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THE U.S. GOVERNMENT SYNTHETIC RUBBER PROGRAM  
1941-1955  
An Examination in Search of Lessons  
For Current Energy Technology Commercialization  
Projects

by

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## PREFACE

This paper was written as a background paper in support of the M.I.T. Energy Policy Study Group's report, "Government Support for the Commercialization of New Energy Technologies; An Analysis and Exploration of the Issues" (M.I.T. Energy Laboratory Report MIT-EL 76-009, October, 1976). Like the other background papers, it examines a specific government program, historical or current, to draw lessons for present energy policies.

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THE U.S. GOVERNMENT SYNTHETIC RUBBER PROGRAM, 1941-1955

An Examination in Search of Lessons  
For Current Energy Technology Commercialization Projects

In 1941, the U.S. government initiated the emergency construction of government-owned but privately operated synthetic rubber plants. Under war-time conditions of scarce raw materials, capital equipment and labor supply, plants were constructed in four years' time with an annual production capacity of one million long tons of synthetic rubber, at an investment of \$700 million. In 1954, after nine years of postwar government ownership and private operation of the majority of synthetic rubber plants, the government finally transferred (through outright sales) its ownership of plants to private companies. Recently this experience has been cited as a model for an American response to the control of imported petroleum by the Organization of Petroleum Exporting Countries.\*

I will attempt to present in this paper the potential lessons, for planners of new government-sponsored industries, which may be derived from the government's synthetic rubber experience. Particular parallels exist between past conditions in synthetic rubber and current conditions for synthetic fuels:

- (1) Synthetic rubber production was initiated to replace a natural raw material in decreasing supply. Alternative energy sources--particularly synthetic sources--are substitutes for major natural raw materials, especially natural gas and oil.

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\* For example: Bueche, A.M. "Synthetic Rubber in World War II." Science. Volume 191 (March 12, 1976).

- (2) Private companies in 1941 possessed the technical knowledge of the rubber production process, but perceived no immediate profit opportunity for large-scale production. Although technical information is now available, it is the economics of the situation which seem to prevent large-scale private investments in alternative energy sources.
- (3) The synthetic rubber industry actually consisted (until 1955) of four major rubber formulations with six main types of production. Large firms with experience in rubber, oil, and chemical production were involved in various combinations of horizontal and vertical integration of markets. Similarly, production of synthetic fuels would involve a variety of processes and end-products.
- (4) New government agencies were established (and transformed over time) to ensure synthetic rubber production and transfer ownership to industrial firms. Alternative energy technologies may be expected to combine government and private operation and financing.

However, particular differences also exist between synthetic rubber then and synthetic fuels now:

- (1) In 1941, the U.S. was threatened with a nearly total curtailment of its natural rubber supplies from the Far East. Beginning in 1942, the U.S. could not import as much rubber as it needed--at any price. Currently, the U.S. must tolerate the insecurity of a possible second oil embargo from the Middle East, but it may import as much oil as it wants at monopolistic prices. There is now no absolute physical shortage of oil.
- (2) The vast majority of people in the U.S. supported the emergency mobilization of government and private industry resources to produce the output necessary to win World War II. At present, more conflicting opinions exist concerning the government's support of private industry production of energy. A plan for massive government support of new energy technologies could not be expected to receive unambiguous popular support.

In using a complete past record of government and private industry experience, one may easily tend to ignore differences of opinion and factional debate, and concentrate exclusively on courses actually chosen and outcomes achieved. I will try to uncover, wherever possible, the questions asked, alternatives considered, and contemporary evaluations of the phases of the synthetic rubber program during its long history. Therefore, I plan to outline

in chronological order the essential facts from 1940-1954 about the synthetic rubber industry. With these facts as a base, in the subsequent six sections of this paper I will examine and derive lessons from specific areas of government decision making. First, goals were formulated and reformulated over time. Second, different structures of government organization were created to implement into actual operation previously determined goals. Third, financing schemes and cost accounting procedures were developed for operation companies. Fourth, numerous incentive plans were considered and some implemented to encourage efficient production and later sale of plants. Fifth, patent procedures and investments in research and development changed with the increased development of the industry. Sixth, analyses of the competitive environment and government actions within markets were committed to the establishment of a competitive private industry. Finally, I will place into perspective the critical lessons of the synthetic rubber experience.

1. The Essential Facts About the Synthetic Rubber Program<sup>1\*</sup>

The wartime record of total industrial expansion supplies a context to the building of the rubber industry.<sup>2</sup> From 1939 to 1945, government investment supported a 25% increase in aggregate production, while private investment supported a 12 1/2% increase. Thus, the bulk of large production projects was financed by the government. In particular, expansion of synthetic rubber facilities was dwarfed by expansion of aircraft, shipbuilding, guns, and explosive industries. Generally, investment decisions were not based on private calculations of current market value, but were rather centrally planned

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\* Superscripts indicate references listed at the end of the paper.

government imperatives for necessary production. Important questions were not concerned with what to do, or how much to do, but rather with how to get it done. Synthetic rubber supply, although expanding dramatically like other raw material supplies, had the distinct feature of replacing natural supply sources almost entirely and very abruptly lost after 1941. The Baruch Report of 1942 declared synthetic rubber an essential good for the war campaign and domestic economy.<sup>3</sup>

