma counties are thought to be suitable.

Arizona has a total population of 2,363,600, of which 72 percent are white, 19 percent Hispanic, and 6 percent Indian. The characteristics are somewhat different by county. It is, therefore, important to look at the characteristics of each county.

A. Maricopa County: Maricopa County contains more than half of Arizona's population. It is the most urbanized county in the state. It contains 5,905,000 acres, or 9,226 square miles. The population density is 146 persons per square mile. The population increased 46.1 percent between 1967 and 1977 from 890,000 to 1.3 million. Whites account for 80 percent of the population. The Hispanic population is the second largest in the County with 190,500 persons, or 15 percent. Blacks are the third largest population group and number 44,400 persons, or just more than 3 percent. Indians account for 15,500 persons, or just more than 1 percent of the total population.

Females constitute 51 percent of the population. Forty-six percent of the female population is less than 24 years of age. Ten percent is older than 65. The male population less than 24 years of age accounts for 48 percent of the total population. Only 9 percent of the male population is more than 65 years of age.

The principal industries in Maricopa County are manufacturing, especially high technology products; agriculture (Maricopa County is the largest producer of crops and livestock in the State); and tourism and travel (more than $1 billion is expended annually).

The total civilian labor force in the County is 563,800. There is an unemployment rate of only 5.3 percent. The non-farm wage and salary employment totals 510,900 persons. Twenty-six percent of the wage and salary employment is in wholesale and retail trade. Services are the next largest employment category with 95,900 (19 percent), followed by government with 91,400 persons (18 percent) and manufacturing with 88,500 persons (17 percent). There are of 24,554 business establishments in Maricopa County. The largest number of these are in services and retail trade, followed by contract construction, finance and wholesale trade. There are 383 agriculture and forestry establishments in the County.

The per capita income in Maricopa County is the highest in Arizona at $6,747. This represents an increase from $5,200 in 1973. There are 8,971 families receiving public assistance or welfare.

There are of 264,268 students enrolled in public schools in Maricopa County. Of this number, 126,833 are in elementary districts, and 55,345 are in high school districts. The remaining 82,090 are enrolled in unified districts.

B. Pima County: Pima County is the second most urbanized county in Arizona. It contains 5,914,000 acres, or 9,240 square miles. The population density is 51.3 persons per square mile. The population increased 43.5 percent between 1967 and 1977, from 324,000 to 464,000. Whites account for 69 percent of the total population. The second largest group is the Hispanic population which constitutes 24 percent of the total. This is a major deviation from the State percentages of the two population groups. In the State as a whole, 72 percent of the population is white and 18.7 percent is Hispanic The Indian and black populations each account for 3 percent of the total. This percentage is less than the State percentage of 5.6 percent for Indians, but is equal to the State black population percentage. As in the State as a whole, females constitute 51 percent of the population. Fifty-five percent of the female population is less than 24 years of age. Eleven percent is 65 years of age and over. Of the total male population, 41 percent is less than 24 years of age. Only 9 percent of the male population is 65 years of age or older.

The principal industries in Pima County are copper mining, manufacturing and tourism. The total labor force is 183,800, of which 5.8 percent, or 11,000, are unemployed. The total non-farm wage and salary employment is 153,600. The three largest employment sectors are government (40,000), wholesale and retail trade (35,600) and services (31,500) Manufacturing industries employ 14,100 persons, while mining accounts for 5,900 persons in the labor force. Transportation and public utilities account for 7,900.

The economic indicators in Pima County were all positive between 1967 and 1977. Retail sales increased by 202.6 percent, from $526,786,000 to $1,593,895,000. Bank deposits were up 192.6 percent, from $454,079,000 to $1,328,678,000. Vehicle registrations increased nearly 62 percent, from 197,952 to 319,858. The amount of motor fuel consumed was up 76.3 percent, corresponding to the rise in vehicle registrations and in line with the winter tourist industry.

The largest number of business establishments in Pima County are in the service sector. This is followed closely by retail trade. Finance, insurance and real estate are a distant third, followed closely by contract construction. There are 113 agriculture and forestry businesses in the County.

The per capita income in Pima County is slightly less than in Maricopa County, but is the second highest in the State at $6,324. There are 3,257 families receiving public assistance or welfare.

