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FIBERS AS RENEWABLE RESOURCES FOR INDUSTRIAL MATERIALS

Prepared by the Panel on Fibers
as a background paper for the

Committee on Renewable Resources for Industrial Materials
Board on Agriculture and Renewable Resources
Commission on Natural Resources
National Research Council

National Academy of Sciences
Washington, D.C. 1976

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RENEWABLE RESOURCES FOR INDUSTRIAL MATERIALS

Fibers as Renewable Resources for Industrial Materials

A Panel Report for

the Committee on Renewable Resources for Industrial Materials
Board on Agriculture and Renewable Resources
Commission on Natural Resources
National Research Council

Prepared by an ad hoc advisory panel as a background paper for consideration of the Committee on Renewable Resources for Industrial Materials. The information in this Report was reviewed by the Committee and was incorporated in part in the recommendations and discussions in its Report "Renewable Resources For Industrial Materials." This Report does not necessarily reflect the Committee's opinions nor those of the National Academy of Sciences/National Research Council.

National Academy of Sciences
Washington, D.C. 1976

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Edwin C. Jahn
Chairman, Panel III
CORRIM

FOREWORD

Potential problems from changes in patterns of materials supply or utilization are causing concern, with the current emphasis being on mineral or nonrenewable resources. The Science and Technology Policy Office (STPO) in support of Dr. H. Guyford Stever, the Science Advisor to the President, requested the National Academy of Sciences (NAS) to reexamine the role of renewable resources, as the other major component of natural resources, in helping to better meet needs for materials in the future. Important factors to be taken into account in assessing the desirable balanace between these different classes of resources for materials are 1) the increasing variety of technological options available for choice of material for a required performance in a given application, and 2) the increasing concern to minimize both consumption of energy and environmental impact. In addition, the usual economic factors apply in the utilization of materials.

While the concept of renewable resources is useful, it still lacks the coherence of statistical information on resources and use, and the scientific perspective that has developed for "materials from minerals" (including metals, ceramics, electronic solids and synthetic organic polymers derived from fossil fuels). Strong specialization exists in forest sciences and wood products on the one hand, and agricultural sciences and associated natural materials (fibers, leathers, etc.) on the other. A broader view is required of the science and technology of natural products and, correspondingly, integrated statistical information on resources, materials flows and utilization (including associated energy and environmental aspects).

The above considerations led to this analysis of renewable materials in the United States economy as a basis for identifying both the optimum use of such resources and the role of science and technology in helping overcome barriers to their use. The following are the principal items adressed in the study at the request of the Science and Technology Policy Office:

1. Quantitative analysis of current materials flows for renewable resources as the basis for assessing the impact of potential future changes (compared with nonrenewable flows). Definition of the limitations (cost and technical) of renewable resources for meeting expanded demands for materials based on them. Delineation of the energy, environmental and social consequences of such increases. International aspects.

2. Interchangeability of renewable and nonrenewable resources as the basis for materials.

3. Assessment (stocktaking of quantity and quality of R&D currently supported in the area of renewable resources by (a) the Federal Government and (b) industry. Evaluation of the relationship of these activities to the size of the industry and its role in the economy. Assessment of changes in scale and emphasis needed to meet future changes.

4. An evaluation of relevant federal, state and local legislation and regulations that influence the effectiveness of the development and utilization of renewable resources.

5. Improvement in materials properties and performance.

6. Improvement in the yield of raw materials and in the efficiency of processing.

7. The potential of renewable resources as "feedstock" for synthetic materials, (a) cellulose based and (b) converted to products (such as ethylene), that can be used to supplement or replace the petrochemical supply used currently for synthetic polymer production.

8. Consideration of the energy and environmental characteristics associated with the implementation of research from the above 3 categories, including the question of water supply and alternative land use.

A Committee on Renewable Resources for Industrial Materials (CORRIM) was established by the Board on Agriculture and Renewable Resources (BARR), under the Commission on Natural Resources of the National Research Council, to undertake an analysis of renewable resources in the United States, identify the optimum production and use of such resources, and look at the role of science and technology in increasing their production and use. The training of manpower in renewable resource fields was not addressed in this study, since other specific studies in education had been proposed by the BARR.

This report - Fibers as Renewable Resources for Industrial Materials - was prepared by a special panel of the Committee on Renewable Resources for Industrial Materials, as background material for the preparation of the main report.

FIBERS AS A RENEWABLE RESOURCE
FOR INDUSTRIAL MATERIALS

CONTENTS

INTRODUCTION

Collectively, the natural fibers provide a major renewable resource for American industry and the national economy. The fiber-based industries form one of the largest industrial groups in the country and their health directly affects the national economy through employment, new capital investment, support of chemical and machinery suppliers and other allied industries, transportation, and export of products. Both cotton and forest products contribute significantly to the national balance of trade. The pulp and paper industry alone accounts for about 3 1/2 million carload shipments a year by rail, with a revenue to the railroads of $847 million, not including inbound shipments of chemicals and other materials used in processing wood fiber.

At no time in our history has there been a greater need to expand and improve the nation's renewable fiber resources. Increasing worldwide population and improved education and living standards in many countries will result in increased consumer demand for paper, paper board and textile products.

To maintain the operation of these renewable resource industries will require sound management, strong R&D activity, and effective governmental incentives. Careful examination and recognition of the many factors which can perturb operations and production are necessary. These include such obvious factors as energy, technological advances, substitution opportunities and governmental regulatory and policy incentives. An example of the latter is the 1944 tax incentives for sustained forest management through capital gain treatment, that resulted in a dramatic increase in timber growing and reforestation on private lands.

In addition to these more readily recognizable factors, there are many other forces that mold the fiber-based industries that are less well recognized and more pervasive. These not only affect industry but society as a whole and should be identified and understood where possible. We live in a setting in which there is an accelerating rate of change. This we sense as a ubiquitous display of tensions across organizations, cultures, nations and the biosphere. Forces generating these tensions are mostly derived from the scientific revolution and are powered by the productivity and mobility of information, commodities and technology. These currents probably cannot be stemmed to any extent, but may be exploited through understanding. Enlightenment may improve judgment values and influence trend directions affecting society, technology, economics and political developments.

Prominent among these forces are new concepts and the recognition of "new" realities including:

1) the global village concept versus nationalism
2) human dependency upon the environment and the fragility of this relationship
3) technological growth
4) population growth
5) need for conservation and wise management of resources
6) energy shortages
7) diminishing growth rates in established industrial countries versus upsurge in others
8) increased sharing of the world's resources by the present affluent countries with emerging industrial countries
9) problems in solving social and political tensions
10) changes in social values and attitudes
11) the realization that the decreasing diversity in nature's organisms could lead to potential disasters in food supply and to instability in the human position as well, calling for reassessment and restatement of political, ethical and philosophical dictums, and
12) others.

The forces of change and the resultant tensions have brought forth a host of problems, including a deteriorating environment, urban declines, inadequate housing, increasing crime and drug addiction, mass transportation needs, energy shortages, shifts in sources and control of vital raw materials (petroleum, natural gas and minerals), changes in productivity and supply of labor, monetary and trade balance problems, political and military threats, health, education, and others. Technical priorities need to be reviewed and directed to meet the demands caused by these societal changes. Up to now our priorities have held relatively stable and too little effort has been directed toward the creation of new technologies.

Certain trends are already indicated for industry and society as a whole in North America and may be expected to grow in the future. These include:

1) dramatic changes in import-export patterns--less so for industries based on renewable resources than

for others
2) husbanding of internal resources and extensive recycling of waste materials
3) more frugal living habits
4) population growth adjustments
5) strong attention to environmental and ecological matters, including antipollution measures, food chains and direct and indirect conversion of solar energy to commodities
6) economic dislocations, rising costs and adjustments towards a near equilibrium state
7) increasing international cooperation through associations, agreements and mergers--hence greater language capability requirements, and
8) strong emphasis on new technologies in the form of new systems for the production of basic commodities, including nuclear and other forms of power.

Faced with the knowledge of the forces shaping our society and the tensions and problems created, we must not only determine trends and projections for the future, but derive from them a plan of strategy. Reliability of information is the key and accuracy and impartiality of interpretation are essential for transformation into equitable and practical decisions and actions.

Materials flow systems in the form of charts have been developed for each major industry and are shown in the respective sections of this report. In addition, simplified flow trajectories were also developed for the renewable resource processes. These are: (A) paper and paperboard, (B) cotton textiles, (C) cellulosics, (D) wool and mohair, and (E) feathers, furs and leather. These trajectories are presented on the following pages.

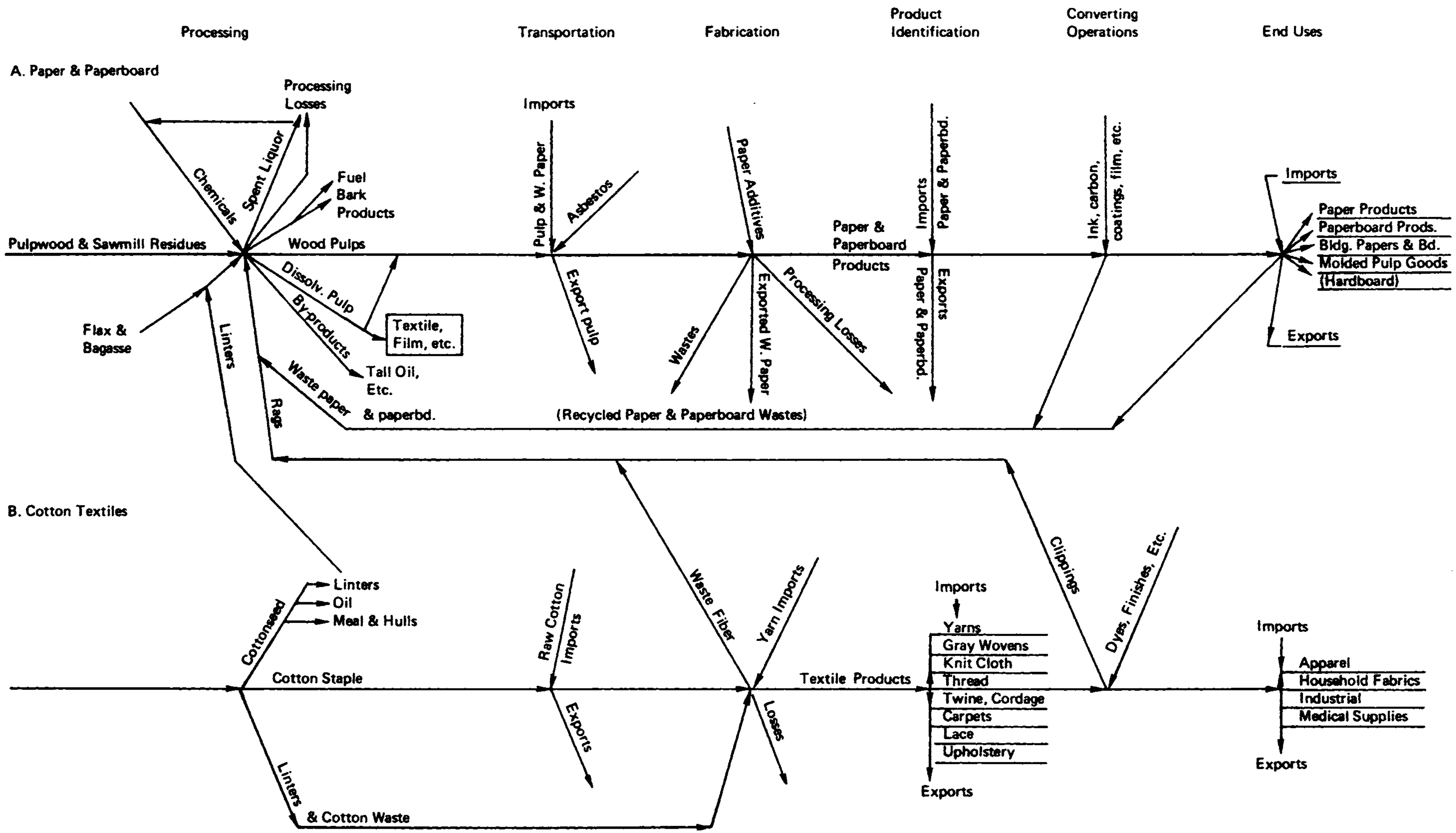
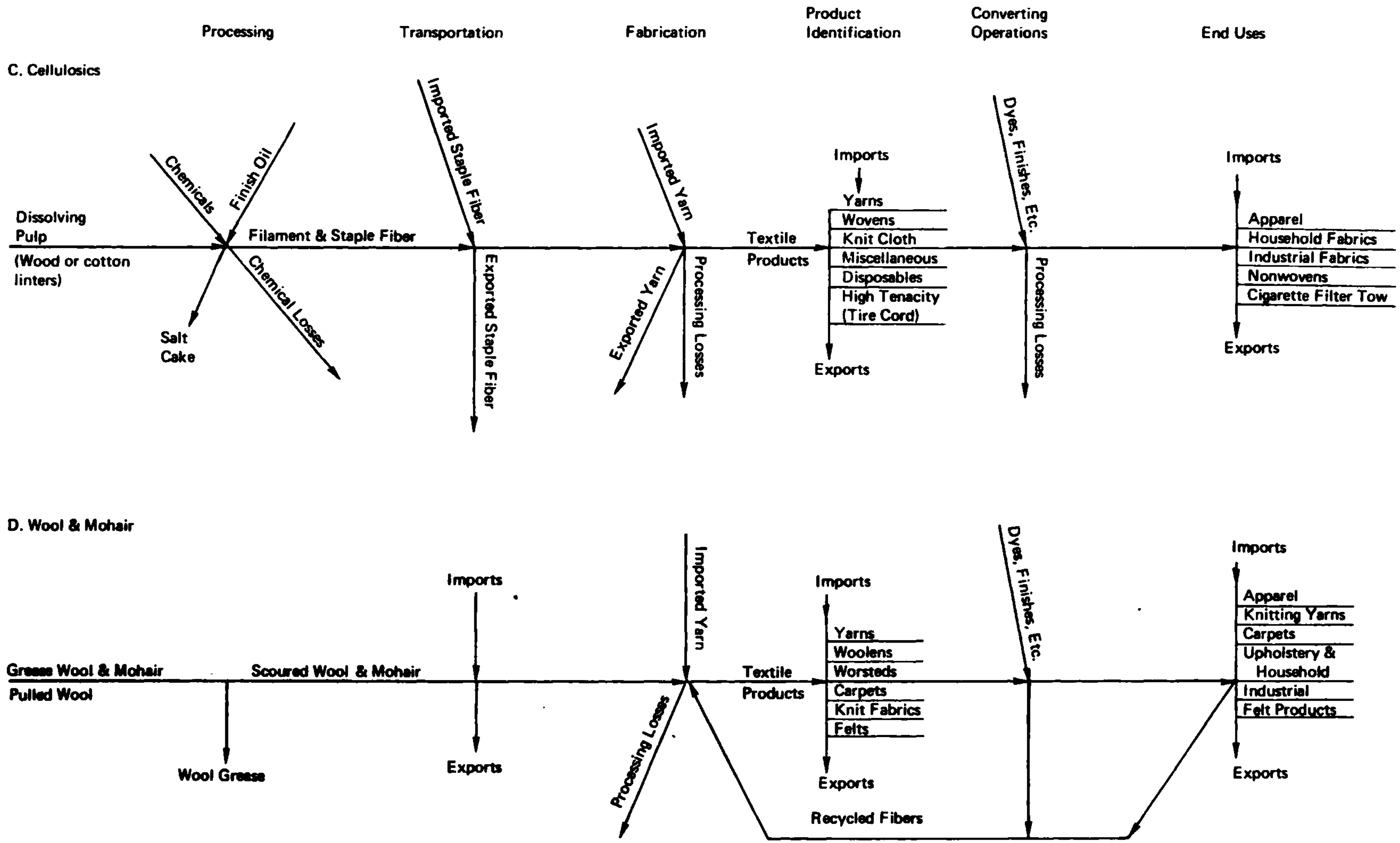
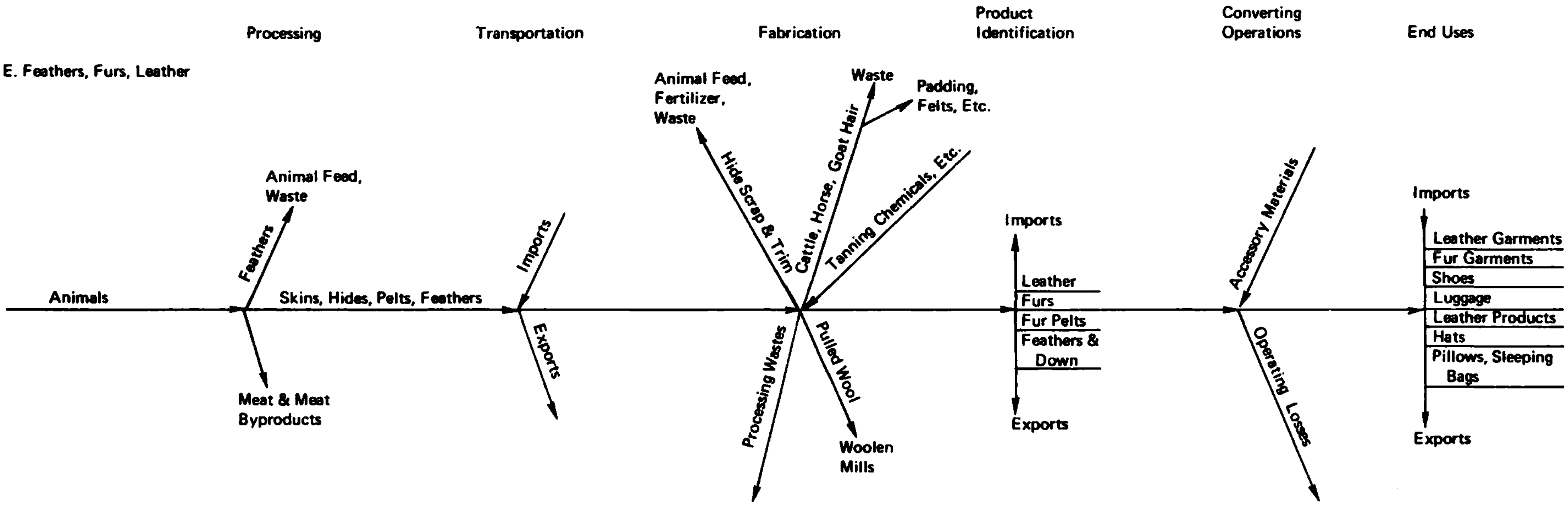