Natural rubber had a history in the 1920's and 1930's of wildly fluctuating prices (a high of 80¢/lb. in 1925 and a low of less than 10¢/lb. in 1932) and sporadic efforts to control supply. In 1934 the International Rubber Regulation Agreement was signed to maintain "fair prices" for "efficient" producers--goals difficult to define given the two-tiered structure of producers (large plantations and native firms) and their different national origins (although 9/10 of natural rubber came from Ceylon, India, and Malaysia). To create a government stockpile of rubber, the Rubber Reserve Company was established in 1940 as the single direct buyer for the government of crude rubber from foreign markets. This organization, a subsidiary of the Reconstruction Finance Corporation, negotiated directly with the International Rubber Regulation Committee (which controlled 98% of the world's natural rubber supply), to increase the shipments (determined by quota) to the U.S. Clearly, an organization under the immediate authority of the U.S. government (as opposed to private industry) was required to effectively acquire stockpiles of rubber for future national security (not current commercial) needs. Imports rose from 500,000 annual long tons in 1939 to 1,029,000 long tons in 1941 and then fell to negligible amounts after the Japanese capture of the Far East. Stocks increased to a peak of 528,000 in 1941 and fell to a precarious low in 1943 of 140,000 long tons.



Five major types of synthetic rubber had been developed by 1940, as shown in Figure 1.

- 1) Buna-S was developed in Germany during the 1920's and 1930's as a general purpose rubber produced from butadiene (76%) and styrene (24%). Butadiene, used exclusively for Buna-S rubber, could be produced from petroleum or grain alcohol. Styrene, possessing multiple uses (particularly later in plastics), could be produced from coal, petroleum, and alcohol.
- 2) Buna-N was at that time a special purpose rubber, used in cable covers and tank linings.
- 3) Butyl developed by Standard Oil of New Jersey was used for inner tubes and other special uses and produced from petroleum and turpentine.
- 4) Neoprene was developed in the 1920's by DuPont for specialized uses such as linings and hoses, and produced from salt, sulphur, lime, and coke.
- 5) Thiokol (not shown on chart) was produced from multiple raw materials for limited specialized uses.

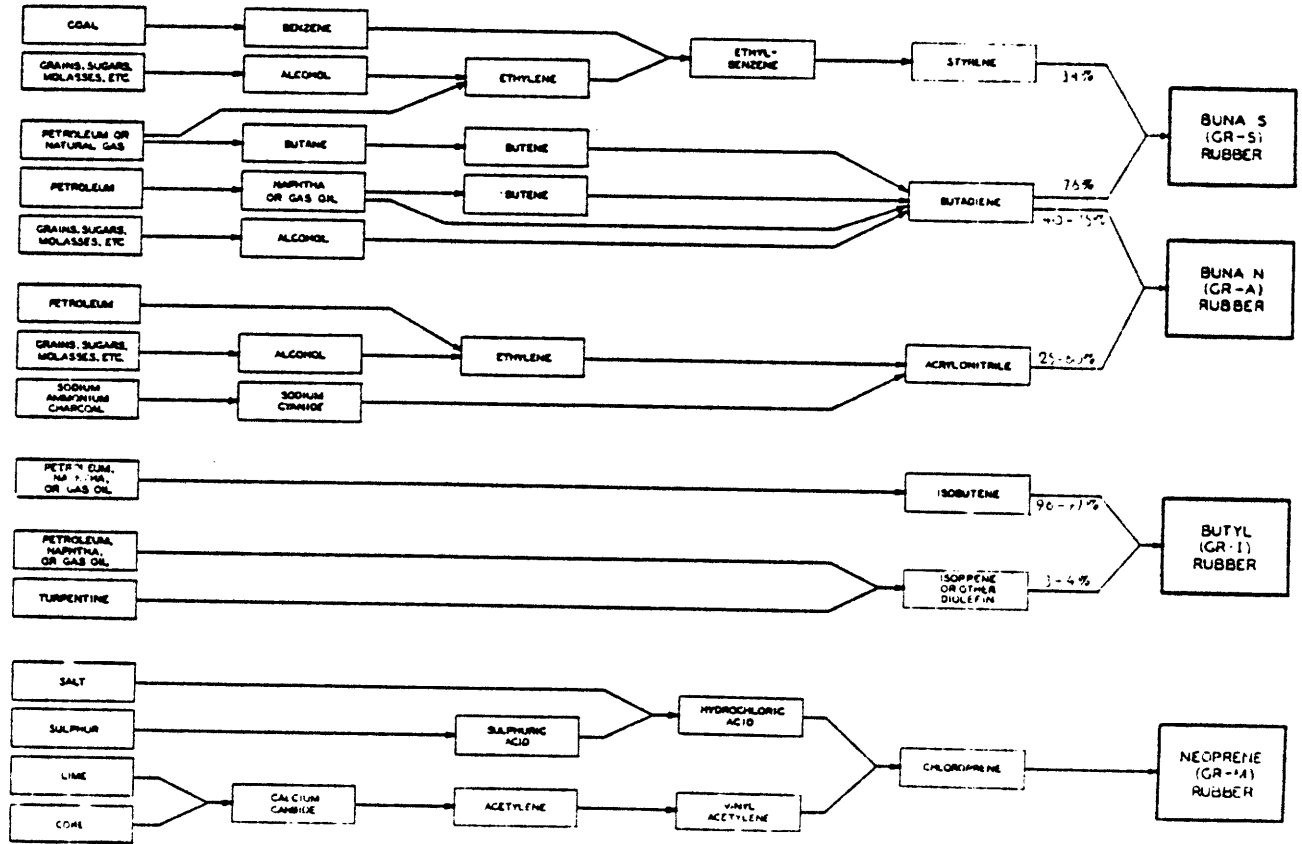
Private production of synthetic rubber in the U.S. from 1939 to 1941 was extremely limited, despite technical feasibility and, presumably, some anticipation (at least in 1941) of impending shortages of natural rubber.<sup>4</sup>