There are 90,655 students enrolled in the public schools in Pima County. Of this number, 52,041 are in elementary districts, 5,592 are in high school districts and 13,022 are in unified districts.

C. Pinal County: Pinal County is primarily rural and is divided into two distinct regions in geography and economy. The eastern portion is characterized by mountains and copper mining. The western region is principally low desert valleys and irrigated agriculture.

Pinal County contains 3,442,000 acres (5,386 square miles). It has a population density of only 16.7 persons per square mile. As in other counties in Arizona, Pinal County has been growing. The population increased by 37.2 percent between 1967 and 1977, from 65,400 to 89,700. Unlike Maricopa and Pima counties, males outnumber females. Slightly more than 51 percent (51.3) of the population is male. Fifty-one percent of the males are less than 24 years of age. Only 7.54 percent are more than 65 years of age. For females, nearly 52 percent are under 24 years of age. Only 7.38 percent are more than 65 years of age.

Only 48 percent of the population is white, while 36 percent is Hispanic. Blacks account for 4 percent, and Indians 9 percent of the population. The population mix of Pinal County varies significantly from that of the State. There is a much higher concentration of Hispanics the State as a whole, while the concentration of whites is far less than the State.

The economic indicators for Pinal County were positive between 1967 and 1977. Retail sales increased 266.4 percent, from $75,523,000 to $276,745,000, between 1967 and 1977. Bank deposits were up 203.6 percent, from $53,801,000 to $163,348,000. Vehicle registrations increased from 34,399 to 64,037, or 86.2 percent. Gasoline consumption was up 76.6 percent, reflecting the positive growth of the economy.

The principal industries in Pinal County are farming and ranching, copper mining, tourism and manufacturing. The total civilian labor force is 28,250. Of this number, 2,950 persons are unemployed, for an unemployment rate of 9.7 percent, well above the national average.

The number of persons employed in non-farm wage and salary occupations is 22,125. The largest employment sector is government (6,250) followed closely by mining (6,150). Wholesale and retail trade firms employ 3,400 persons, while manufacturing operations employ 2,275 persons. There are 35 agriculture and forestry firms in the county.

The per capita income of Pinal County is $5,509. This is an increase from $4,002 in 1973. There are 1,063 families that are receiving public assistance or welfare.

There are 21,503 students enrolled in public schools in the County. Of this number 9,706 are in elementary schools, 3,477 in high schools, and 8,320 in unified districts.

D. Yuma County: Yuma County is predominantly desert land, accented with rugged mountains. However, there is an abundance of arable land in the valley regions that is irrigated with Colorado River water. The County contains 6,391,000 acres (9,991 square miles). It has a population density of 8.1 persons per square mile. The population grew from 57,500 persons in 1967 to 74,900 persons in 1977 (30.3 percent). Fifty one percent of the population is male. The majority of the male population (52 percent) is less than 24 years of age. Less than 8 percent is more than 65 years of age. Not quite half (49 percent) of the female population is less than 24 years of age. However, less than 8 percent is more than 65 years of age.

Sixty-five percent of the population is white. The second largest segment of the population is Hispanic (26 percent). Indians and blacks each account for 3 percent of the population. The social and ethnic mix deviates from the State mix somewhat. Whites and Indians account for a lower proportion of the population in Yuma County than they do in the State. Hispanics constitute a larger share of the population than in the State, while the proportion of blacks is the same as in the State.

The principal industries in the County are farming, cattle feeding, tourism and government (Yuma Proving Ground and Marine Air Corps Station). The labor force is 30,850, of which 2,725, or 8.5 percent, are unemployed. The unemployment rate is higher than the national average.

The non-farm wage and salary employment totals 20,325. The three largest employment sectors are government (29 percent), wholesale and retail trade (28 percent), and services (17 percent). Both construction and manufacturing firms employ 1,600 people, or 7 percent each.

There are 1,353 business establishments in Yuma County. The business sectors with the largest number of firms are retail trade (451), services (383) and contract construction (127). There are 48 firms in the agriculture and forestry sector.

The per capita income of Yuma County is $5,598. This is an increase from $3,817 in 1973. There are 559 families receiving some type of public assistance or welfare.