FIGURE 1 SIMPLIFIED FLOW TRAJECTORIES—FIBERS


Processing
Transportation
Fabrication
Product Identification
Converting Operations
End Uses
C. Cellulosics
Dissolving Pulp
(Wood or cotton linters)
Chemicals
Finish Oil
Filament & Staple Fiber
Chemical Losses
Salt Cake
Imported Staple Fiber
Exported Staple Fiber
Imported Yarn
Exported Yarn
Processing Losses
Textile Products
Imports
Yarns
Wovens
Knit Cloth
Miscellaneous
Disposables
High Tenacity (Tire Cord)
Exports
Dyes, Finishes, Etc.
Processing Losses
Imports
Apparel
Household Fabrics
Industrial Fabrics
Nonwovens
Cigarette Filter Tow
Exports
D. Wool & Mohair
Grease Wool & Mohair
Pulled Wool
Wool Grease
Scoured Wool & Mohair
Imports
Exports
Imported Yarn
Processing Losses
Textile Products
Imports
Yarns
Woolens
Worsteds
Carpets
Knit Fabrics
Felts
Exports
Recycled Fibers
Dyes, Finishes, Etc.
Imports
Apparel
Knitting Yarns
Carpets
Upholstery & Household
Industrial
Felt Products
Exports

E. Feathers, Furs, Leather



SECTION A

THE PULP, PAPER AND PAPERBOARD INDUSTRY

CONTENTS

CONTENTS

Page

SECTION A

THE PULP, PAPER AND PAPERBOARD INDUSTRY

INTRODUCTION

The pulp and paper industry, like the textile industry, is a supplier of basic products to every segment of the population, fulfilling essential societal needs. Through intelligent forest and corporate management and effective research, and with the assistance of sound governmental policies, the industry can continue to meet the demands for its products by society for the decades ahead and probably indefinitely.

This industry is fortunate to be based on a major renewable resource, the forest. The United States paper industry depends upon the forest for about 98 percent of its fiber requirements. With wise management our forests can supply the industry's future needs on a continuous basis. Through integrated operations we are achieving fuller utilization of our forests. Today, about 38 percent of the pulpwood used in the U.S. for the manufacture of pulp comes from forest and manufacturing residues. Other residual fibers are also used, such as linters, rags and bagasse. In addition, about 22 percent of the fiber used for paper and board is recycled fiber. Thus, the industry draws more than one-half of its fiber supply from fibers that, in the past, were mostly discarded or burned.

The federal government--and hence society--has a special interest in forest products, since it is the nation's largest timber holder. This interest cannot stop with the growing of trees but must include optimum use, not only for recreation, watershed protection and wildlife, but for the forest products essential to the nation's and the world's people.

About 94 to 95 percent of the fiber used in the world for paper products comes from the forest and the remainder mainly from other vegetable fiber and is expected to remain so through the year 2000. Yet the world demand for paper and paperboard in 2000 is expected to be 415 million metric tons (Keays 1975) compared to 141 in 1972. On the basis of present forest operations, this will produce a substantial shortfall of fiber by 2000. However, this gap can be more than readily overcome by improved forest operations, more complete use of the tree, use of other species and tapping the resources of the tropical regions.

World trade holds a very large future for the North American pulp and paper industry, according to one of the nation's leading industrialists (Wilson 1975). Various analyses, including the recent paper by Keays (1975), agree that North America will be the primary supplier to the world of pulp, paper and paperboard products in the year 2000. Through improved forest operations, better utilization and improved technology, the U.S. will also continue to supply most of its fiber needs for paper and paperboard products in 2000.

Thus, notwithstanding the anticipated enormous increased demands for its products, the industry can continue to rely upon the forest for its renewable supply of fiber. There is also a very substantial amount of agricultural by-product fiber (over 310 million tons available annually) that can supplement our renewable resources supply of fiber in the future.

By proper forest management and corporate policies, by governmental incentives and by vigorous products research, the threat of any substantial inroads of nonrenewable fibers in the paper and paperboard industry can be avoided. Through products research, paper and paperboard can be combined with other materials to create new products with different properties, thereby extending the use of paper and paperboard. Renewable fibers must earn the right to keep markets.

The paper industry, though dependent in part upon oil and electrical energy, now supplies about 42 percent of its energy needs from its own by-products and wastes. This can probably be increased somewhat to decrease further the dependence of the industry on oil and other forms of purchased energy.

CHAPTER 1

ASSESSMENT OF THE INDUSTRY

REFERENCE MATERIALS SYSTEM AND DATA FOR 1972

Recognized classified paper and paperboard products number into the several hundreds. Therefore, in the materials flow chart and tables these have been grouped into manageable categories whose terminology are officially used by industry and government agencies. The categories in the tables do not always match the available data.

In Table 1, the footnote referring to "3 D sections" uses the Census code, "D," for "data withheld to avoid disclosure of the operations of individual mills." This means that there were three types of pulpwood for which figures were not recorded; hence some additional cords are not included in the 69,085,000 cords reported. This figure is from the 1972 Census of Manufactures (U.S. Department of Commerce 1974). In the American Paper Institutes' (API) 38th Edition of "Wood Pulp and Fiber Statistics" (American Paper Institute 1974), a figure of 71,537,897 cords is given for 1972. This same figure is in the "1973 Annual Current Industrial Reports, Pulp, Paper and Board" of the Bureau of Census (U.S. Department of Commerce 1975). This figure is probably the more nearly correct figure for 1972 and includes the unrecorded cords noted above.

The cord figures include all wood (roundwood, chip and mill residues) calculated as cords; there is no acceptable factor converting cords to weight. A cord of wood weighs from 4000 to 6500 lbs. depending mainly upon species and water content. A rough figure sometimes used is 2-1/2 tons per cord of wood, as purchased, which could contain an average of 50 percent or more water. It is estimated that pulpwood has a solid wood content of 75 to 83 ft^3 per cord and weighs on the average about 30 lbs. per ft^3. Therefore, if we take 80 ft^3 as about average, the weight of the solid, bone-dry wood, excluding bark, in a cord is about 2400 lbs. The wood used for all types of pulps being produced is about 1.5 cords per ton of pulp.

Also in Table 1, the figure of 471,000 tons of nonwood fibers for building paper and board includes 131,000 tons of asbestos fiber. Thus, the total nonwood cellulose fiber is 916,000 tons. These figures are from the 1972 Census of Manufactures (U.S. Department of Commerce 1974). On the Materials Flow Chart (page previous to Table 1) a figure of 892,000 tons is shown for rags and nonwood fiber. This is from the Current Industrial Reports, Pulp, Paper and Board for 1973 (U.S. Department of Commerce 1975), which reported the final 1972 figure for nonwood cellulose fiber.

The materials flow chart and 14 tables present a picture of the pulp, paper and paperboard industry as of 1972 (in some cases only 1971 or 1973 figures were available as indicated) and also a projection to the years 1985 and 2000. Subject matter is indicated in the following titles.

1972 Materials Flow for Renewable Resources - Pulp, Paper and Paperboard (including production, import and export data throughout the activities listed).

TABLE 1. Pulp, Paper and Board Materials Input for 1972
TABLE 2. Dollar Value of Materials Consumed - 1972
TABLE 3. Pulp, Paper and Board, Employment and Salary Data
TABLE 4. Pulp, Paper and Board, 1971 Fuel Data
TABLE 5. Pulp, Paper and Board, 1971 Fuel Ratios
TABLE 6. Pulp, Paper and Board Capital Expenditures and Costs, 1972 and 1973 Reference Data
TABLE 7. Production of Total Paper and Board, Summary for 1972, 1985 and 2000
TABLE 8. Total Paper and Board 1972, New Supply, Exports, Imports, Production
TABLE 9. Total Paper and Board 1985, New Supply, Exports, Imports, Production
TABLE 10. Total Paper and Board 2000, New Supply, Net Imports, Production
TABLE 11. Import-Export Projections, year 2000
TABLE 12. Consumption of Wood Pulp at Paper and Paperboard Mills in 1973
TABLE 13. Consumption of Wood Pulp at Paper and Paperboard Mills in 1985
TABLE 14. Consumption of Wood Pulp at Paper and Paperboard Mills in 2000

The term "New Supply" in Tables 8, 9 and 10 is production plus imports less exports. The figures under the heading "Trend" in these same tables are extrapolations of the past ratios of new supply to real GNP for each of the paper and board grades shown. With some few exceptions (e.g., printing paper grades in 1972-1974 and the entire experience of 1975) these ratios have moved in a smooth and rather readily projectable trend. These trends may be interpreted as a summation of the factors which affect production and consumption of paper products (such as new technology, environmental and other regulatory constraints, economic incentives, energy considerations, competing materials, etc.). Thus, the trend shows the selective position of the use of each grade of paper in the total economy.

The real GNP is a proxy for the market and the trend is a proxy for the relative importance of each grade within its markets. The relative importance is determined by technology, consumer acceptance, the product price versus the price of competitive materials and similar factors.

PROJECTIONS FOR 1985 AND 2000

The long-term forecasts are based on the assumption that the past trends will continue. Perturbations can be computed as changes in the trends for the various reasons and possibilities indicated. For example, the total paper and board factor being used for 1985 is 80,460 tons per $1 billion of real GNP and for 2000 the figure of 76,630 tons per $1 billion of real GNP. As an example of a perturbation, let us suppose that the environmental regulations would restrict the growth of paper so that there was a 10 percent drop in the above ratio to 69,000 tons per $1 billion (year 2000) of real GNP which would change the new supply projection from 153 million tons to 138 million tons. On the other hand, technological analysis may suggest that paper and board will become more important in the future and thereby the trend could be raised accordingly.