	U.S. Private Output (long tons)	Estimated German Output (long tons)	Estimated Russian Output (long tons)
1939	2,500	14,000	
1940	4,500	41,000	80,000
1941	20,000		
1943		115,000	

The private U.S. economy lagged sharply behind the national production levels of Germany and Russia. Private prices were high for the specialized rubbers-- \$.65 - \$.75/lb. for neoprene and \$.35 - \$.70/lb. for thiokol until fixed war-time prices of \$.225/lb. for natural rubber and \$.185/lb. for synthetic.

FIGURE 1

SYNTHETIC RUBBER MANUFACTURE: RAW MATERIALS TO FINISHED PRODUCT



In 1944, a comparison was made by the Office of the Rubber Director (War Production Board) of actual and intended capacities (by the 1942 Baruch committee):<sup>5</sup>

<u>1944 Critical Material</u>	<u>Intended % Capacity</u>	<u>Actual % Capacity</u>
Buna-S	80%	85%
Butyl	10	7
Neoprene	5	7
Thiokol	5	0

There were indeed significant differences between planning and execution. In particular, butadiene produced from alcohol accounted surprisingly for 83% of the supply in 1943 and 80% of the supply through 1944. According to Robert Solo:<sup>6</sup>

The 42,000 tons of scheduled butadiene capacity which government officials were forced very late in the day by the threat of Congressional rebellion to allot to the alcohol-based processes was treated by them as a bone thrown to the howling political dogs, but insofar as the need for synthetic rubber was concerned, it was that alcohol-based butadiene capacity that carried the nation through the critical phases of the war.

The plants were located predominately in the East Coast industrial sites. Significantly, plants were not built in remote areas requiring migration of people and development of supporting services. The \$700 million investment could be broken down into the following aggregate percentages for production facilities: 50% butadiene, 25% Buna-S plants, 8% butyl, 11% styrene.

After World War II, under the direction of the Inter-Agency Policy Committee on Rubber, production of synthetic rubber was continued, with the mandatory use of synthetic rubber in certain materials, and with price con-

trols. Between 1946 and 1949, plants above "national security needs" with 25% of the total wartime capacity were sold (many with contracts stipulating the rates of production or non-production) for less than 50% of the government investment to date in those plants. A limited number of these plants (particularly styrene and neoprene plants) continued to operate privately from 1946 on. The Rubber Act of 1948 declared the following policy:

It is declared to be the policy of the Congress that the security interests of the United States can and will be best served by the development within the United States of a free, competitive synthetic rubber industry. In order to strengthen national security through a sound industry, it is essential that Government ownership of production facilities, Government production of synthetic rubber, regulations requiring mandatory use of synthetic rubber and patent pooling be terminated whenever consistent with national security as provided in this Act.

However, only beginning in 1949 did the competitive position of the synthetic rubber relative to natural rubber strengthen.<sup>7</sup> Compelling needs for national security (in anticipation of another war), a violent upsurge in natural rubber prices (due to troubles in the Far East), and technical improvements (leading to decreased synthetic rubber costs and increased quality), prompted serious consideration of sale of all plants (outlined in the Steelman Report of 1950)<sup>8</sup>, but was delayed by the start of the Korean War. The Rubber Disposal Act of 1953 ordered the sale of all Government-owned synthetic rubber plants with the four goals of: 1) fostering the interests of national security, 2) establishing a free competitive industry, 3) protecting the interests of small businesses, and 4) obtaining full fair market values of facilities.<sup>9</sup>

With the notable exception of a production complex in California (including styrene, butadiene and buna-S plants) purchased by Shell Chemical, virtually all the plants were purchased (mostly in full, but several in

partnership) by the current operating companies without competitive bids from other companies.

Finally, the Attorney General in 1961 reported on the synthetic industry's competitive structure.<sup>8</sup> At this time, synthetic rubber dominated natural and reclaimed rubber in production, consumption, and stocks. Except for the addition of two new types of synthetic rubber--N-type, and Polybutadiene and Polyisoprene--the list of synthetic rubber companies in 1961 greatly resembled the list of original operators in 1944.

To summarize, the synthetic rubber industry during the twenty year period from 1941 to 1961 exhibited: 1) continuous operation without transfers between companies of the majority of plants, 2) increased market share relative to natural and reclaimed rubber, and 3) stable growth of all sectors (excluding thiokol which terminated in 1943) and the addition of two new technologies (after 1955).