Students enrolled in the public schools total 17,681. Of this total, 12,285 are in elementary districts and 5,396 are in high school districts.

III. New Mexico

There are four counties that are potential guayule growing counties in New Mexico. However, two have been eliminated because of external constraints. The two counties that have the most potential for guayule are Dona Ana and Luna.

A. Dona Ana: The population of Dona Ana County grew from 69,800 in 1970 to 83,900 in 1977. The population is divided equally between males and females. Fifty-seven percent of the male population is less than 24 years of age, while 7 percent are more than 65 years of age. For females, 56 percent are less than 24 years of age, while only 6 percent are more than 65 years of age. Of the males 14 years of age and older, 61 percent are married and 35 percent are single. Only 4 percent are divorced or widowed. Sixty-two percent of the females more than 14 years of age are married. Only 26 percent are single. Both the divorced and widowed rates are higher for females: 3.69 percent and 7.55 percent, respectively.

There are 32,257 persons in the civilian labor force in Dona Ana County. Of this number 30,427 are employed and 1,830 are unemployed, an unemployment rate of 5.9 percent. The County ranks 18th in per capita income in the State. The per capita income is $4,673. This is less than the State average of $5,857.

There are currently 21,263 students enrolled in school in the county.

B. Luna: The population of Luna County grew from 11,700 persons in 1970 to 14,400 persons in 1977. Fifty-one percent of the population is female. Fifty-two percent of the females are less than 24 years of age, while only 50 percent of the males are less than 24 years of age. Ten percent of both females and males are more than 65 years of age.

Nearly 67 percent of the males more than 14 years of age are married. Twenty-six percent are single. Only 3 percent are divorced while 4 percent are widowed. In the case of females, 62 percent are married and 21 percent are single. However, 22 percent are widowed.

There are 5,142 persons in the civilian labor force in Luna County. Of this number 4,789 are employed and 353 (6.9 percent) are unemployed. The County ranks 14th among all New Mexico counties with a per capita income of $4,825. This is below the average for the State.

There are 3,569 students enrolled in the public schools, down from 3,744 in the 1974-1975 school year.

IV. Texas

Approximately 31 percent of the projected guayule production region is expected to be in Texas. Most will take place in western and southwestern counties that are primarily rural. Texas is the only state in the projected growing area where guayule grows naturally.

Because of the large number of counties and the associated large geographic area involved, it was decided to focus on one particular county. Pecos County was selected because of the existing interest in guayule among the agricultural community and because of the experimentation that is taking place in the County.

Pecos County is the second largest county in Texas in area. It contains 4,736 square miles. The altitude ranges from 2,000 to 5,200 feet. Average annual precipitation is 13.07 inches. The minimum January temperature is 33 F and the July maximum is 94 F. The growing season is 224 days.

Oil and gas production are the chief factors in the economy of Pecos County. More than 710 million barrels of oil have been produced since production began in 1926. There also is a large gas output and high sulfur production.

Agribusiness is the second leading factor in the economy. About 60 percent of the $14 million average annual income in the century is from agriculture, chiefly from cattle, sheep, goats, cotton, grain and vegetables. Pecans are increasing in importance.

Pecos County, like most of West Texas, is conservative, both economically and politically. The County voted Republican in both the 1972 and 1976 presidential elections. In 1972, 73 percent of the vote was Republican. In 1976 it was 53 percent. The County also voted Republican in the 1978 gubernatorial election. Of the 7,900 persons registered to vote, only about 42 percent did so in the last presidential election.

While the area of the County is large, the population is only 14,300. This represents an increase from 1970 when the population was 13,748. However, the population was 11,957 in 1960. The population of males and females in Pecos County is nearly equal with 7,135 males and 7,165 females. While whites have the largest share of the total population, Hispanics number 5,332 persons, or 37 percent of the population. Fifty-one percent of the female population is less than 24 years of age, as is the male population. Only 5 percent of the male population is 65 years of age or older, while 6 percent of the female population is more than 65 years of age.

The population of Pecos County is growing by natural increase. Between 1970 and 1977 there have been 2,000 births and 700 deaths. However, there has been a net out-migration of 800, or 5.5 percent. The birth rate in the County is 20.3.