It can be seen, therefore, that this study is set up so that the various perturbations can be imposed directly on the trend to determine the new demand figures within the framework of the GNP shown.

Table 7 summarizes the production forecasts for 1985 and 2000 compared with 1972, following the format of column VII of the materials flow chart. Tables 9, 10 and 11 cover new supply, imports, exports and production projections for 1985 and 2000. These form the basis for a projection of data in other columns of the materials flow chart. Table 8 gives the comparable figures for the base year 1972.

The real GNP forecast for 1985 is consistent with the assumption that the economy will return to its long-term trend position of $1.0 trillion (real GNP) in 1980 and then follow 3-3/4 percent per year growth to the 1985 level of $1.2 trillion. After that the trend is projected to grow at

3.5 percent per year to the year 2000. The $2 trillion figure is rounded down slightly from the calculated level.

TABLE 1

PULP, PAPER AND BOARD
MATERIALS INPUT

1972

Standard Industrial Classification		Pulpwood	Wood Pulp	Waste Paper	Inorganic Chemicals inc. Clay & Starch	Non-Wood Fibres
		000 Cords	------------------000 Tons			
2611	Pulp Mills	7,584[1]	--	117	940	231[2]
2612	Paper Mills	26,733	21,190	2,051	5,133	290
2613	Paperboard Mills	33,715[1]	22,438	8,235	2,920	55
2661	Building Paper & Board Mills	1,053	not incl.	1,002	102	471[3]
	Sub Totals	69,085[1]	43,628	11,405	9,095	1,047
	All Pulpwood	71,538[4]				

PRODUCTION TOTALS

All Wood Pulp	44,385-excl. exploded, defibrated and dissolving pulps 46,767-incl. all types wood pulp[4]				
Paper	25,435				
Paperboard	28,670				
Building Paper & Board[5]	(3,444)				
Insulating Board	1,528				
Construction Paper	1,916				
Total Paper and Board[5]	57,549				
Ratios					
Raw Material to Wood Pulp	1.56	--	--		
Raw Material to Total Paper & Board	--	.758	.198	.158	.018
Paper & Board/Total Fibrous Material		.984			

[1]Plus 3 D sections.
[2]Cotton Linters only.
[3]Includes 131,000 tons of asbestos.
[4]From U.S. Department of Commerce (1973) (4).
[5]Excludes hardboard.

Source: American Paper Institute, Economics Department, June 30, 1975, based on 1972 Census of Manufactures, U.S. Department of Commerce (1973).

TABLE 2

DOLLAR VALUE OF MATERIALS CONSUMED - 1972

	Pulp Mills	Paper Mills Ex. Building Paper	Paper-board Mills	Building Paper & Board Mills	Total1/
	-----------------------$ Million			-----------------------	
Pulpwood	207.4	677.1	830.9	22.3	1,737.7
Stumpage Cost	*	6.8	(D)	*	6.8
Chemicals	44.1	205.9	127.8	1.6	379.4
(Chemicals from Misc.)	(69.2)	(323.1)	(200.5)	(2.5)	(595.3)
Purchased Wood Pulp		608.6	33.2	*	641.8
Wastepaper	5.6	125.4	273.8	21.3	426.1
Kaolin & Ball Clay	-	83.0	9.7	2.1	94.8
Starch	-	78.0	17.2	3.3	98.5
Other Materials	7.8	54.8	1.6	19.8	84.0
Miscellaneous**	69.1	1,194.6	532.7	68.3	1,864.7
(Misc. and Other Materials ex. estimated Chemicals)	(7.7)	(926.3)	(333.8)	(85.6)	(1,353.4)
Sub-Totals	334.0	3,034.2	1,826.9	138.7	5,333.8
Not Reported	6.0	0	23.3	10.9	40.2
Total	340.0	3,034.2	1,850.2	149.6	5,374.0
Electricity and Fuels	44.0	452.0	332.0	63.0	891.0
Contract & Resale	0.7	4.3	3.1	6.8	14.9

ADDITIONAL DATA

	Pulp Mills	Paper Mills Ex. Building Paper	Paper-board Mills	Building Paper & Board Mills	Total1/
Payroll (All Employees)	125.1	1,440.3	773.9	116.4	2,455.72/
Value Added by Manufacture	279.5	2,880.3	1,944.9	259.5	5,364.2
Cost of Materials, Fuels, etc.	384.7	3,490.5	2,185.3	219.4	6,279.9
Total Value of Industry Shipments	691.4	6,379.7	4,136.5	467.8	11,675.4
Employees (000)	10.5	130.3	68.2	12.1	221.1

* Not reported separately
** Includes own pulp made at other establishments.

Tonnage data (million tons)	Paper Mills	Paperboard Mills
Own Pulp made at other establishments	2.7	0.3
Purchased Wood Pulp	4.3	0.3
Wood pulp made at same establishments	14.2	21.8
Total	21.2	22.4

1/ Total of figures shown.
2/ Excludes fringes.
(D) Withheld to avoid disclosure.

COST SHEET

PULP, PAPER AND BOARD MILLS - 1972

	Paper Mills	Paperboard Mills	Total Pulp, Paper & Board
	------------------Percent	Distribution----------	
Pulpwood and Stumpage	10.7	20.1	15.0
Chemicals, Minerals & Starch	10.8E	8.5E	10.0E
Purchased Wood Pulp	9.5	0.8	5.5
Waste Paper	2.0	6.6	3.7
Miscellaneous Materials*	14.6E	8.1E	11.7E
Not Reported	0.0	0.6	.3
Electricity & Fuels	7.1	8.0	7.6
Total Materials	54.7	52.8	53.8
Payroll & Fringes	25.0E	20.8E	23.3E**
Contribution to Overhead, Profit, Central Office, etc.	20.3	26.4	22.9
Total Value of Shipments	100.0	100.0	100.0

Source: Calculations from U.S. Department of Commerce (1972).

* - Excludes estimated chemicals, includes own wood pulp made at other establishments and other materials and contract & resale.
** - Excludes central headquarters cost and affiliated operations, e.g. warehouses.
E - Estimate.

TABLE 3

PULP, PAPER AND BOARD

Employment and Salary Data
1972

	Pulp Mills	Paper Mills	Paperboard Mills	Building Paper and Board	Total	Total exc. Pulp Mills
No. of Establishments	58	358	275	95	787	729
Total Employment (000)	10.5	130.3	68.2	12.1	221.1	210.6
Employment of Production Workers	8.4	103.7	54.3	10.3	176.7	168.3
Other Workers	2.1	26.6	13.9	1.8	44.4	42.3
Man-Hours of Production Workers (Million)	17.5	227.5	120.5	22.4	387.9	370.4
Production of Paper & Board (000 tons)	3,700E	25,435	28,670	3,444	61,249	57,549
Production Worker Man-Hours/Ton of Paper & Board	4.73	8.94	4.20	6.5	6.33	6.44
Tons/Man-Hour	.211	.112	.238	.154	.158	.155
Tons per Employee						
All Employees	352.4	195.2	420.4	284.6	277.0	273.3
Employees per Ton						
All Employees	.0028	.0051	.0024	.0035	.0036	.0037
Production Workers	.0023	.0041	.0019	.0030	.0029	.0029
Other Workers	.0006	.0010	.0005	.0005	.0007	.0007
Wages & Salaries ($Million)						
All Employees	125.1	1,440.3	773.9	116.4	2,455.7	2,330.6
Production Workers	94.6	1,092.3	585.3	95.1	1,867.3	1,772.7
Other	30.5	348.0	188.6	21.3	588.4	557.9
Wages & Salaries/Ton ($Million)						
All Employees	33.81	56.62	26.99	33.80	40.09	40.50
Production Workers	25.57	42.94	20.41	27.61	30.49	30.80
Other	8.24	13.68	6.58	6.19	9.61	9.69

E - Estimate by American Paper Institute

Source: American Paper Institute, Economics Department, June 30, 1975, based on 1972 Census of Manufactures, U.S. Department of Commerce (1973).

TABLE 4

PULP, PAPER AND BOARD
Fuel Data
1971 DATA

	Pulp Mills	Paper	Paperboard	Building	Total	Total exc. Pulp
Production of Paper & Board (000 Tons)-1972	3,700E	25,435	28,670	3,444	61,249	57,549
1971	3,500E	23,811	26,274	3,283	56,868	53,368
Purchased Fuel for Heat and Power						
Kwh Equivalent (Billion)	23.8	154.3	128.0	11.6	317.8	294.0
Total Cost ($ Million)	41.5	240.4	200.1	20.8	502.8	461.3
Fuel Oil Total						
Barrels (000)	6,312.7	26,905.8	26,236.1	1,240.5	60,695.0	54,382.3
Dollars (Million)	21.9	94.5	88.9	5.6	210.0	189.0
Distillate						
Barrels (000)	1,473.9	7,451.1	6,988.6	423.7	16,337.3	14,863.4
Dollars (Million)	6.3	25.0	25.7	1.9	58.9	52.6
Residual						
Barrels (000)	4,838.8	19,454.7	19,247.5	816.7	44,357.6	39,518.8
Dollars (Million)	15.7	69.5	63.2	3.6	152.1	136.4
Bituminous Coal, Lignite & Anthracite						
Tons (000)	157.1	5,679.1	3,124.3	243.7	9,204.2	9,047.1
Dollars (Million)	2.0	63.4	36.4	3.0	104.8	102.8
Natural Gas						
Billion Cubic Feet	36.2	195.2	175.3	22.8	429.5	393.3
Dollars (Million)	14.5	73.0	62.8	10.0	160.3	145.8
Other Fuels						
Dollars (Million)	3.1	7.1	9.3	1.9	21.4	18.3
Electric Energy Purchased						
Kwh (Billion)	2.5	16.8	6.7	1.6	27.6	25.1
Dollars (Million)	16.4	134.8	56.1	14.7	222.0	205.6
Generated Less Sold Kwh (Billion)	2.3	12.5	10.4	n.a.	25.2	22.9
Purchased Fuel and Electric Energy						
Kwh Equivalent (Billion	26.3	171.1	134.7	13.2	345.4	319.1
Dollars (Million)	57.8	375.3	256.2	35.5	724.7	666.9

E - Estimate by American Paper Institute

Source: American Paper Institute, Economics Department, June 30, 1975.

TABLE 5

PULP, PAPER AND BOARD

Fuel Ratios
1971 DATA

	Pulp Mills	Paper	Paperboard	Building	Total	Total exc. Pulp
Production of Paper & Board (000 Tons)	3,500E	23,811	26,274	3,283	56,868	53,368
Purchased Fuel for Heat & Power						
Kwh Eq/Ton	6,800	6,480	4,872	3,533	5,588	5,509
Total $/Ton	11.86	10.10	7.62	6.34	8.84	8.64
Fuel Oil						
Barrels/Ton	1.80	1.13	1.00	.38	1.07	1.02
Dollars/Ton	6.26	3.97	3.38	1.71	3.71	3.54
Distillate						
Barrels/Ton	.42	.31	.27	.13	.29	.28
Dollars/Ton	1.80	1.05	.98	.58	1.04	.99
Residual						
Barrels/Ton	1.38	.82	.73	.25	.78	.74
Dollars/Ton	4.49	2.92	2.41	1.10	2.67	2.56
Bituminous Coal, Lignite & Anthracite						
Tons of Coal/Ton	.04	.24	.12	.07	.16	.17
Dollars/Ton	.57	2.66	1.39	.91	1.84	1.93
Natural Gas						
Cubic Feet/Ton	10,343	8,198	6,672	6,945	7,553	7,370
Dollars/Ton	4.14	3.07	2.39	3.05	2.82	2.73
Other Fuels						
Dollars/Ton	.89	.30	.35	.58	.38	.34
Electric Energy Purchased						
Kwh/Ton	714	706	255	487	485	470
Dollars/Ton	4.69	5.66	2.14	4.48	3.90	3.85
Generated Less Sold						
Kwh/Ton	657	525	396	n.a.	443	429
Purchased Fuel & Electric Energy						
Kwh Eq/Ton	7,514	7,186	5,127	4,021	6,074	5,979
Dollars/Ton	16.51	15.76	9.75	10.81	12.74	12.50

Source: American Paper Institute, Economics Department, June 30, 1975.

TABLE 6

PULP, PAPER AND BOARD
CAPITAL EXPENDITURES AND CAPITAL COSTS

1972

	Pulp Mills	Paper	Paperboard	Building Board	Total
Capital Expenditures					
$ Million	131.3	447.7	295.2	19.4	893.6
Depreciation Costs					
$Million					850.0E
Pollution Abatement Equipment - Capital Expenditures					
$ Million - Total					339
Water					205
Air					129
Solid Waste Disposal					5
Using Public Supplies - Water - ($ Million)					17.1
Using Non-Public Supplies - Water ($ Million)					58.9
Air ($ Million)					21.4
Solid Waste ($ Million)					18.6
Sub-Total					116.0
Fixed					100.2
Administrative					16.9
Research and Development					10.5
TOTAL					$243.6

1973 DATA-FOR REFERENCE ONLY

Pollution Abatement Equipment

Operating Costs ($ Million)	145
Fixed Costs ($ Million)	221
Administrative Costs ($ Million)	23
Research and Development ($ Million)	12
TOTAL	401

Source: American Paper Institute, Economics Department, June 30, 1975

TABLE 7

PRODUCTION OF TOTAL PAPER AND PAPERBOARD

SUMMARY

000 Short Tons

	1972	1985F	2000F
Newsprint	3,436	5,350	8,400
Groundwood	1,329	2,020	3,300
Other Printing & Writing	10,958	18,115	29,300
Packaging & Industrial Converting	5,695	7,895	12,000
Tissue	3,977	5,935	9,000
TOTAL PAPER	25,396	39,315	62,000
Solid Wood Pulp Paperboard	20,965	32,040	48,330
Recycled Paperboard (inc. Wet Machine Board)	7,686	11,875	18,530
TOTAL PAPERBOARD	28,503	43,780	66,700
TOTAL WET MACHINE BOARD	148	135	160
Construction Paper and Board exc. Hardboard	3,444	5,130	8,000
Construction Paper and Board incl. Hardboard	5,352	8,015	12,500
TOTAL PAPER AND BOARD exc. Hardboard	57,491	88,360	136,860
TOTAL PAPER AND BOARD Inc. Hardboard	59,398	91,245	141,360

F - Forecast trend by American Paper Institute
Real GNP trend 1972 to 2000 2.580X 28 years 3.5% per year average.