## 2. Goal Formulation

Goals and program planning were evolved throughout the history of the synthetic rubber program. Occasionally general goals were set, merely articulating the problems perceived at the time. At other times specific goals were set, providing definite production targets and guidelines for judging program success. In 1940, the first initiative to build synthetic rubber plants originated from the Army and Navy Munitions Board. Their concern was focused on national security, not consumer interests, and on anticipated, not current, needs. They wanted plants in part for the output of synthetic rubber, in part as models for future construction needs. The plants' usefulness was based not on current conditions but grimly forecasted future conditions of war: "Some characterized it in 1940 as a 'battleship policy';

since battleships serve no purpose in peacetime, but cannot be done without in war."<sup>11</sup>

Goals were fomulated prior to real needs. In fact, the investments in synthetic rubber were not justified under current supply conditions (i.e.,

1940). Their value was judged within the worst possible scenario of events (perhaps vaguely comparable to a complete Arab oil embargo today of the U.S.). Significantly, questions raised then about synthetic rubber resemble questions about synthetic fuels today:

- 1) What types of rubber to produce?
- 2) What size of production units?
- 3) What kinds of plants most easily implemented?
- 4) What uncertainties in patents?
- 5) What about obsolescence of plants?
- 6) What effects of public efforts on private investments?

The Baruch Committee, a high priority and carefully selected committee, filed a report in September, 1942, which had a strong impact.<sup>12</sup> They first defined the nature of the rubber shortage--not enough rubber in absolute terms, and not enough at the right place and right time. Then, after examining all available production, distribution, and conservation techniques, they advocated an integrated plan of 1) construction of synthetic plants, 2) rationing of consumer tires (aided by gasoline rationing), 3) conservation and development of existing natural rubber supplies (expanding the reclamation of rubber and guayule plantations). Efforts were made to integrate and control supply and demand. Third, the committee designated exact target goals for 1) the quantities produced of four types of rubber, 2) the number, sizes, and completion dates of plants, and 3) the standard production techniques. With no goals left indefinite, they established

a firm baseline for measuring production success. Fourth, in order to maximize the likelihood of high levels of outputs, the committee recommended the use of tested (as opposed to experimental) production techniques. Of course, production decision-making was more greatly centralized in Washington during World War II than today.

Decisions were made not on resource prices (many of which were artificially fixed) but on physical constraints. In fact, a simple "gap analysis"--concerned exclusively with physical flows of synthetic and natural rubber--served as the basis for production and allocation decisions. The government controlled prices of input factors (both capital and labor) and products of the rubber industry (and all other major industries). A market analysis--concerned with prices of rubber products, operating and capital costs of competing technologies--was not then made. This type of analysis would have required a large number of adjustments of controlled costs and prices to reflect "real" economic value.

After the war, the following arguments (among others) were presented for protecting the synthetic rubber industry:

- 1) to insure supplies of strategic materials,
- 2) to avoid junking existing plants,
- 3) to promote full employment,
- 4) to lower dependence on foreign supplies potentially subject to monopoly control, and
- 5) to achieve stable prices through an increased domestic supply.

These arguments were open to great debate, dependent on different interpretations of postwar rubber (natural and synthetic) market conditions. Some of these arguments bear striking resemblance to current arguments in favor of Project Independence.

In evaluating the validity of the arguments, one needs first to look at the actual (very small) and anticipated (rather large) differences in synthetic and natural rubber production costs. (The difficulty of determining costs for synthetic rubber will be discussed later). What premium should domestic and military users have paid for the assurance of synthetic supplies? Second, one needs to examine the financing of plant reconversions from military to civilian production. Was there a "sunk cost fallacy" in attempting to maintain plants with a negative net social value? Third, the impacts of regional unemployment seemed to affect national production planning. Who should have borne the burden of labor displacements in closing plants? Fourth, there seemed little concrete evidence of a strong foreign cartel building in the late 1940's. The U.S. was in an extraordinarily dominant position in world trade (with a highly favorable balance of payments). Subsidizing inefficient synthetic rubber only slightly benefited rubber consumers, but did so at a cost to both American taxpayers and foreign producers.

### 3. Implementation

Inherent in any government program of 15 years' duration are evolving plans and organizations to execute those plans. The Baruch Committee in 1942 set definite goals for implementing the construction of synthetic rubber plants, which had lagged behind schedule in the past year.<sup>13</sup> The Truman Committee in the same year sharply criticized the initial pilot construction of four 2,500 long-ton capacity plants (later increased to 10,000 for the "Big 4" rubber companies (Goodyear, Goodrich, Firestone, and U.S. Rubber)): "Lack of unified responsibility resulted in a failure to meet situations as they arose with the resultant failure to set a



definitive goal at an early date, failure to provide adequately for production of new materials, and failure to transform engineering plans into construction jobs.<sup>14</sup>

There were three separate government boards responsible for plant construction in 1941: the Production Management Board (later the War Production Board), the Reconstruction Finance Corporation, and the Office of the Petroleum Coordinator. The Baruch Committee, however, recommended the establishment of a single agency--to be accountable for all supply and demand decisions related to natural and synthetic rubber.