The overwhelming majority of the population is married. Only 24 percent of the males 14 years of age and older are single; 72 percent are married. The remaining are either separated, widowed or divorced. For females, the percentage married is still higher (74 percent). Only 17 percent of the females are single. However, 8 percent are widowed, while just over 2 percent are separated or divorced.

Pecos County has a total civilian labor force of 5,556 persons. Of that number, 5,331 persons are employed. Only 225 persons are unemployed, or only 4 percent.

Forty-six percent of the labor force is employed in three occupational categories: craftsmen, 16.77 percent; operatives, 16.24 percent; and professional, technical and kindred workers, 12.67 percent. Additionally, 11 percent of those employed are clerical workers. This is not a particularly surprising fact when the number of business establishments is examined. There are 10 manufacturing establishments with $100,000 annual wages. There are 28 wholesale establishments with a total of 135 employees. The annual payroll is $750,000. The wholesale establishments have total sales of $16.3 million.

The mineral industries have the largest number of establishments, 182. There are 2,100 persons employed in the mineral industries that have a payroll of $203 million annually.

There are 2,921,000 acres of land in agriculture in the County. This represents 96 percent of all the land. The farm population is 540 persons, with 43 percent of the farm operators residing on the farm.

In recent years, farming has been declining because of the high cost of irrigation. This is one reason that farmers and ranchers are looking seriously at both jojoba and guayule.

The mean family income in Pecos County is $8,980. However, 510, or 15 percent, of all families have incomes below the poverty level. Public welfare or assistance is paid to 113 families. In addition, there are 178 recipients of aid to families with dependent children.

Community services are somewhat limited in Pecos County. There are 15 municipal police officers in Fort Stockton, which is both the largest community and the County seat. However, there are only 11 county police officers and seven State Department of Public Safety officers to patrol the remainder of the County.

The fire departments in the County, as well as Fort Stockton, are all volunteer. This means that there is limited training and expertise in various methods of firefighting. The volunter fire department in Fort Stockton has only 35 persons.

Communications via the media also are limited. There is only one semiweekly newspaper. There is also only one radio station. There are no television stations, although there is cable service that provides six channels.

Both education and health care facilities appear to be adequate. There are 3,345 students enrolled in public schools, with 211 classroom teachers for a student-teacher ratio of 16:1. There are four elementary schools, one junior high school and one high school in Fort Stockton.

There is an adequate number of physicians to serve the population of Pecos County. However, patients with more serious disorders are transported 150 miles to Midland or Odessa, Texas.

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APPENDIX D

DETAILS OF WORLD ELASTOMER SUPPLY AND DEMAND PROJECTIONS

The following two tables show the alternate "high-growth" and "low-growth" world elastomer supply-and-demand projections, from Tables II-3 and II-4, year by year from 1980 through 2000.

TABLE D-1

A HIGH-GROWTH FUTURE FOR WORLD ELASTOMER SUPPLY AND DEMAND

	SR Production from Petroleum Feedstocks (6% p.a. growth)	NR Production for Hevea		Total Elastomer Production from Existing Sources	Total Elastomer Demand 6% p.a. growth	Potential NR Market Share	Potential NR Demand	NR Shortfall[1/]
	10^6Mg	10^6Mg	% p.a. growth	10^6 Mg	10^6Mg	%	10^6Mg	10^6Mg
1980	10.13	4.34	3.5	14.47	14.47	30	4.34	-
1981	10.74	4.49		15.23	15.34		4.60	0.11
1982	11.38	4.65		16.03	16.26		4.88	0.23
1983	12.06	4.81		16.87	17.23		5.17	0.36
1984	12.78	4.98		17.76	18.26		5.48	0.50
1985	13.55	5.15		18.70	19.36		5.81	0.66
1986	14.36	5.33		19.69	20.52		6.16	0.83
1987	15.22	5.52		20.74	21.75		6.52	1.00
1988	16.14	5.71		21.85	23.06		6.92	1.21
1989	17.11	5.91		23.02	24.44		7.33	1.42
1990	18.14	6.12	4.0	24.26	25.91		7.77	1.65
1991	19.22	6.36		25.58	27.46		8.24	1.88
1992	20.38	6.61		26.99	29.11		8.73	2.12
1993	21.60	6.87		28.47	30.86		9.26	2.39
1994	22.90	7.14		30.04	32.71		9.81	2.67
1995	24.27	7.43		31.70	34.67		10.40	2.97
1996	25.72	7.73		33.45	36.75		11.02	3.29
1997	27.27	8.04		35.31	38.96		11.69	3.65
1998	28.91	8.36		37.27	41.30		12.39	4.03
1999	30.64	8.69		39.33	43.77		13.13	4.44
2000	32.48	9.04		41.52	46.40		13.92	4.88