Source: American Paper Institute, Economics Department, June 30, 1975

TABLE 8

TOTAL, PAPER AND BOARD

YEAR 1972
000 Short Tons

	Trend	New Supply	Exports	Imports	Production
Newsprint	13.11	10,392	145	7,101	3,436
Uncoated Groundwood	1.84	1,460	18	149	1,329
Coated Papers	4.35	3,451	76	-	3,527
Uncoated Free Sheet	7.35	5,823	116	116	5,823
Thin Papers	.42	331	-	5	326
Cotton Fiber	.15	121	-	-	121
Bleached Bristols	1.47	1,162	-	1	1,161
Total Printing & Writing	15.58	12,347	210	270	12,287
Unbleached Kraft Packaging & Industrial Converting Papers	4.92	3,896	102	82	3,916
Other Packaging & Industrial Converting Papers	1.67	1,323	15	66	1,272
Special Industrial Papers	.56	441	67	1	507
Total Packaging & Industrial Papers	7.14	5,660	184	149	5,695
Tissue	4.99	3,957	20	0	3,977
TOTAL PAPER	40.83	32,356	559	7,520	25,396
Containerboard	20.21	16,018	2,000	-	18,018
Folding Boxboard	5.60	4,440	14	-	4,454
Milk Carton & Food Service	2.09	1,656	218	-	1,874
Set-Up	.57	455	0	-	455
All Other	4.67	3,701	0	-	3,701
TOTAL PAPERBOARD	33.15	26,272	2,231	-	28,503
Unbleached Kraft	14.36	11,381	1,888	-	13,269
Bleached Kraft	4.38	3,468	218	-	3,686
Semi-Chemical	4.92	3,898	112	-	4,010
Recycled	9.49	7,524	14		7,538
Wet Machine Board	.18	146	6	4	148
Construction Paper & Board exc. Hardboard	4.42	3,503	45	104	3,444
Construction Paper & Board incl. Hardboard	7.24	5,734	79	461	5,352
TOTAL PAPER & BOARD exc. Hardboard	78.58	62,278	2,841	7,628	57,491
TOTAL PAPER & BOARD incl. Hardboard	81.40	64,509	2,875	7,985	59,399

Real GNP $792.5 billion

Source: American Paper Institute, Economics Department, June 30, 1975.

TABLE 9

TOTAL PAPER AND BOARD

YEAR 1985
000 Short Tons

	Trend	New Supply[1]	Exports[2]	Imports[2]	Production[3]
Newsprint	12.40	15,150	200	10,000	5,350
Uncoated Groundwood	1.85	2,260	30	270	2,020
Coated Papers	4.50	5,500	80	0	5,580
Uncoated Free Sheet	8.35	10,200	200	200	10,200
Thin Papers	.525	640	0	0	640
Cotton Fiber	.106	130	0	0	130
Bleached Bristols	1.28	1,565	0	0	1,565
Total Printing & Writing	16.61	20,295	310	470	20,135
Unbleached Kraft Paper	4.65	5,680	120	100	5,700
Other Packaging & Industrial Converting	1.20	1,465	40	40	1,465
Special Industrial Papers	.52	635	100	5	730
Total Packaging & Industrial Papers	6.37	7,780	260	145	7,895
Tissue	4.84	5,915	20	0	5,935
TOTAL PAPER	40.22	49,140	790	10,615	39,315
Containerboard	21.80	26,645	2,600	0	29,245
Folding Boxboard	5.30	6,475	55	0	6,530
Milk Carton & Food Service	1.24	1,515	395	0	1,910
Set-Up	.39	475	0	0	475
All Other	4.60	5,620	0	0	5,620
TOTAL PAPERBOARD	33.33	40,730	3,050	0	43,780
Unbleached Kraft		18,725	2,435		21,160
Bleached Kraft		4,500	395		4,895
Semi-Chemical		5,820	165		5,985
Recylcled		11,685	55		11,740
Wet Machine Board	.115	140	5	10	135
Construction Paper & Board exc. Hardboard	4.21	5,145	90	105	5,130
Construction Paper & Board incl. Hardboard	6.80	8,310	160	455	8,015
TOTAL PAPER & BOARD exc. Hardboard	77.87	95,155	3,935	10,730	88,360
TOTAL PAPER & BOARD incl. Hardboard	80.46	98,320	4,005	11,080	91,245

[1]Real GNP times trend
[2]Projections from trend
[3]Production=New Supply + Exports - Imports

Real GNP $1,222 Billion

Source: American Paper Institute, Economics Department, June 30, 1975.

TABLE 10

TOTAL PAPER AND BOARD

YEAR 2000

000 Short Tons

	Trend	New Supply[1]	Net Imports[2]	Production[3]
Newsprint	12.00	24,000	15,600	8,400
Uncoated Groundwood	1.85	3,700	400	3,300
Coated Papers	4.50	9,000	0	9,000
Uncoated Free Sheet	8.50	17,000	0	17,000
Thin Papers	.50	1,000	0	1,000
Cotton Fibre	.065	130	0	130
Bleached Bristols	1.085	2,170	0	2,170
Total Printing & Writing	16.50	33,000	400	32,600
Unbleached Kraft	4.50	9,000	0	9,000
Other Packaging & Industrial Converting	1.00	2,000	0	2,000
Special Industrial Papers	.50	1,000	0	1,000
Total Packaging & Industrial Papers	6.00	12,000	0	12,000
Tissue	4.50	9,000	0	9,000
TOTAL PAPER	39.00	78,000	16,000	62,000
Containerboard	20.00	40,000	-4,000	44,000
Folding Boxboard	5.20	10,400	- 100	10,500
Milk Carton & Food Service	1.10	2,200	- 500	2,700
Set-Up	.25	500	0	500
All Other	4.50	9,000	0	9,000
TOTAL PAPERBOARD	31.05	62,100	-4,600	66,700
Unbleached Kraft		27,480	-3,800	31,280
Bleached Kraft		6,990	- 500	7,490
Semi-Chemical		9,360	- 200	9,560
Recycled		18,270	- 100	18,370
Wet Machine Board	.08	160	0	160
TOTAL PAPERBOARD & WET MACHINE BOARD		62,260	-4,600	66,860
Construction Paper & Board exc. Hardboard	4.04	8,075	75	8,000
Construction Paper & Board incl. Hardboard	6.50	13,000	500	12,500
TOTAL ALL GRADES exc. Hardboard	74.17	148,335	+11,475	136,860
TOTAL ALL GRADES incl. Hardboard	76.63	153,260	+11,900	141,360

[1]Real GNP times trend
[2]Projections from trend
[3]New Supply minus net imports

Real GNP $2,000 billion

Source: American Paper Institute, Economics Department, June 30, 1975

TABLE 11

IMPORT - EXPORT PROJECTIONS
YEAR 2000*

(Figures in thousand tons)

	Exports	Imports	Net Imports
Paper	1,000	17,000	16,000
Paperboard	4,600	0	-4,600
Wet Machine Board	10	10	0
Construction (excl. hardboard)	100	175	75
Hardboard	100	525	425
Total, excl. hardboard	5,710	17,185	11,475
Total, incl. hardboard	5,810	17,510	11,900

*Forecasting the import-export trend to the year 2000 is very difficult and is largely guess-work.

Source: American Paper Institute, Economics Department, 1975.

TABLE 12

CONSUMPTION OF WOOD PULP AT PAPER AND PAPERBOARD MILLS IN 1973

Restructured Data

TONS
(000)

			Chemical Wood Pulp Printing Writing			Industrial Papers									
Wood Pulp	Newsprint	Unc. Ground-Wood	Coated	Unc. Free Sheet	Thin	Un-bleached	Bleached	Spec-ialty	Tissue	Bleached Bristols	Bleached Packaging	Unbl. Paper-board	Semi-chem Paper board	Recycled Paper-board	Building Paper- and Board
Dissolving	0	0	2	17	1	0	5	15	3	0	0	0	0	7	0
Bleached Sulphite	12	35	182	726	48	0	93	68	839	23	50	11	0	31	11
Unbleached Sulphite	148	100	57	32	3	0	23	5	60	5	6	10	0	28	9
Bl. & Semi-Bl. Sulphate	736	118	1,904	3,734	196	315	1,084	289	1,614	1,213	3,922	700	0	311	51
Unbleached Sulphate	25	18	12	253	22	3,800	97	112	223	77	43	12,746	300	133	18
Groundwood	2,136	1,100	620	47	2	10	0	9	157	0	46	0	33	83	760
Semi-Chemical	20	14	41	285	21	11	10	5	92	0	33	0	2,945	16	365
Soda and Other	23	16	146	495	25	15	5	10	66	0	25	154	0	19	2,193
Total Wood Pulp	3,100	1,401	2,964	5,590	317	4,151	1,317	513	3,054	1,318	4,125	13,621	3,278	628	3,408
Waste Paper	490	60	328	530	20	94	10	159	1,179	0	0	400	1,000	8,458	1,296
Other Fibrous Material	8	6	3	67	7	0	2	126	40	0	17	0	0	42	320
Total Fibrous Material	3,598	1,467	3,295	6,188	344	4,245	1,329	798	4,273	1,318	4,142	14,021	4,278	9,128	5,024
Production	3,431	1,447	3,824	6,509	345	4,019	1,258	564	4,039	1,255	3,864	13,562	4,260	7,884	5,558

PERCENTAGE DISTRIBUTION #

Wood Pulp	Newsprint	Unc. Ground-Wood	Coated	Unc. Free Sheet	Thin	Un-bleached	Bleached	Spec-ialty	Tissue	Bleached Bristols	Bleached Packaging	Unbl. Paper-board	Semi-chem Paper board	Recycled Paper-board	Building Paper- and Board
Dissolving	0	0	*	0.4	0.4	0	0.4	2.7	0.1	0	0	0	0	0.1	0
Bleached Sulphite	0.3	2.4	4.8	11.2	14.0	0	7.4	12.1	20.8	1.8	1.3	0.1	0	0.4	0.2
Unbleached Sulphite	4.3	6.9	1.5	0.5	0.8	0	1.8	0.9	1.5	0.4	0.2	0.1	0	0.4	0.2
Bl. & Semi-Bl. Sulphate	21.5	8.2	49.8	57.4	56.8	7.8	86.2	51.2	40.0	96.7	101.5	5.2	0	3.9	0.9
Unbleached Sulphate	0.7	1.2	0.3	3.9	6.3	94.6	7.7	19.9	5.5	6.1	1.1	94.0	7.0	1.7	0.3
Groundwood	62.3	76.0	16.2	0.7	0.5	0.2	0	1.6	3.9	0	1.2	0	0.8	1.1	13.7
Semi-Chemical	0.6	1.0	1.1	4.4	6.0	0.3	0.8	0.9	2.3	0	0.9	0	69.1	0.2	6.6
Soda and Other	0.7	1.1	3.8	7.6	7.3	0.4	0.4	1.8	1.6	0	0.6	1.1	0	0.2	39.5
Total Wood Pulp	90.4	96.8	77.5	85.9	92.0	103.3	104.7	91.0	75.6	105.0	106.8	100.4	76.9	8.0	61.3
Waste Paper	14.3	4.1	8.6	8.1	5.7	2.3	0.8	28.2	29.2	0	0	2.9	23.5	107.3	23.3
Other Fibrous Material	0.2	0.4	0.1	1.0	1.9	0	0.1	22.3	1.0	0	0.4	0	0	0.5	5.8
Total Fibrous Material	104.9	101.3	86.2	95.1	99.7	105.6	105.6	141.4	105.8	105.0	107.2	103.4	100.4	115.8	90.4

*Less than 0.5
Fiber consumption divided by production expressed as percent.

Source: American Paper Institute, Economics Department, February 13, 1975.

TABLE 13

CONSUMPTION OF WOOD PULP AT PAPER AND PAPERBOARD MILLS IN YEAR 1985

TONS
(000)

Wood Pulp	Newsprint	Printing Writing: Unc. Groundwood	Printing Writing: Coated	Printing Writing: Unc. Free Sheet	Printing Writing: Thin	Industrial Papers: Unbleached	Industrial Papers: Bleached	Industrial Papers: Specialty	Tissue	Included with Printing Writing Bleached Bristols	Paperboard: Bleached Packaging	Paperboard: Unbl. Paperboard	Paperboard: Semi-Chem. Paperboard	Paperboard: Recycled Paperboard	Building Paper and Board	Total
Dissolving	0	0	*	41	3	0	6	20	6	0	0	0	0	12	0	88
Bleached Sulphite	16	48	268	1,142	90	0	108	88	1,234	28	64	21	0	47	16	3,170
Unbleached Sulphite	230	139	84	51	5	0	26	7	89	6	10	21	0	47	16	731
Bl.& Semi-Bl. Sulphate	1,150	166	2,779	5,855	364	445	1,263	374	2,374	1,513	4,968	1,100	0	458	73	22,882
Unbleached Sulphate	37	24	17	398	40	5,392	113	145	326	95	54	19,890	419	200	24	27,174
Groundwood	3,333	1,535	904	71	3	11	0	12	231	0	59	0	48	129	1,117	7,453
Semi-Chemical	32	20	61	449	38	17	12	7	137	0	44	0	4,136	23	538	5,514
Soda and Other[1]	37	22	212	775	47	23	6	13	95	0	29	233	0	23	3,219	4,734
Total Wood Pulp	4,836	1,955	4,324	8,762	589	5,888	1,534	664	4,487	1,643	5,228	21,245	4,602	939	4,996	71,692
Waste Paper	765	83	480	826	36	131	12	206	1,733	0	0	614	1,406	12,597	1,899	20,788
Other Fibrous Materials	11	8	6	102	12	0	1	103	59	0	20	0	0	59	473	914
Total Fibrous Materials	5,612	2,046	4,810	9,700	638	6,019	1,547	1,032	6,279	1,643	5,247	21,879	6,009	13,595	7,308	93,424
Production of Paper & Bd.	5,350	2,020	5,580	10,200	640	5,700	1,465	730	5,935	1,565	4,895	21,160	5,985	11,740	8,150	

	Base Line Forecast: Trend	Base Line Forecast: New Supply	Base Line Forecast: Exports	Base Line Forecast: Imports	Base Line Forecast: Production	Alternate - reduced sulphite: New Supply	Alternate - reduced sulphite: Exports	Alternate - reduced sulphite: Imports	Alternate - reduced sulphite: Production
Bl. & Semi-Bl. Sulphate		22,882	1,200	8,000	16,082	24,650	1,300	8,000	17,950
Unbleached Suphate		27,174	60	350	26,884	27,174	60	350	20,884
Sulphite		3,901	800	500	4,201	2,133	600	400	2,333
Dissolving & Special Alpha	1.09	1,332[2]	750	200	1,882	1,332	750	200	1,882
Chemical, Total		55,289	2,810	9,050	49,049	55,289	2,710	8,950	49,049
Mechanical		7,453	0	300	7,153	*		300	*
Semi-Chemical		5,514	-	-	5,514	*			*
Soda		388	-	-	388	*			*
Defibrated & Screenings		4,346	-	-	4,346	*			*
						*			
Wood Pulp, Total		72,990	2,810	9,350	66,450	*	2,710	9,250	*
Total exc. Defibrated & Screenings		68,644	2,810	9,350	62,104	*	2,710	9,250	*

[1] 91.8% is Defibrated & Screenings

[2] Real GNP times trend (1.09)

*No change from base line forecast.