The rubber "czar" William Jeffers faced few technological problems, but rather processing problems of putting equipment from various sources together. There was general agreement that companies were sharing information after the patent agreements of 1941 and 1942: "In fact the companies that know the methods to be adopted are cooperating wholeheartedly in the assistance to getting together information so that it can be generally given to the industry for whatever it can produce."<sup>15</sup>

However, careful examination of Table 1 will reveal important distinctions between targeted goals and actual capacity in 1944. The thiokol rubber production facility was completely curtailed in 1943. Actual U.S. Buna-S capacity in 1944 was 705,000 long tons as compared to 845,000 planned. The vast majority of butadiene in 1943 and 1944 was produced from alcohol plants--operating at twice the planned capacity--not petroleum plants of larger planned capacity. Certainly in examining completed government programs a bias is introduced if one overlooks risks perceived at the time

TABLE 1

INTENDED AND ACTUAL 1944 U.S. ANNUAL PRODUCTION CAPACITIES

## SYNTHETIC RUBBER (long tons)

	INTENDED BY BARUCH REPORT	ACTUAL 1944
BUNA-S	845,000	705,000
BUTYL	132,000	68,000
NEOPRENE	69,000	63,000
THIOKOL	60,000	---
TOTAL	1,106,000	836,000

## BUTADIENE (short tons)

	INTENDED BY BARUCH REPORT	ACTUAL 1944
1) FROM GRAIN OR ALCOHOL	247,000	230,000
2) FROM BUTANE	60,000	75,000
3) FROM BUTYLENE	250,000	250,000
4) FROM NAPHTHA	125,000	37,000
5) FROM 3 AND 4	85,000	55,000
6) FROM NATURAL GAS BY ALDOL	----	10,000
TOTAL	767,000	657,600

and ignores differences in the success of programs at different times. One might agree with Robert Solo in his assessment that the synthetic rubber program failed to produce adequate quantities of materials in the single war year 1943.<sup>16</sup>

As a general pattern, government investments in expanded production were based on the following considerations: 1) the probable adaptability of the final product as a replacement of scarce products, and 2) the state of development and industrial timetables of needs, and 3) estimated construction time of plants.<sup>17</sup> J.H. Krug, Director of the U.S. War Production Board, outlined general principles for government control of production under the operation of private firms: 1) the power to contract is equivalent to the power to control; 2) simple controls designed within current business practices work most effectively; 3) new accounting systems, distinct from routine private company accounts, ought to be established; 4) authorities for different industries must bargain with each other for scarce resources; and 5) total overall output as opposed to short term, sectional output, should be maximized.<sup>18</sup>

The striking feature of the postwar operations of the synthetic rubber industry was the nine year lag from 1945 until 1954 in implementing the disposal of the majority of plants. The Inter-Agency Policy Committee on Rubber executed a series of small plant sales from 1946 to 1949, without a strong commitment to a particular future structure of the sectors of the synthetic rubber industry. After the Rubber Act of 1948 established the firm policy of disposal of plants, there were two delays in 1949 and 1952 (caused by increased military demands for the Korean War) before actual disposal in 1954. The Steelman Report of 1950, prepared by the Assistant to

the President for the Congress, suggested financing schemes, bid solicitation procedures, and guidelines for the market structure of future synthetic rubber markets. None of these were adopted by the Rubber Facilities Disposal Commission.

#### 4. Financing Schemes and Cost Accounting Procedures

The government did a minimum of experimentation with alternative financing schemes and cost accounting procedures within the rubber program. During most of the war, prices did not operate to equate supply and demand in markets for raw materials, physical capital and labor. The productive resources were allocated to meet centrally determined production quotas. According to J.A. Krug of the War Production Board:

Over a large area of production, the decision as to what should be produced, who should produce it and to whom it could be sold were government decisions. Prices and wages were controlled by government and government helped guide the movement of labor from plant to plant, from industry to industry, and from region to region. <sup>19</sup>

Without doubt the social value of scarce resources vastly exceeded their market prices. In particular, synthetic rubber had a value in 1943 far in excess of its nominal price. Further, the investment in the construction of rubber plants and in their operation had extremely high opportunity costs in production foregone elsewhere.

There appeared to be virtually no debate in 1941 to 1942 about the government paying the full cost of constructing and operating all but a very few specialized plants (neoprene and styrene which were previously constructed). Either there were no perceived profit opportunities for private firms in synthetic rubber production or the opportunities were dominated by the cost plus fixed-fee operating contracts of the government. The steel in-

dustry would provide potentially a better example than the synthetic rubber industry of shared public and private financing.

In 1944, the Office of the Rubber Director reported on the costs of individual plants.<sup>20</sup> Despite the elaborateness of the breakdown of investment and operation costs, one can derive little relevant information concerning real comparative costs (measured in social values, not nominal prices) of different processes and different companies using the same processes. A variety of tables, based on different input prices, were also calculated to estimate expected postwar production costs. These tables estimate only out-of-pocket costs without depreciation, sales expense, profits, or interest on investments. In the 1950 Steelman Report profit and loss statements for average plants (similar to those for a private firm) were estimated (assuming 10% annual depreciation and 1 7/8% interest).<sup>21</sup> Again these figures supply very little useful information, especially without the accounts (not readily available) of the private operating firms. Interestingly, the profit and loss statements were formulated to approximate those of privately owned synthetic rubber plants under competitive market conditions. However, the rubber at this time had government price setting, output setting, specification requirements, and guaranteed sales levels (all of these regulations were not actually binding restraints). Further, the accounts do not include royalty charges, research and development expenses, sales and distributive costs and profits.