1/ Equal to total elastomer shortfall.

TABLE D-2

A LOW-GROWTH FUTURE FOR WORLD ELASTOMER SUPPLY AND DEMAND

	SR Production from Petroleum Feedstocks a/		NR Production from Hevea b/ 3% p.a. growth	Total Elastomer Production from Existing Sources	Total Elastomer c/ Demand 3.5% p.a. growth	Total Elastomer Shortfall	Potential NR Market Share	Potential NR Demand	NR Shortfall
	10^6 Mg	%p.a. change	10^6 Mg	10^6 Mg	10^6 Mg	10^6 Mg	%	10^6 Mg	10^6 Mg
1980	10.13	3.5	4.34	14.47	14.47	-	30-35	4.34 - 5.06	0.00 - 0.72
1981	10.48	3.5	4.47	14.95	14.98	0.03		4.49 - 5.24	0.02 - 0.77
1982	10.85	3.5	4.60	15.45	15.50	0.05		4.65 - 5.42	0.05 - 0.82
1983	11.23	3.5	4.74	15.97	16.04	0.07		4.81 - 5.61	0.07 - 0.87
1984	11.62	3.5	4.88	16.50	16.60	0.10		4.98 - 5.81	0.10 - 0.93
1985	12.03	3.5	5.03	17.06	17.18	0.12		5.15 - 6.01	0.12 - 0.98
1986	12.45	3	5.18	17.63	17.78	0.15		5.33 - 6.22	0.15 - 1.04
1987	12.82	3	5.34	18.16	18.40	0.24		5.52 - 6.44	0.18 - 1.10
1988	13.20	2	5.50	18.70	19.04	0.34		5.71 - 6.66	0.21 - 1.16
1989	13.46	1	5.66	19.12	19.71	0.59		5.91 - 6.90	0.25 - 1.24
1990	13.59	0	5.83	19.42	20.40	0.98	35-40	7.14 - 8.16	1.31 - 2.33
1991	13.59	0	6.00	19.59	21.11	1.52		7.39 - 8.44	1.39 - 2.44
1992	13.59	0	6.18	19.77	21.85	2.08		7.65 - 8.74	1.47 - 2.56
1993	13.59	0	6.37	19.96	22.61	2.65		7.91 - 9.04	1.54 - 2.67
1994	13.59	0	6.56	20.15	23.40	3.25		8.19 - 9.36	1.63 - 2.80
1995	13.59	0	6.76	20.35	24.22	3.87		8.48 - 9.69	1.72 - 2.93
1996	13.59	-1	6.96	20.55	25.07	4.52		8.77 -10.03	1.81 - 3.07
1997	13.45	-1	7.17	20.62	25.95	5.33		9.08 -10.38	1.91 - 3.21
1998	13.32	-1	7.39	20.71	26.86	6.15		9.40 -10.74	2.01 - 3.35
1999	13.19	-1	7.61	20.80	27.80	7.00		9.73 -11.12	2.12 - 3.51
2000	13.06	-	7.84	20.90	28.77	7.87		10.07 -11.51	2.23 - 3.67

a/ Petroleum shortages and/or skyrocketing petroleum prices slow growth in production during the 1980s and halt the growth of synthetic rubber production from this feedstock source in 1990. Production is declining slightly at the turn of the century.

b/ Growth in hevea rubber producion is limited by the incursion of oil palm, cocoa, coffee, cashews, and other cash crops on land previously devoted to the cultivation of rubber trees. Labor problems and political disturbances also cause additional problems in the prime growing areas in Southeast Asia.

c/ Growth in world elastomer demand slows from the 6 percent per annum rate of past years to a 3.5 percent per annum rate due to the impact of fuel shortages and high fuel prices on the consumption of rubber trees. Expanding elastomer markets in the developing nations and the use of fuels not derived from petroleum (i.e., oil shale and coal derived fuels, alcohol derived or extended fuels, other biomass derived fuels, hydrogen, electric battery power, etc.) as well as the expansion of elastomer market areas outside the tire sector, allow continued modest growth in elastomer demand despite the petroleum situation.