Source: American Paper Institute, Economics Department, June 30, 1975.

TABLE 14

CONSUMPTION OF WOOD PULP AT PAPER AND PAPERBOARD MILLS IN YEAR 2000

TONS
(000)

	Printing Writing					Industrial Papers				Included with Printing Writing	Paperboard					
Wood Pulp	Newsprint	Unc. Ground-Wood	Coated	Unc. Free Sheet	Thin	Un-bleached	Bleached	Spec-ialty	Tissue	Bleached Bristols	Bleached Packaging	Unbl. Paper-board	Semi-Chem Paper-board	Recycled Paper-board	Building Paper and Board	Total
Dissolving	0	0	*	68	4	0	8	27	9	0	0	0	0	18	0	134
Bleached Sulphite	25	79	432	1,904	140	0	148	121	1,872	39	97	31	0	73	25	4,986
Unbleached Sulphite	361	228	135	85	8	0	36	9	135	9	15	31	0	73	25	1,150
Bl. & Semi-Bl. Sulphate	1,806	271	4,482	9,758	568	702	1,724	512	3,600	2,098	7,602	1,627	0	716	114	35,580
Unbleached Sulphate	59	40	27	663	63	8,514	154	199	495	132	82	29,403	669	312	38	40,850
Groundwood	5,233	2,508	1,458	119	5	18	0	16	351	0	90	0	76	202	1,734	11,810
Semi-Chemical	50	33	99	748	60	27	16	9	207	0	67	0	6,606	37	836	8,795
Soda and Other[1]	59	36	342	1,292	73	36	8	18	144	0	45	344	0	37	5,001	7,435
Total Wood Pulp	7,594	3,194	6,975	14,603	920	9,297	2,094	910	6,804	2,278	7,999	31,405	7,352	1,470	7,761	110,656
Waste Paper	1,201	135	774	1,377	57	207	16	282	2,628	0	0	907	2,247	19,711	2,950	32,492
Other Fibrous Materials	17	13	9	170	19	0	2	223	90	0	30	0	0	92	734	1,399
Total Fibrous Materials	8,812	3,343	7,758	16,167	997	9,504	2,112	1,414	9,522	2,278	8,029	32,344	9,598	21,272	11,445	144,595
Production of Paper & Bd.	8,400	3,300	9,000	17,000	1,000	9,000	2,000	1,000	9,000	2,170	7,490	31,280	9,560	18,370	12,660	

	Base Line Forecast					Alternate - reduced sulphite			
	Trend	New Supply	Exports	Imports	Production	New Supply	Exports	Imports	Production
Bl. & Semi-Bl. Sulphate		35,580	2,000	12,000	25,580	39,106	2,000	13,000	28,106
Unbleached Sulphate		40,850	100	600	40,350	40,850	100	600	40,350
Sulphite		6,136	1,000	2,000	5,136	2,610	500	500	2,610
Dissolving & Special Alpha	.85	1,700[2]	1,000	300	2,400	1,700	1,000	300	2,400
Chemical, Total		84,266	4,100	14,900	73,466	84,266	3,600	14,400	73,466
Mechanical		11,810	-	500	11,310	*		500	*
Semi-Chemical		8,795	-	-	8,795	*			*
Soda		610	-	-	610	*			*
Defibrated & Screenings		6,825	-	-	6,825	*			*
Wood Pulp, Total		112,306	4,100	15,400	101,006	*	3,600	14,900	*
Total, exc. Def. & Screenings		105,481	4,100	15,400	94,181	*	3,600	14,900	*

[1] 91.8% is Defibrated & Screenings
[2] Real GNP times trend (.85)

* No change from Base Line Forecast

Source: American Paper Institute, Economics Department, June 30, 1975

CHAPTER 2

SOME FACTORS AFFECTING THE INDUSTRY

The pulp and paper industry is being molded by the same forces shaping society as a whole. Many are of a worldwide character and are difficult if not impossible to manipulate. However, an understanding of them may give some potential for positive and intelligent action.

Some factors can be strongly impacted by new technological advances. Others can either be constrained or enhanced by governmental policies and societal values. Some examples of major perturbation factors are:

1. Fiber raw material availability (including price, quality, ability to produce quality fiber from lowest cost material and integrated use).
2. Environmental constraints
3. Energy constraints (availability, use and recovery)
4. Capital requirements and availability (for growth, updating and environmental needs)
5. Productivity: (a) existing facilities, (b) new processes for new capital facilities
6. Products meeting use requirements based on: (a) performance specifications and (b) changes in societal values.

Of the above items 1, 2, 3, 5 and 6 can be impacted by new technological advances. Items 1, 2, 3, 4 and 6 can either be constrained or significantly enhanced by governmental policies and societal values. Demand and consumption are influenced by other factors, although to varying extents they are interlocked with the above factors affecting production, product quality, etc. According to Keays (1975), the indicators used in forecasting demands for paper and paperboard are several and consumption is dependent upon clusters of interacting variables, such as the following:

1. population growth and distribution
2. total GNP and its composition
3. disposable income and its distribution
4. literacy and education levels

5. social custom and usage
6. population mobility
7. method of mass transport, and
8. prestige symbolism.

Keays points out that "To some extent, all projections dealing with a subject as complex and multi-component as paper and paperboard use, must have a strong intuitive or subjective component. In one sense, the problem is a simple one. The sum total of economic, technological, competitive, sociological and cultural pressures and judgements relating to the demand for paper and paperboard has produced a consumption-time curve of given shape. The analyst must make a subjective judgment in answering the question: "Will the sum total of all factors operative over the next 25 years result in a continuation of the consumption-time trend of the past 25 years? In the present analysis, the answer to this question is assumed to be yes."

The world consumption-time curve referred to above is shown in Figure 1.

FIBER RAW MATERIAL AVAILABILITY

This subject for the U.S. is fully covered in the Report of the Panel on Productivity. However, a brief summary of Keays' estimates on world demand is included here. By the year 2000, the estimated world demand for paper and paperboard is estimated by Keays (1975) to be about 415 million metric tons, compared to a world production of 141 million metric tons in 1972. An analysis of previous projection analyses would suggest that the value of 415 million tons per year may be low by 10 to 20 percent. (See Appendix I). The projected U.S. demand for paper and paperboard is estimated at 134 million metric tons (148 million short tons) by 2000. This is estimated to be 32 percent of world consumption at that time.

Keays' estimates for world demand for all types of pulp, paper and board products by 2000 are given in the following table (Table 15):

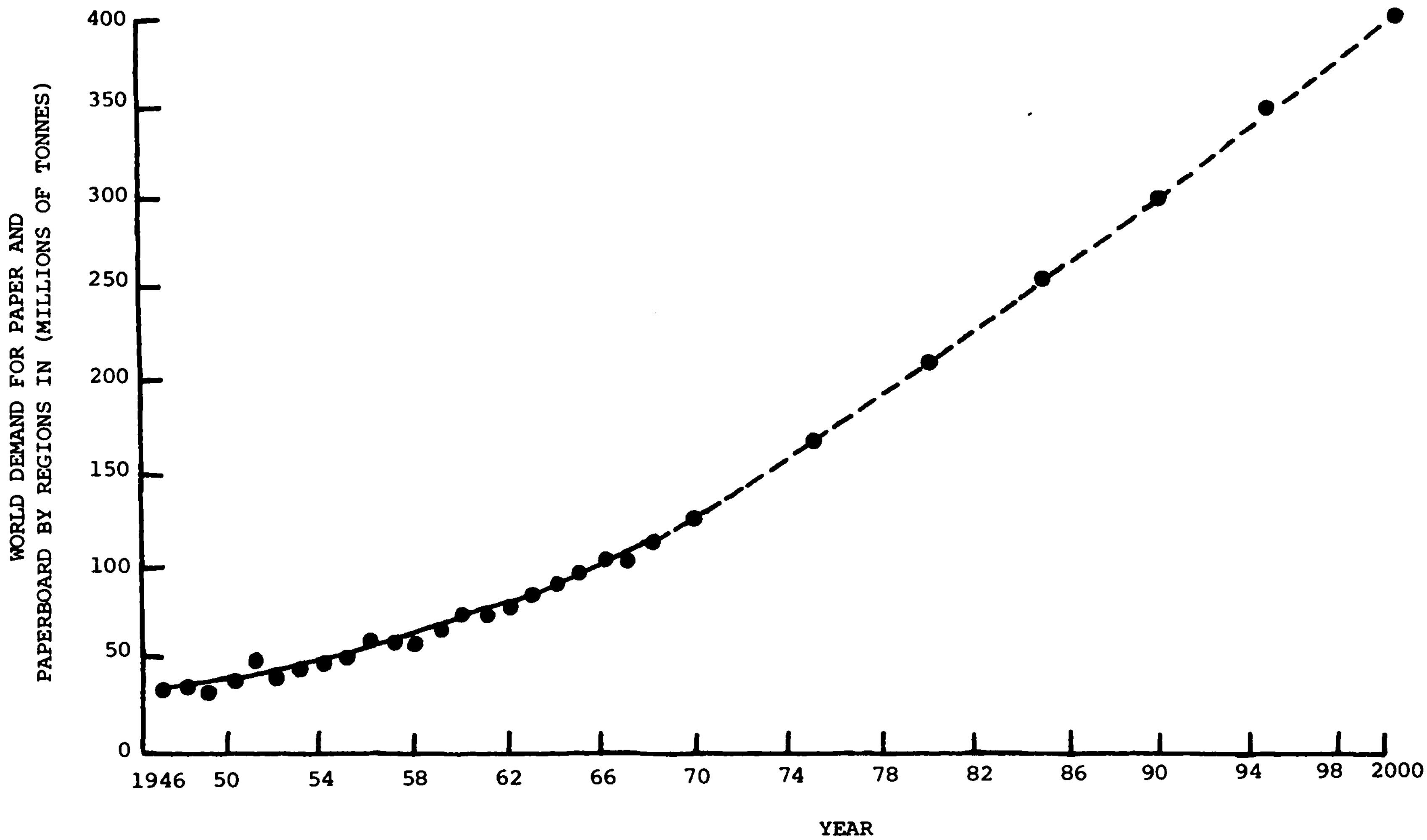


FIGURE I <u>WORLD DEMAND FOR PAPER AND PAPERBOARD TO YEAR 2000</u>

Source: Keays (1975).

TABLE 15

WORLD DEMAND FOR FIBER PRODUCTS BY 2000

Product	World demand (millions of m.tons)	Product yield percent	Wood Requirements Millions of m.tons	Millions of cu. m
Dissolving pulps	16	35	46 (a)	120 (approx.)
Paper and paperboard				
Total	415			
Pulp required (b)	332			
Wood pulp required (c)	315	60	525 (a)	1,310
Fiberboard and particle boards	200	-	- (d)	400
			Total	1,830
			Round out to	1,900

(a) Specific gravity of wood assumed to be 0.4
(b) Use of recycled fiber and fillers assumed to be 20 percent
(c) Wood is assumed to constitute 95 percent of the raw material used in the manufacture of paper and paperboard
(d) Specific gravity of the wood assumed to be 0.5 (mainly hardwoods used).

Wood will continue to be the major source of fiber through the year 2000 and will make up 94 to 95 percent of the total world's fiber requirements for paper products. However, there is a growing deficit of wood in western Europe, which is expected to reach 75 million cubic meters by the end of the 1980s. There are wood surpluses in the USSR, Brazil and other tropical areas. North America, however, will be the major market supplier of pulp and paper to the deficit areas in the years ahead.

According to Keays, "By the year 2000, the supply of wood available for use by the present conventional practices of forest harvesting will be of the order of 200 million cubic metres per year short of demand. Various ways in which additional wood fibre might be made available are discussed. The most practical additional source of fibre will come from a more complete utilization of the world's forests already in use. Application of the concept of full-forest harvesting would increase the amount of wood fibre available from world forest resources by 50 to 100 percent. This would represent an increase of potential fibre which is multifold that of the projected fibre shortfall."

ASSESSMENT OF RESEARCH AND DEVELOPMENT

Quantitative Assessment of R&D

The following table, taken from National Science Foundation (1970, 1974) and McGraw-Hill (1975) reports, depicts the principal quantitative parameters of R&D activities in the paper industry since 1957.