The Steelman Report did, however, suggest imaginative financial incentive schemes to attract small firms to purchase plants at disposal. The actual purchase arrangements in 1954, full cash payments or 25% cash downpayment with 10% annual equal payments, did not include the following innovative plans suggested four years previously: 1) installment payments

with unlimited walkout privileges, 2) functional payments adjusted to percentage capacity at which plants operated, 3) price discrimination for selling prices, and 4) combinations of flexible credit, low interest rates, and small down payments.<sup>22</sup>

5. Incentive Schemes to Encourage Operating Efficiency and Sale of Plants

As indicated in the section on financial incentive schemes, directors of the synthetic rubber program were less than imaginative in implementing incentive programs for efficient management of plants by the private operating firms. During World War II, there was little discussion of government-imposed devices to explicitly motivate private firms to minimize costs. All government raw materials and capital equipment were distributed under very tight control. Presumably given the scarcity of resources and the unambiguously enthusiastic ideological support of the war might have been expected not to intentionally pad costs or falsify output records.

However, after the war, writers have to search much harder for incentives for operators of plants to minimize costs and direct efforts to the most effective goals. Robert Solo, a commentator on the synthetic rubber industry, suggested two self-regulatory motives for operating companies after the war: 1) they would as a matter of pride want their costs to equal other operators', and 2) they would presume subsequent purchase of their (hopefully efficient) plants.<sup>23</sup> It seems hard to imagine how these incentives might have been compelling. In comparison, the incentives to maintain government ownership of plants were also powerful: 1) the operating contracts were profitable to certain (or all) companies, and 2) government ownership pre-

vented a change in the market shares of firms in different sectors of the synthetic rubber industry.

In the Steelman Report of 1950, a lengthy list of alternatives was considered to insure adequate levels of consumption of synthetic rubber after the disposal of government-owned plants.<sup>24</sup> The Report identified the following interested parties in government decisions affecting the synthetic rubber markets: 1) raw material suppliers (mostly petroleum after 1944) for synthetic rubber, 2) producers of synthetic rubber (four kinds), 3) natural rubber suppliers, 4) manufacturers of rubber final goods, 5) consumers of rubber final goods, and 6) general taxpayers. The report considered seriously several alternatives with benefits and costs to several groups. First, a tariff on imports of natural rubber would increase synthetic rubber consumption. However, the tariff would need frequent revision to adjust synthetic rubber prices to changing natural prices (given the history of fluctuating natural rubber prices). Also, consumers and natural rubber producers would be forced to bear the full burden of costs. Second, mandatory purchase of quantities of synthetic rubber by manufacturers of final rubber products would guarantee consumption levels. Presumably this plan could result (if it were effective) in a two-tiered market for each of the four types of synthetic rubber--with one price for mandatory purchases of synthetic rubber, and a second (lower) price for rubber redistributed among the final goods firms. Third, the government could make specifications for the mix of natural and synthetic rubber in particular rubber products. This plan would demand the most direct control by the government (and the most complicated enforcement) and would potentially produce undesirable shifts in product lines. Fourth, subsidies could be

paid directly to synthetic rubber producers, to the benefits of consumers and the cost of taxpayers.

The government decided in the period from 1945 to 1955 1) to maintain ownership of the plants, 2) to control prices of synthetic rubber (which stayed below natural rubber prices for the most part), 3) to guarantee minimum levels of purchases of synthetic rubber, and 4) to specify minimum ratios of synthetics to natural rubber in certain products. Notably the latter two government controls proved to be unnecessary in maintaining synthetic rubber production. These multiple controls, in a market dominated by government ownership, prevented a clear assessment of "real costs" for synthetic rubber and final rubber goods. Significantly, government interventions into private synthetic rubber market were curtailed after the disposal of plants in 1954.

#### 6. Patent Arrangements and Research and Development Programs

Throughout the fifteen year period of active government participation in the synthetic rubber industry (from 1941-1955), there was substantial debate about the handling of patent exchanges between operating firms, and on the best designs for government supported research and development. The Steelman report outlined the usual government procedures (not followed in 1941) to examine patents before supporting a new industry: 1) extensive searches are conducted for all patents relevant to operations, 2) validity of application of patents are checked, 3) operations are examined to determine whether they impinge on patents, and 4) separate licenses are negotiated for the operation of each plant.<sup>25</sup>



Instead, the government in 1941 called together all U.S. companies which were presumed to have knowledge of relevant production processes. One firm, Standard Oil of New Jersey, had acquired the U.S. patent rights for Buna-S, Buna-N (a general purpose rubber not developed commercially until the mid-1950's) and Butyl rubber in 1939 from the German firm I.G. Farben (in exchange for petroleum processing patents). Thurman Arnold of the Justice Department, one of many Standard Oil's critics, brought suit against the firm for cartel arrangement with I.G. Farben to divide international markets. The Truman Committee, a Congressional Committee investigating synthetic rubber, in 1942 identified the issue of divergence between a private firm's objective function (profit maximization of market values) and the national objective function (to maximize immediate synthetic rubber production):

It suffices that the record indicates the possibility that in important areas of international business relationships and/or basic industrial decision-making, there have been in this instance, and that there might be general divergences between the legitimate commercial criterion of business action and the interests of national security and survival.<sup>26</sup>

Certainly in 1941 Standard Oil possessed the patents, technology, research, and funds to initiate on a large scale production of synthetic rubber (in particular Buna-S and Butyl). Instead of pursuing an immediate profit opportunity--investing in production facilities--they threatened a suit against Goodrich and Goodyear in 1941 (which intended to produce synthetic rubber) to preserve a future profit opportunity. Again the Truman Committee identified these actions as in restraint of production: "Standard is only one of a group of companies producing critical materials which,

by cartel agreements and by the subsequent control of patents, have sought to restrict and control production."