APPENDIX E

GUAYULE RUBBER FUTURES MARKET*

According to interviews conducted with lending institutions regarding loans to small holders for investment in guayule cultivation and processing it seems advisable to forecast the establishment of a guayule rubber futures market and briefly describe how it may operate. The purpose of a guayule futures market is: a) to stabilize prices and to prevent, or dampen, excessive price changes; and b) to provide a controlled market through contractual arrangements with growers and processors. The futures market would provide a measure of guarantee to all parties-at-interest, thus lowering risk.

Presently, no formal rubber futures market exists, although there are many international traders in rubber and rubber products with offices in New York. As supplies tighten and world demand grows during 1980-2000, it appears likely that a natural rubber futures market will be created, especially now with the establishment of a buffer stock of natural rubber as part of the agreement between major rubber-producing and -consuming countries (UNCTAD agreement, Geneva, 1979).

Small holders, including individual farmers, American Indians, entrepreneurs, etc. are anticipated to act separately or as part of farmed-owned cooperative organizations to undertake the cultivation and/or processing of guayule rubber. At the same time, U.S. tire and rubber companies are forecast to begin guayule cultivation on a larger scale for captive use, but they may contract with small holders or cooperatives to purchase mature guayule plants or processed rubber on a three- or four-year cycle.

Guayule rubber would be exported or stored by cooperatives and sold to U.S. tire and rubber companies, the federal government, and speculators. (The former possibiligy is unlikely under Scenario B.)

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* Prepared with the assistance of P. McGee, Investment Specialist, Old American Insurance Co., Kansas City, Missouri.

Incentives to small growers and processors include low-cost crop insurance, loans and other assistance by the Small Business Administration (SBA), the Bureau of Indian Affairs (BIA), Office of Minority Business Enterprise (OMBE), Farm Credit Administration (FCA), Commodity Futures Trading Commission (CFTC), Federal Crop Insurance Coporation (FCIC), etc. These agencies have on-going programs to assist the small holder. No new legislation, therefore, is needed to provide for a guayule futures market.

Lenders may be encouraged by these organizations to defer interest payments until harvest and sale, three to four years later. (This practice is generally unknown in the United States since most crops are harvested annually. However, orchards require several years to become productive. Coffee, a major futures commodity, requires seven years to come into production.)

A guayule futures market would lower the risk for all parties by specifying and offering guidance in contractual details and by providing a guaranteed market to the grower or processor at a specific date. The government may set a minimun floor price. If the futures price fell below the floor price, the government could compensate the growers by direct payments.

Accrual of equity for the lender may take the form of photographic evidence of thriving guayule plants and fields obtained by on-site inspections and aerial photography, annual examination of records and costs by the grower or processor, determination of rubber content from sample cuttings, etc. This evidence may be gathered and notarized by a certified independent agent or lending representative.

The CFTC would oversee the operation and status of guayule futures market, would prevent price manipulation and market corners, and would stop dissemination of false and misleading commodity and market information affecting prices. Additionally, the CFTC would protect market users against cheating, fraud and abusive practices in commodity transactions and would safeguard the handling of traders' margin money and equities.

APPENDIX F

AN INTEGRATIVE STRUCTURE FOR FUTURE GUAYULE RESEARCH

The enclosed chart was developed using "structured programming" and is intended as an integrative device to allow appropriate coordination of guayule research. Coordination of research, coupled with effective internal and external information exchange and dissemination systems, is viewed as essential for the successful development of guayule to the point of commercialization. The enclosed chart is taken from the 1979 Office of Arid Lands Studies report, An Integrated Approach to Guayule Research, by William G. McGinnies and Jonathan G. Taylor. A more complete discussion of research inter-relationships can be found in that document.