TABLE 16

QUANTITATIVE R&D PICTURE OF THE PAPER INDUSTRY

Year	Funds ($10⁶)	Funds as % of Sales	R&D Scientists and Engineers	R&D Scientists and Engineers Per 1000 Employees
1957	35	0.6	1,500	6
1958	42	0.7	1,700	6
1959	49	0.6	2,000	6
1960	56	0.7	2,400	6
1961	59	0.7	2,600	6
1962	65	0.7	2,600	6
1963	69	0.8	2,500	6
1964	77	0.8	3,800	6
1965	94	0.8	3,800	6
1966	117	0.9	4,300	6
1967	128	0.9	4,700	6
1968	144	0.9	4,800	6
1969	188	1.0	4,800	6
1970	178	0.9	4,900	8
1971	187	0.9	5,000	8
1972	186	0.8	4,900	8
1973	198	0.7	4,900	
1974 (Est.)	234	0.59		
1975 (Planned)	250	0.60		
1978 (Planned)	295	0.53		

Sources: 1957-1962 National Science Foundation (1970)
1963-1972 National Science Foundation (1974)
1973-1978 McGraw-Hill (1975)

Further quantitative data available are the following: For 1974, of the total of $234 million spent on research in the paper industry, $26 million was on R&D for pollution control and $9 million on R&D related to energy. For 1975, of the total of $250 million planned for R&D expenditure, $28 million was for R&D for pollution and $12 million on R&D

related to energy. The figures for 1978 (planned) are $295 million total, $27 and $18 million for pollution and energy, respectively.

R&D expenditures, as a percent of capital spending in the paper industry, were 9.07 percent for 1974, 8.14 percent for 1975 (planned) and 9.67 percent for 1978 (planned).

R&D expenditure in the paper industry is predominantly devoted to development--e.g., in 1969, $71 million, and in 1970, $76 million. Most of the remaining is usually for applied research--e.g., in 1969, $37 million, and in 1970, $40 million, compared to $3 million in each of 1969 and 1970 spent on basic research.

Another way of dividing total R&D expenditure is by purpose--i.e. to create new products, to invent new processes, and to improve existing products. For the paper industry these are expressed in the following table:

Percent Expenditure of Total R&D on:

	New Products	New Processes	Improving Existing Products
1974	30	29	41
1975	33	26	41

As a result, the paper industry expects about 7 percent of its 1978 sales will be in new products. This will amount to $3.89 billion.

Most of the research of the pulp and paper industry is done by the larger companies. Thus, in 1972, 81 percent of all research was done by companies employing 10,000 or more workers, 7 percent by those employing 5,000 to 9,999 workers, and 12 percent by all others. In other words, companies employing 5,000 or more workers were responsible for 88 percent of all R&D expenditure.

No data are available for federal expenditure on R&D for pulp and paper. It is negligibly small, and the industry is responsible for almost all R&D funds.

Qualitative Assessment of R&D

It is difficult to assess the quality of the R&D work carried out. It has already been stated that the paper industry expects 7 percent of its 1978 sales will be in new products. Perhaps comparison with other industries manufacturing nondurables might give a perspective. In the following comparison of different nondurable materials, paper appears to stand favorably with other materials of its type of manufacture (Table 17).

TABLE 17

COMPARISON OF NONDURABLES IN EXPECTED SALES OF NEW PRODUCTS
1978

Nondurables	Expected percent of 1978 sales in new products	Expected sales in billions of dollars for new products in 1978
Chemicals	9	11.13
Paper	7	3.89
Rubber	6	1.90
Petroleum	3	2.23
Food and beverages	8	18.68
Textiles	24	10.75
Others	3	2.48
Total Nondurables	8	51.06

Development of new products represented by anticipated percentage of sales in new products is certainly a base measure of R&D productivity and quality. Other measures for judging R&D quality are difficult to evaluate. In any organization research quality depends upon the individuals involved. There are outstanding research individuals in the paper industry and the institutions allied with it but certainly not enough to meet our needs. Increasing this number should be a long-range strategy by educating more talent. This, of course, requires the availability of supporting funds for education and research.

R&D productivity and quality are not confined to products. Much effort also goes into better understanding and use of raw materials, more efficient equipment, and process development.

Technological Developments

[Refer also to III H "Development of New Technology" in this section (Section A) of this report.]

Process Changes

The emphasis on environmental protection will generate much research on modified and new pulping and bleaching processes during the years immediately ahead. This may result in modification of the kraft process or in a modified soda process in combination with delignification by oxygen. Use of oxygen in bleaching operations appears promising for the future.

The dominant pulp that will be produced during the early 1980s will be by the kraft process or its modification. In view of the intensive research activity in oxygen pulping and in the elimination of sulfur from the kraft process effluents, it is possible that the kraft process will be considerably modified or even superseded.

The second pulp type in quantity produced during the 1980s will be the various mechanical pulps. Thermomechanical pulping is receiving wide research attention today and has a high potential for future development. An increase can be expected in the use of high-yield lignin-containing pulps, namely refiner ground wood, mechanical pulps and ultra-high-yield pulps. Some ground wood is going into coated papers and paper laminates and these trends will increase. Improvements in the quality of these pulps will permit their wider usage.

The NSSC process will continue expanding. In the sulfite process, the trend towards soluble bases, such as Mg, Na and NH_4 will continue and the old Ca base process will not survive. Both the batch and continuous pulping processes will be in operation at the beginning of the next decade. However, the continuous process will come increasingly into use and will be the major pulping method of the future. It, like the batch process, will be under automatic control.

Evolutionary changes are also under way in the papermaking process, both at the wet and dry ends of the machines. New forming devices have been introduced on a commercial scale and it is likely that these will gradually replace Fourdrinier sections. More uniform fiber deposition, speedier water drainage and less two-sidedness are advantages indicated. At the same time the Fourdrinier is being improved upon and, because of its existing large capital investment, will be kept productive and profitable into the 1980s. New techniques for drying paper more uniformly and faster are now under development.

The industry during the next decade will become highly mechanized and automated from wood harvesting to storage and shipment of the final product. Processing will be a world of applied mathematics and digital control by computers; wherever possible processes will be continuous and fully computerized. Emphasis will be placed on closing the loop on all operations to reduce raw material demands by reuse wherever possible, such as process water, and by by-product recovery. Already the paper industry has moved into the use of process-oriented computer hardware and software with increasing success. A much wider choice of computer equipment is becoming available by which better quality control and greater efficiency is obtained. The key to computer process control is suitable instrumentation to measure accurately the process variables. Improvements in measuring and sensing technology have been developed both by instrument manufacturers and computer companies, often working together.

Technology growth is accelerating the rates of change taking place throughout our society. Problems are now arising that demand answers on a quicker time scale than previously, such as those dealing with pollution abatement, recycling, noise abatement (a major problem is in the refiner area), and safety measures. As technological sophistication and automation increase in the future, the time span for problem solving will decrease, such as those problems involving rapid shifts to new grades and products, quick adjustments to raw material variables and elimination of lost production time and quality rejects.

Product Development

Paper coatings and laminates are becoming more sophisticated and complicated to meet specific functional requirements. Continual improvement in these products can be expected, including surface treatments for new printing and reproduction processes, as for new types of office copiers. Major opportunities lie ahead for development of polymers and chemicals for paper treatment as well as synthetic-natural fiber blends to control and improve sheet properties. Such new printing developments as dry offset may change paper quality requirements in the future. Increased manufacturing costs and postal rates will result in demands for lighter weight papers with retention of good printing, appearance and handling properties. Clay coatings will also increase in use since they often improve quality and reduce costs. New coating techniques make possible use of lighter weights of paper without loss of printability, opacity, etc. Some quality standards will change due in part to cost and in part as a result of fiber recycling and pollution control. Brightness is an example.

Improvements will be made in the quality of high-yield, lignin-containing fibers permitting their wider use in coated papers and paper laminates. The use of paper and paperboard in laminates and composites with other materials will increase. The latter includes uses in building construction, A-frame houses, cabinets, furniture and coffins. The traditional types and grades of paper will be produced under highly sophisticated direct digital controlled processes and equipment, producing more uniform and better quality paper in great quantities. The paper industry will continue to improve in the area of disposable products, such as the nonwoven materials, leading to altered production processes to accommodate the new material demands. It may also lead to new methods for making special types of papers.

Changes in distribution systems for goods as well as in life styles of people have a marked effect on packaging materials. As air transport becomes more common, the weight and volume of packaging material becomes more important. Food processing, which now uses about two-thirds of the packaging material in the U.S., will undergo changes that will result in new lighter packages. Retail marketing will continue to change with resultant new packaging and materials handling systems.

The challenge to paper and paperboard packaging materials from synthetic materials will continue. Shrink film packaging is an example of innovative competition. The paper and paperboard industry will counter this competition by improvements in its own products and by developing versatile paper-plastic composites. Advancements in materials science will produce many changes in the packaging and shipment of goods.

Automation in information handling will lead the paper industry into close cooperation with computer data handling. Likewise, automation in publishing will increase, including microfilming and micropublishing. This will require the skills of materials scientists working together with computer scientists. Electronic communications systems will continue to develop and remain competitive.

ENVIRONMENTAL ISSUES

This material on the environmental issues affecting the pulp and paper industry deals with (1) estimated loadings to the environment from the manufacture of pulp and paper

TABLE 18

ESTIMATED WASTEWATER LOADINGS REACHING SURFACE WATERS FROM THE MANUFACTURE OF SELECTED PULP AND PAPER PRODUCTS, LBS/TON

	1972		1985		2000	
	BOD	Susp. Solids	BOD	Susp. Solids	BOD	Susp. Solids
1. Unbleached kraft pulp, packaging paper and linerboard	20	15	5.5	12	2.5	3.5
2. Corregating medium and semichemical pulp	65	30	8.0	10	5.5	5.0
3. Paperboard from waste paper	6	10	3.0	5	1.5	1.5
4. Bleached kraft pulp, packaging paper and board	50	20	9.0	20	3.0	5.5
5. Bleached sulfite pulp	400	40	35.0	40	15.0	6.0
6. Sulfite dissolving pulp	500	50	55.0	40	10.0	10.0
7. Kraft dissolving pulp	75	30	15.0	20	5.5	5.5
8. Chemigroundwood	40	25	15.0	15	5.5	3.5
9. Printing paper	25	40	7.0	8	1.5	2.0

Source: National Council of the Paper Industry for Air and Stream Improvement, Inc., New York, N.Y., 1975.

products for the year 1972, along with forecasts of these same loadings for 1985 and 2000, and (2) a general assessment of the environmental quality regulatory situation surrounding this industry as it may relate to its future growth. In connection with item (1), two tables are assembled containing estimates of unit quantities of selected constituents reaching the environment for a number of pulp and paper products.

Estimates of Wastewater Material Discharge to Surface Waters

Table 18 consists of estimates of BOD and suspended solids, expressed in lbs/ton, reaching surface waters in 1972 and conditional forecasts for 1985 and 2000. For 1972, data assembled for an OECD (1973) report on environmental problems in the paper industry was adjusted to reflect an estimated 20 percent improvement since the OECD report's 1970 base year.

The 1985 data are based on use of published EPA (1974) Effluent Limitation Guidelines and Standards for the Pulp, Paper and Paperboard Point Source Category for the unbleached packaging grades, indicating the agency's expectation of industry performance in 1977, as well as a study contractor's recommendations (WAPORA, Inc. 1974) to EPA as to what these limitations should be for the remaining industry categories. The industry has expressed serious differences as to the accuracy of EPA's judgment as to normal performance capability of control technology currently in use, which is the basis for EPA's determination of expected performance by 1977. In addition, responsible political views are beginning to be heard suggesting that once the desired performance level is reached in 1977, a reasonable time period be set aside to determine whether the 1977 environmental quality goals have been met, and if so, by how wide a margin, and whether in fact the 1983 environmental goals may have been met. Conceivably then, the stated EPA 1977 objectives may serve as the performance level for 1985 for all practical purposes.

In forecasting the discharge levels for the year 2000, a similar process of reasoning was applied to both the published EPA Effluent Limitation Guidelines for the unbleached packaging grades for 1983 achievement, as well as an EPA study contractor's recommendations for 1983 for the remaining industry categories.

Estimates of Materials Emitted to the Ambient Atmosphere

Table 19 consists of a set of estimates for 1972 and conditional forecasts for 1985 and 2000 of emissions to the atmosphere of particulate matter, SO_2 and TRS (an expression of the odorous reduced sulfur compounds emitted during kraft pulping). The 1972 kraft pulping estimates are based on findings in a joint NCASI-EPA (1974) study of the kraft industry with a 1968 base year, adjusted to reflect an estimated 25 percent reduction in process particulate and TRS emissions. Particulate emissions for other chemical pulps for 1972 were estimated at 1/3 that for kraft due to less extensive chemical recovery and/or spent liquor incineration. For 1985 it was assumed that promulgation of federal new source performance standards for new kraft mills in late 1975 or early 1976 will accelerate development of state regulations for existing kraft mills and lead to a TRS level of 0.5 lb/ton by 1985. A further reduction to 0.25 lb/ton by 2000 is speculative but certainly plausible. Regulations leading to attainment of a 4 lb/ton particulate level by 1985 and an additional reduction to 2 lbs/ton by 2000 are certainly foreseeable.

For waste paperboard and printing paper grades it is assumed that there are no process emissions of particulates, SO_2 or TRS. Emissions attributable to fuel combustion assume an average sulfur content in 1972 of 3 percent, a reduction to 2 percent by 1985, and a further reduction to 1 percent by 2000. Particulate emissions for these grades were estimated at 0.5 lbs. per 10^6 Btu in 1972, with a reduction of 60 percent forecast by 1985, and a further 50 percent reduction by 2000. The fuel use computation base was drawn from a report prepared by A. D. Little (1975) for the Boxboard Research and Development Association in 1974.