Beginning in 1941, the government, through the Rubber Reserve Company, brought companies together to arrange patent exchange agreements. Generally, the agreements (signed in 1941 and 1942) paid small royalties to firms previously possessing patent rights, but required the pooling of all new patents until 1948. The exact contracts varied across sectors of the synthetic rubber industry.

The Baruch Committee set two not entirely harmonious goals for maximum flow of information among firms and maximum competition in research and development advances.<sup>27</sup> With a free flow of information, firms would not be able--in an exclusive sense--to capitalize their research gains into new operating techniques. Particularly in the postwar period, firms with cost-plus-fixed-fee unit operating contracts had no incentives to reduce costs (and perhaps disincentives in order to maintain management fees). There was no reason for these firms to necessarily share the national objectives of increased U.S. independence in rubber supplies and increased competitiveness of synthetic rubber products. In fact, Robert Solo argued persuasively for a government bureaucrat, accountable for achieving those national objectives, to manage the research and development programs: "It is the lesson that any research and development program must be directed and run by a technically competent and responsible authority who stands accountable for the results, and whose position and reputation and/or monetary reward depend directly on the failure or success of that program."<sup>28</sup>

To judge the performance of government supported R&D, one must look at the entire portfolio of investments. From 1940 to 1949 the government

invested \$23 million in R&D -- \$2 million to research institutes, \$7.5 million to universities, and \$13 to private firms. Again Robert Solo argued that in the period from 1948 (after the end of patent pooling except for government sponsored R&D) to 1954 (at the disposal of plants) major technical innovations were achieved by a small number of firms not on government research grants. Specifically, private research led to developments in cold resistant butyl, cold rubber processing, and black master batch. The success of these projects coincided with the commercial self-interests of the companies. Particularly in an industry dominated by government-owned plants, operators cannot be expected to generate innovations whose rewards they cannot internalize.

7. The Competitive Environments and Market Structures of the Industrial Sectors

During World War II, the industrial environment surrounding synthetic rubber production was characterized by emergency government controls. Related industries were closely regulated by the government and the government owned a horizontally and in part vertically integrated group of synthetic rubber production plants (although it did not own suppliers of raw materials or final product plants).

Soon after the war, however, economic conditions changed, which could potentially have allowed the transfer of plants to private ownership. Despite the considerable funds already invested by the government in plant and equipment, potential private purchasers of existing (or future) plants were faced with important sources of uncertainty.

In the late 1940's the state of technology in Buna-S (general purpose) rubber allowed it to substitute for natural rubber (or a mixture with it)

in most products. Neoprene and butyl had specialized uses, in which they were actually superior to natural rubber. However, the costs of producing these products (barring a technical breakthrough) and the prices at which their sales were set, could be expected to exceed natural rubber prices (which were rumored to drop to \$ .10/lb.).

In fact, the demand for Buna-S rubber for general use could have decreased drastically, if a price gap formed between cheap natural rubber and more expensive synthetic. The second area of uncertainty concerned the government's actions in the future synthetic rubber market. In particular, would the government continue to insure profitable operation of plants it no longer owned? Would the removal of guaranteed levels of purchases of different types of synthetic (buna-S, neoprene and butyl) rubber, on one hand, cause large stockpile of certain types to form, or, on the other hand, reduce the number of producers, such that production might not meet future national security needs? As it happened plants providing 25% of the 1945 production capacity were sold to their respective operating companies, and continued to produce (presumably quite profitably with strong demand for their products) at high levels. With price setting, patent pooling, and specification requirements, there were no shocks to the operation or changes in the structure of the synthetic rubber markets resulting from the transfers of plants to private ownership before 1954.

The Disposal Committee had a pair of criteria in establishing private competitive markets in the synthetic rubber sectors in 1954:

That the disposal program be designed best to afford small business enterprises and users, other than the purchaser of a facility, the opportunity to obtain a fair share of the end products of the facilities sold and at fair prices;

That the recommended sales shall provide for the development within the United States of a free, competitive, synthetic rubber industry, and do not permit any person to possess unreasonable control over the manufacture of synthetic rubber or its component materials.<sup>29</sup>

Within these criteria, the Disposal Committee achieved a variety of sectoral solutions: the two butyl plants were both sold to Standard Oil of New Jersey (the current operator) without alternative bids offered. In a lame attempt to promote competition, the committee included in one contract the option to require the sale of one plant after three years if a bidder arose. The lone styrene plant (12% of the industry capacity) had numerous bidders and was sold to Shell Oil Company, also the purchaser of buna-S and butadiene plants at the same location in California. The non-operating alcohol butadiene plant was sold at a nominal price to a single bidder.