Sulfur dioxide emissions from process sources for the chemical pulps were estimated from an extremely limited information base which assumed progressive reductions from 1972 levels of at least 50 percent by 1985 and an additional 50 percent by 2000. Even though the fraction of total estimated sulfur dioxide emission accounted for by process sources is substantially less than that for fossil fuel use, regulatory efforts can expect to be directed toward both sources as the national air quality improvement program progresses. The basis for estimating fossil fuel-contributed sulfur dioxide and particulate matter was drawn from a report by Gordian Associates (1974) prepared for EPA containing data on fossil fuel usage for several paper grades. Fossil fuel usage for semichemical corrugating medium production was assumed to be half that for the fully chemical pulps, and that for chemigroundwood was assumed to be half again less.

TABLE 19

ESTIMATED EMISSION LOADINGS REACHING THE ATMOSPHERE FROM THE MANUFACTURE OF SELECTED PULP AND PAPER PRODUCTS, LBS/TON

Product	1972 Particulate	1972 SO_2	1972 TRS	1985 Particulate	1985 SO_2	1985 TRS	2000 Particulate	2000 SO_2	2000 TRS
1. Unbleached kraft pulp, packaging paper and linerboard	19	26	10	8	17	0.5	4	8.5	0.25
2. Corrugating medium and semichemical pulp	8	19	0	7	12	0	3.5	5.5	0
3. Paperboard from waste paper	7.5	30	0	3	20	0	1.5	10	0
4. Bleached kraft pulp, packaging paper and board	19	26	10	8	17	0.5	4	8.5	0.25
5. Bleached sulfite pulp	10	34	0	8	19	0	4	9.5	0
6. Sulfite dissolving pulp	4	34	0	4	19	0	2	9.5	0
7. Kraft dissolving pulp	13	26	10	4	17	0.5	2	8.5	0.25
8. Chemigroundwood pulp	2	8	0	1.5	5	0	0.8	2.5	0
9. Printing paper	7.5	30	0	3	20	0	1.5	10	0

Source: National Council of the Paper Industry for Air and Stream Improvement, Inc., New York, N.Y., 1975.

Other Potential Sources of Environmental Impact

Little of a quantitative nature can be said regarding other potential sources of paper product manufacture environmental impact, particularly with regard to generation levels for 1985 and 2000. Disposal of solid waste materials generated during manufacture, including dewatered sludges, is still predominantly by land storage but can be expected to steadily revert to incineration disposal should, or as, land availability pressures become greater. Technical possibilities are materializing that may permit recapture of the mineral filler and coating component of high ash content sludges from paper manufacture, that should facilitate incineration disposal of such resultant residues as well. The PCB problem that earlier had preoccupied the waste paper stock-based segments of the industry has steadily subsided and should disappear as a factor in time, certainly well before 1985.

General Comments on Environmental Problems Facing the Paper Industry

There are at least five principal current paper industry preoccupations with environmental problems that bear citation as additional background material for this study. These can be listed as follows:

(1) The difficulties that arise in coming to agreement with EPA as to the control technology actually available to various segments of the industry at any given time for coping with agreed upon discharge problems of industry-wide importance. This is particularly serious for those regulatory programs based on either use of an EPA-selected technology or achieving end-of-pipe (or out-of-stack) discharge levels that EPA determines to be achievable, by some preselected date for all mills in a given product category.

(2) The tendency of the agency (EPA) or to a lesser degree state agencies, to respond in a subjective or unbalanced fashion to isolated claims or observations of a relation between the presence of some incompletely defined chemical parameter in discharges to the environment and a claimed adverse environmental effect. Such instances give rise to hastily developed, technically unsound, and in some cases technically unachievable regulations. Instances displaying one or more of these symptoms include the controversies surrounding the presence of, or interpretation of the significance of presence of, such constituents

in mill discharges as PCB, mercury, coliform organisms, color, suspended solids of a non-settleable nature, and stack particulate sulfates. The degree to which any of these parameters, or others that may materialize in the future as sources of agency concern, become identified in regulatory programs can have a major effect on the industry's effluent or emission control programs. A counterpart to this problem is the absence in many EPA-directed programs of any well-identified environmental benefits that would flow from execution of the particular program beyond the stated municipal reduction in discharge of the particular constituents cited in that program.

(3) The economic impact of already identified and time-scheduled EPA-directed regulatory programs. There is already industry-wide concern over its ability to sustain environmental protection capital expenditure programs substantially in excess of the approximately $0.5 billion annual level that have been met during the current 5-year period (1973-77). There is a widespread view in the industry that these and earlier expenditures and the associated operating costs have already had a measurable effect in diverting limited capital funds from industry modernization, selective expansion and productivity improvements. A current API-financed study is exploring this problem as well as the general difficulty in assembling adequate capital to finance the industry's continued growth in the face of sharply rising construction costs, which are influenced to an increasing degree by environmental protection program costs.

(4) The degree to which (a) major production technology changes will be needed to resolve environmental problems, and (b) the search for technologies which should be justified by, or based on, the presumption that they will free the industry from its environmental concerns, once they are found and substituted for existing processes. Other related considerations are (a) complete identification, at the point of early decision, regarding all significant environmental aspects of new technologies requiring major investments and (b) the cost and time required to transform production technology in any given segment of the industry.

(5) The degree to which greater regulatory attention to environmental aspects of growing, harvesting

and transporting forest-derived raw materials to the paper industry may compound the environmental cost-derived difficulties that have already been identified.

It should be noted that these concerns are not unique to this industry, and must preoccupy and attach elements of uncertainty regarding environmental forecasts for other competing raw materials industries based on renewable or nonrenewable natural resources that constitute the subject of this study.

AN OVERVIEW OF ENERGY FACTORS

Introduction

The national concern regarding materials and energy conservation is reflected in the National Materials Policy Act of 1970. This resulted in the creation of the U.S. National Commission on Materials Policy for the purpose of recommending policy for "supply, use, recovery and disposal of materials in order to enhance environmental quality and conserve materials." This Commission sought advice from the National Research Council on issues and research needs to be considered and on the materials policies of other countries. The NRC has advised that a prudent public or private decision affecting the flow of materials and fuels through the world's economies must take into account issues far more difficult than short-term money costs. The core of the problem is "how to sustain a continuing flow of needed raw materials without encountering unacceptable environmental, social, political or fiscal costs" (National Commission on Materials Policy 1973).

According to the National Materials Advisory Board (NRC 1974), the issues to be confronted by a materials policy are societal and pervasive and not peculiar to any industry or group of industries. They include population growth, economic equity, and habits of consumption. The report further states that "conservational measures are needed, not only to stretch our resources, but to restore, protect and perpetuate a livable human habitat." Increased per-capita demand and decreasing supplies of fuels and of many materials are major problems.

The present energy crisis in the U.S. has been much heralded in the recent past technical literature. Energy consumption is expected to increase at an annual rate of 4.2 percent, whereas domestic supplies will grow only 2.6 percent per year. By 1985, domestic sources will supply only 70.3 percent of the energy of the U.S. compared to 87.6 percent in 1970. The situation in oil and natural gas is especially bleak. This means increasing dependence upon imported oil and gas resulting in higher costs and uncertain and disquieting political implications.

For the short and mid-term periods, serious study is being given to methods for conservation of energy without great interference with present life styles. It is claimed that energy conservation measures could reduce U.S. energy demand by as much as 7.3 million barrels of oil per day in 1980. This, however, would require massive voluntary public cooperation. The probability of increased costs for oil and gas products is likely to help in energy conservation by the public.

Importance of Energy to the Pulp and Paper Industry

For the U.S. pulp and paper industry, energy shortages will add to operational costs. This will pressure the industry to seek processes that are most efficient in terms of energy dependency and to conserve energy and resources at every stage of operation, including more complete use of raw materials, reuse of secondary fibers, and use of all mill residues as industrial or energy resources. The position of the industry due to its renewable resource base will be strengthened in relation to competition from products based on petroleum and natural gas.

The importance of energy in the competitive position of paper versus nonrenewable resource materials can be viewed in at least four perspectives:

(1) The paper industry is a major consumer of purchased energy*, even though the use per ton of its product is less than for other products as shown below.

Material	Energy (kWh/ ton)	Industry Tonnage (M tons in 1968)	Total Industry Use (kWh)
Paper	6,400	50	320,000
Plastics	15,000**	6	90,000
Rolled Aluminum	67,200	4	270,000
Glass Plate	7,200	10	72,000

* For consumption of purchased fuels and fuel ratios see Tables 4 and 5.
** Includes an estimated 12,100 kWh/ton energy equivalent for feedstock materials as well as 2,900 kWh/ton for direct processing energy.

(2) The pulp and paper industry currently supplies 42 percent of its energy need from its own process wastes. Primary plastic producers can also use their own wastes and by-products, but aluminum and glass use only purchased energy.

(3) Energy cost for paper is a smaller share of total manufacturing cost than energy cost for nonrenewable materials like plastic and aluminum. This is shown in the following figures:

	Energy Cost as a Percent of Total Manufacturing Cost		
	1973	1983	
		Low Energy Cost	High Energy Cost
Unbleached Kraft Paper*	6	10	13
High Density Polyethylene Resin			
Utilities Only	5	6	6
Fossil Fuel as Raw Material	39	59	65
Primary Aluminum Ingot	20	25	30

(4) Competitive materials should be compared in the marketplace on the basis of performance, not weight.

* Energy costs for the paper industry as a whole are higher, estimated to be 10 percent for 1974-75 by API and as high as 16 percent by FEA. However, by late 1975, other raw material and production costs had risen to bring the energy cost back to a proportional range of from 8 to 12 percent.

Conclusions and Recommendations

If the costs for fuels increase, it will increase the cost of a ton of paper less than the increase of a ton of competitor's nonrenewable resource material. And in times of energy shortage, meeting a need with a paper product becomes more important. Furthermore, since the pulp and paper industry now produces 42 percent of its energy requirement, new technology to improve this capability would further increase this advantage.

Paper can increase its competitive position by further reducing energy consumption, especially against plastics which use fossil fuels as feedstock. Typical approaches include reducing the weight of fiber in the end-use product (e.g., lighter basis weight paper); producing low energy/high yield products (e.g., lower brightness papers); reducing the energy used in processing steps (e.g., more efficient drying and refining); recovering low level heat from process streams (e.g., better heat exchange and recycling); and improved generation of energy from processing wastes (e.g., better recovery furnace operation).

The foregoing provide opportunities for improving the competitive position for paper and other renewable fibrous materials relative to nonrenewable materials. However, many factors (e.g., energy, environment, productivity) impact the final cost comparison, and no one factor will be the sole determinant of the status of a given pair of competitive products.

Recommendations for energy conservation are:

(1) Examine each step in the manufacturing process requiring energy, and specifically identify opportunities to reduce energy consumption.

(2) As suggested in our "Overview of Product Substitution," look in detail at the cost-performance comparisons for a selected number of the most sensitive threats or opportunities for renewable fibers. Such study should consider <u>all</u> the factors mentioned, not just energy.

(3) Develop a list of research goals specifically related to energy conservation or production from process wastes.

ECONOMIC AND SOCIAL FACTORS

Economic problems will have a strong influence upon the direction of technology, leading to high priority efforts to develop maximum efficiency and productivity in order to lower manufacturing costs. These will include, among others, the following: more sophisticated, larger and more expensive equipment to reduce manufacturing costs which means complex systems with greater volume of production at high speed and more information data at high speed to analyze; greater mechanization in wood harvesting, chip preparation, and transport; more efficient and complete utilization of forest resources, including all species, most of the tree and residual wastes; maximum possible yields of pulp; improved quality of high-lignin containing pulps, such as stone groundwood, refiner mechanical pulp, thermomechanical pulp, NSSC pulp, etc.; producing as bright as possible an unbleached pulp from the digester to avoid or minimize subsequent bleaching; improved use of chemical additives and treatments to control retention, formation, and drainage rate and to realize closed paper machine systems; husbanding of all internal resources, reuse of all wastes, maintaining closed loop systems, and energy conservation; and continuous improvement in paper forming machines that operate smoothly at high speeds without breaks and with near-perfect formation.

The future financial stability and profitability of the industry will probably be helped by the present trend towards larger operating units through mergers, sometimes with other paper or forest products companies and often with different industries forming conglomerates. At the same time older small mills, particularly sulfite mills are closing. The objectives for forming larger units are (1) reduction of overhead, (2) pooling and elimination of duplication of experts, (3) more efficient use of production facilities, (4) central purchasing, (5) centralization of R&D, (6) single sales force, and (7) better use of forest resources. However, the many small specialty mills will continue to play an important role in the industry. Their contributions to the quality and variety of paper products available to society are now and will be an important asset in the future.

Changes are taking place in social attitudes towards the concept of ownership, ethics and morality, motivation, initiative and responsibility. These affect worker attitudes and productivity, bargaining, rights of control, and the general psychological climate in personnel relationships. These changes in social attitudes will need careful and continuous scrutiny and increased skill in solving human problems on the part of management.

There will be a growing demand for decision making and action at lower levels within the organization and for group decision making processes. Other problems will be attitudes towards work, job prestige, and making jobs attractive, challenging and within the capabilities of the persons that can be employed.

All things considered tend to suggest some restructuring of the management force to accommodate the efficient handling of sociopsychological problems, relations with government agencies at all levels, international business relations, relations with transport media and the weighing of market forces affecting final consumers.

LEGISLATIVE AND REGULATORY ISSUES

Legislation and regulations designed to accomplish worthwhile objectives usually have important secondary effects. These can have a marked impact on the extent to which renewable resources can be provided and utilized. A complete analysis of all existing and pending legislation and regulations for such impacts is beyond the scope of this report. However, it is vitally important that the country's decision makers have good information on the total societal, political, economic, technical and value impacts. All such issues have to be considered for each new technology and product application.

The following paragraphs give a few examples. The statements about the impacts of the listed issues are not meant to imply a judgment about the value of or the need for the regulation.

Land Use Regulation

Land use regulation now exists in several coastal states. Such legislation can influence the location of industrial development in floodplain, scenic or historic areas.

Environmental Legislation and Regulations

The amount of capital available for the expansion and improvement of cost effectiveness of a business is limited by the cash flow and profits that can be generated by that business. The extent to which this amount of capital is allocated to facilities or operations that are solely for environmental purposes reduces the amount available for expansion and cost reduction. Furthermore, many older plants may have to be closed prematurely because they cannot meet new environmental requirements at reasonable costs. Consequently, productive capacity is curtailed and falls behind product demand. This, and the failure to reduce costs, leads to higher prices and inflation.