The critical market structure of decisions occurred in the petroleum butadiene and buna-S sectors. Five of the eight plants sold in each sector were purchased by single companies in pairs of butadiene and buna-S plants. These firms had a competitive advantage in vertically integrating the two processes. In the petroleum butadiene sector almost half the production capacity was purchased by a pair of integrated oil companies (Goodrich-Gulf and Texas-U.S. Chemical). In the buna-S sector the "Big 4" rubber companies also purchased about 50% of the capacity.

Clearly the Disposal Committee made some compromises and some default decisions (due to no bidders) in tolerating the vertical integration of raw materials suppliers, synthetic rubber producers, and rubber manufacturers. The Disposal Committee also traded competitive structures which might have offered long-term benefits to consumers for receipts of sale (from a limited number of bidders) of immediate benefit to taxpayers.

## 8. Conclusions

Certain quite general lessons from the synthetic rubber experience are applicable to today's energy commercialization projects. First, decisions have impacts over a much longer period than the planning horizons within which they are made. There is remarkable stability in the structure of the rubber industry in the twenty year period from 1941 to 1961. This stability resulted largely from the favorable coincidence of the goal of maximizing synthetic rubber production during World War II and the long-term goal of establishing a permanent post-war industry. The single criterion (derived from "gap analysis") of production levels can be applied to the war-time rubber program. Did physical production meet in an absolute sense emergency needs? Yes it did, although it lagged behind intended output. The post-war government support of the synthetic rubber industry offers greater difficulties to analysts of benefits and costs. Despite the numerous records of nominal investment and operative costs, one cannot determine definitely the net economic benefits of the program even with the best estimates of "real values" on inputs and outputs. Further, the synthetic rubber program does not offer evidence as to comparative costs of production between government and privately owned plants. Measures of effectiveness of private operators and government directors are difficult to establish.

Second, an industry is really a combination of separate sectors. Overall goals should be set and programs coordinated in separate sectors. During World War II there were primarily logistical problems of coordinating production under emergency conditions. General lessons derived from this experience concerning the implementation of a program might include: 1) the usefulness of exact production targets, construction deadlines, and

scheduling of inputs; 2) the need for an assertive single overseer of production, distribution, and conservation of a product; and 3) the necessity of well controlled information processing systems (today supported by computers) to file accurate individual reports from companies.

After the war, problems focused about the application of controls and supports to separate sectors of the industry. In order to be effective, price controls, guarantees of purchases, and material mix specifications required detailed knowledge of all stages of the production process. This type of government intervention into the market must be flexible enough to respond to new market conditions--in particular, to changes in prices of substitute raw materials and alternative technical processes. Certainly the cost-plus-fixed-fee financial arrangement for operating firms offers (without other controls) no built-in incentives to lower costs. There was, in fact, some evidence in the early 1950's that government-supported research and development was less effective than private efforts. Again certain lessons are evident. The weakness of government-supported R&D is most likely not in basic research, but in implementation techniques of research discoveries. There is no strong substitute for the market mechanism in allocating resources to different research projects. The government direction of R&D must have a clear concept of national objectives and must transmit target expectations to contracted researchers (in particular private firms with different incentives) which will meet these objectives.

Third, the relative mix of government and private efforts in an initially government-supported industry must evolve over time with changing economic conditions. Although the synthetic rubber program had frightfully little lead time in developing replacement supplies for natural rubber, the program

had an extremely lengthy lag time in disposing of plants and establishing a privately owned and operated industry. One might account for the delay in plant disposal from 1941 until 1954 in several ways: 1) the program was justified in part to insure national security, the value of which does not easily translate into nominal costs and benefits, and specific criteria for program design; 2) inertia built up among special interest groups, which benefited from the government's on-going expenditures--the operating contracts must have been profitable; 3) there was evidence of proprietary knowledge on the part of individual operating firms about their plants--precluding competition from other firms for purchase of these plants. Perhaps the dominant lesson from the synthetic rubber experience might be the difficulty of effecting a transition from government ownership of plants to private ownership. The synthetic rubber program offers only examples of 1) multiple government controls in non-competitive markets (1941-1954), and 2) virtually no controls in privately established (relatively competitive) markets (post 1954). Energy planners must look elsewhere for examples of government and privately owned firms competing in relatively less controlled markets.

Finally, the crucial difference between government support for commercialization of new technologies under conditions of wartime and peace must be emphasized. During World War II our economy bordered on being centrally planned. Needs for rubber were calculated at levels necessary to support production of necessary industrial material, and strong measures were taken to restrict consumption of rubber by consumers. While managers attempted to run the program at minimum cost, cost considerations were strictly secondary to meeting targeted needs. The Japanese cut-off, combined with the defense build-up, had produced a "gap" which had to be filled. The situation today is very different. New energy technologies must ultimately compete in



a marketplace on the basis of their economics. While the government may influence this economics, with taxes or subsidies, it seems unlikely that physical constraints (analogous to the requirements for minimum synthetic/natural rubber ratios in inputs to industrial processes) will be used. Nor will the government buy at any price in order to fill a gap. Thus, new energy technologies must be carefully evaluated to see whether, in the expected economic environment of the future, they will be competitive. The sense of urgency in World War II overrode the economics, the "energy crisis" does not seem to have that power. Therefore, at its core, the widely cited analogy between government-supported programs for synthetic rubber and synthetic fuels does not apply.

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