Pulp and paper, along with other basic capital intensive industries, face relatively higher capital and operating costs than other materials industries, including plastics. This implies an increasing cost for this renewable resource relative to its nonrenewable competition and restricts the rate at which industry capacity can grow, further reducing the competitive position of the industry. As the country seeks to increase its use of renewable versus nonrenewable resources in meeting its needs, serious consideration must be given to the appropriate tradeoffs in establishing the timing and level of new standards (API 1975, DeBell and Richardson, Inc. 1974). Some examples follow:

(1) Kraft paper production cost would increase 4.1¢/lb. using "Best Available Demonstrated Technology" for water treatment vs. 0-0.2¢/lb. for plastics, steel, and aluminum (DeBell and Richardson, Inc. 1974).
(2) Viscose rayon production capacity is declining due in part to severe pollution control costs.
(3) Solid waste regulations can control or tax packaging. The Minnesota Pollution Control Board can prohibit any package if "it poses a solid waste problem." Washington has a litter tax for any product sold that will enter the solid waste stream. Vermont requires the industry to prove biodegradability of milk cartons.
(4) New York and Oregon are considering legislation to require certain levels of post-consumer waste in paper purchased by the state. Quotes for such specialty paper in New York were 4 to 16 percent higher than present grades.

Food and Drug Regulations

(1) Proposed regulation restricting PCB (polychlorobiphenyl compounds) in paperboard made from recycled fibers could significantly reduce recycling.
(2) Labeling regulations could favor the use of paperboard containers which are more printable than glass or plastics.
(3) Generally, packaging is subject to regulations as severe as the food it contains.

Legislation on Energy

Legislation on energy could impact the industry through allocation, taxation, costs, research funding, etc.

Occupational Safety and Health Administration Regulations

OSHA will have substantial impact on the costs of production and on the choice of materials, as the following examples indicate.

(1) A study by the American Paper Institute (Julian Kien 1975 private communication, American Paper Institute, New York) indicates that required noise reduction could cost the industry $1 billion in capital. (at 90 dbA)
(2) Controls on asbestos have resulted in a change of materials in many cases.

Interstate Commerce Commission Regulations

The ICC controls container specifications and construction, as well as tariff rates. Design, performance, and preferential incentives are involved.

(1) Design example - based on physical properties rather than on performance.
(2) Performance example - shrink-film container.
(3) Preferential incentive example - freight rates to encourage the use of secondary fibers.

Consumer Protection Legislation

Consumer protection legislation can influence the choice of materials in labeling. Examples are:

(1) Flammable apparel is restricted for children.
(2) Paper drapes must be labeled as flammable.

Enhancement of Recycling

Increased use of recycled fiber could be enhanced by regulations providing for waste segregation and by helping to finance new efficient facilities and inventory.

CHAPTER 3

ENHANCEMENT OF AVAILABILITY AND UTILITY OF MATERIALS WITH REDUCTION IN COSTS

BETTER UTILIZATION

The presently used pulping processes which provide fiber for paper and paperboard cover a wide range of yield as well as fiber characteristics. Their respective uses are governed by the performance requirements of the paper grades being made. Typical yields for the various pulping methods on both softwoods and hardwoods are given in Table 20.

Wood costs have always been a major factor in developing more efficient wood use practices. Table 21 shows that the wood used per unit ton of all pulp types being produced has been cut from a figure of 1.60 cords per ton in 1960 to 1.51 cords per ton in 1972 and 1973. This reduction is somewhat due to the shift to greater percentages of hardwood use but is primarily related to the technological changes that made it possible to run higher yield pulps in the manufacture of paperboard and other packaging papers.

Traditionally, the pulp and paper industry has used the best fiber available at the right price. This has resulted in changing use patterns alluded to previously. The potential of the sawmill residues, first the slabs and edgings and then later the sawdust as well was recognized on the West Coast as a fiber resource for the pulp and paper industry, where today little, if any, roundwood is used for pulp. This concept grew rapidly and is an important element (Table 22) in all of the pulp producing areas of the U.S.

The utilization of hardwood fibers was slow in gaining momentum to expand from the so-called normal usage. As their value, both for economy and for quality, became more widely known the demand rose to the present rate (Table 22).

TABLE 20

Typical pulp yields - percent

	Softwoods	Hardwoods
Groundwood	95-98	95-98
Chemimechanical	Not used	88-92
Semichemical	Not used	70-85
Unbleached kraft	50-60	54-62
Bleached kraft	43-45	48-50
Unbleached sulfite	50-52	Not used
Bleached sulfite	44-46	48-50

Source: Forest Products Laboratory, U.S. Department of Agriculture, Madison, Wisconsin

TABLE 21

WOOD USE/UNIT OF PULP

Year Year	Cords Wood MM	Tons Pulp MM	Cords/Ton
1950	23.627	14.849	1.59
1960	40.485	25.316	1.60
1970	67.524	43.546	1.55
1972	71.538	47.347	1.51
1973	73.596	48.772	1.51

Source: U.S. Department of Agriculture, Forest Products Laboratory, Madison, Wisconsin. Data for 1972 and 1973 from Bureau of Census, U.S. Department of Commerce, Washington, D. C.

TABLE 22

WOOD USE PATTERNS - MM. CORDS

Year	Roundwood	Residues	Total Wood	
			Hardwood	Softwood
1950	22.374	1.253	2.943	20.684
1960	33.652	6.833	8.106	32.379
1970	46.794	17.776	16.430	48.140
1972	45.355	25.045	17.930	52.470
1973	45.752	25.701	18.233	53.220

Source: U.S. Department of Agriculture, Forest Products Laboratory, Madison, Wisconsin.

Since 1970, the concept of whole tree utilization has resulted in some usage of whole tree chips and of the recovery of logging residue for pulping. The recent recession has somewhat slowed further adoption of this procedure but there is no question that as fiber shortages become acute greater dependence on the whole tree for fiber will occur. This will fully tap the resource and we may find that no roundwood may be necessary to supply the fiber needs of the paper industry. This more or less makes the pulp industry the scavenger of the forest so that better forest management practices can be instituted to achieve optimum growth rate.

Although wood costs in themselves will cause the trend toward higher pulp yields, certain technologies which are developing seem to lend themselves more readily to the higher yield pulps. This is fortunate and will help to realize their development and application at an early date.

IMPROVED PROPERTIES AND PERFORMANCE

With the pulp and paper industry assuming the role of scavenger* for the remainder of the forest products industry, the question is not so much the improvement of properties but one of knowing the properties of the variety of fiber sources available. There follows, of course, the proper application of the advantageous properties and making the necessary corrections for flaws.

Much needs to be learned about the mechanisms of failure in product performance. These can be as much related to the sheet structure as to the properties of the components. Performance criteria must be related to controllable factors in the pulp and papermaking operations.

MORE EFFICIENT END USE

Adequate criteria to effectively design fiber products for efficient end use are at present not available. This

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*According to American Paper Institute figures, 38 percent of the wood used in 1973 for the manufacture of pulp in the U.S. came from forest (5.2 percent) and manufacturing (32.5 percent) residues. When we take into account other residual fibers (linters, rags and bagasse) and waste paper, then more than half of the fiber supply that the industry draws upon comes from fibers that would otherwise be discarded. This leads to a fuller use of the forest on an integrated operations basis.

results in the improper design prevalent in most such products in today's market. If such criteria were available, more efficient use of the fiber resource would be seen in lighter weight papers, in locating specific types of fibers in particular segments of the paper structure, in new products where now some uncertainty regarding performance exists and in broadening the fiber resource base.

ECONOMIC INCENTIVES AND TIME-FRAME

Economic incentives take the form of outright grants, investment tax credits or other special legislation available to the government to encourage the adoption of the technology and concepts to expand the broader use of the natural fiber resource. The use of this procedure, however, does not guarantee success since many other factors play an equally important role. All things being equal, economic incentives can speed up acceptance of new technology and operating concepts by as much as five years.

ALTERNATE USE OF BY-PRODUCTS

In addition to the bark and the sludges generated by the pulp and paper industry today, the use of a broader based wood resource would no doubt add some low-quality material to the by-product list.

All of these materials can of course be used as fuel to provide energy for the production of forest products. They can be the base for the production of protein and for useful chemicals. There is no single best solution to use these by-products but localized answers that can be attuned to economic use appears to be feasible. Almost all of the lignin removed from the wood by the industry is converted to heat and energy during the chemical recovery process. Whether or not the industry can be induced to consider alternative uses of lignin depends primarily on fuel availability.

INCREASED RECYCLING

Today about 22 percent of paper fiber is recycled. In recent years the industry has quite thoroughly assessed the potential for recycling. That primary and secondary manufacturing wood residues are usable has already been demonstrated. Waste wood products from urban forestry, construction, demolition, pallets, railroad box cars, and other areas are also potential fiber resources. Some of them are already being used, and we can expect this source of fiber to grow where locations of fiber product manufacture are strategically located to this supply.

In "Paper Recycling: the Art of the Possible," a study by Midwest Research Institute (1973) for the paper industry, wastepaper recycle was expected to peak at some quantity under 30 percent. This figure was based on the economics and technology of collection, handling, and transportation. This appears to be quite reasonable for the U.S. market and quality demands since research has shown that the virgin fiber loses its strength potential after the third recycle. It is possible to regenerate some of its lost potential by chemical treatment but costs and pollution are factors mitigating against such efforts.

As more and more of our major cities burn their organic wastes for heat and energy, a portion of the wastepaper will go that route. Only the higher quality and readily collectible clean waste will find its way to recycle for more paper.

IMPROVED TECHNOLOGY TRANSFER, DOMESTIC AND INTERNATIONAL

Even though the paper industry is a highly fragmented industry with consequential repetitiveness in research effort, there is a great deal of technology transfer across several interfaces, namely; intra-industry transfer within the U.S., between the paper industry and other industries in the U.S., and intra-industry across international boundaries.

Within the industry, there are several active channels for technological transfer. The industry supports several universities and other institutions with funds devoted to education and research on paper science and technology. The Institute of Paper Chemistry is almost totally funded by the industry. Five foundations supported by the industry supply funds in five different "Paper Schools" at universities in different parts of the country. The Empire State Paper Research Institute at Syracuse, N.Y., jointly funded by industry and the State University of New York, devotes its energies to research in pulp and paper science and technology. Joint efforts at research are made at Fourdrinier Kraft Institute, Corrugated Industry Development, and, for special purposes as on the Paraquat Project, at the Forest Products Research Laboratories, Madison, Wisconsin. In these institutes, schools and activities, technology is aided by the industry volunteering its personnel to give lectures and seminars, joining research and educational advisory committees, and also by performing some work at individual companies and publishing the results in the open literature. The activities of the

Technical Association of Pulp and Paper Industry help in technology transfer. The Technical Manpower Development Department of TAPPI organizes continuing education programs throughout the year to augment similar programs in the various schools and universities concerned with paper. The industry follows a vigorous program of patenting and licensing its inventions with concomitant transfer of the technology involved.

There is no doubt that much more beneficial transfer of technology would be effected were it not for fear of transgressing the antitrust laws.

Transfer across the industrial interface may be illustrated by the control and computer technologies developed outside the paper industry being adapted and adopted by paper companies for their own use. Another area is energy generation. The paper industry is a very large producer of electrical and thermal energy in its own mills. Boiler, turbine and electrical generator technologies developed outside the industry are incorporated in their latest and most efficient forms for the needs and purposes of pulping and paper making. In reverse flow, coating and finishing technology developed within the industry is used by photocopying industries in the form of specialty papers. Similar flows outward from the industry occur in packaging technology, special chemical manufacture, and use of pulp and paper by-products in the chemical industry (active carbon adsorption, lignin dispersants, tall oil specialties, etc.). Nonwovens made on paper machines using paper technology is a contribution to the textile industry as well as certain specialties.

International transfer of technology occurs in many areas along several distinct channels. In the academic and research sectors, there are constant visits, joint seminars and international thematic conferences in which U.S., Canadian, European, Near East, Far East, South African and South American scientists and technologists exchange information. Another channel is along trade lines in installing foreign equipment and inventions in the U.S. and American equipment and inventions abroad. A most important channel of transferring technology to developing countries is the building and running of pulp and paper mills in these countries using U.S. money and know-how. The industry also has active and thriving licensing programs all over the world, both selling inventions and know-how to other countries, and adapting foreign inventions to U.S. needs.

In addition to the above three major types of technology transfer within and between industries, as well as between government laboratories and universities working on problems relating to the paper industry, there is need for better transfer of scientific knowledge and technology to industry use from other primary sources. These are (1) universities and institutes and (2) government laboratories in general. Much research in chemistry, engineering, biology and the other sciences and technologies have the potential for transfer and the enhancement of the paper industry. Probably much of the industry's and the country's capabilities in technology transfer varies for the different types of transfer discussed above.

Although the paper industry does a reasonably good job of technology transfer, incentives should be provided to increase the rate at which it is accomplished. Industry should make universities, research institutes and government agencies aware of its needs and encourage them to establish a dialogue that may reveal areas of mutual interest.

DEVELOPMENT OF NEW TECHNOLOGY

[Refer also to II B 3 "Technological Developments" in this section (Section A) of this report.]

Industrial research on pulp and paper covers all areas from tree genetics to final use and recycling of products. In pulping, several new unit processes have been developed in the last ten or twenty years--continuous pulping at rates exceeding 1000 tons a day of pulp, diffusive washing, thermomechanical pulping, oxygen bleaching, many different new forming methods, new types and methods of pressing wet webs, novel methods of drying, several ingenious automatic inspecting-cutting-sorting-sheet stacking methods, novel finishing operations, and computer control of pulping and paper making processes. Similarly, a series of new products have been created: in-plain compaction of sheets (Clupak), specialty electrical and photoelectrical papers, many new systems of packaging, nonwovens, and many new chemical entities.

All or most of these and other new processes and products demanded and resulted in new technologies. Handling of disperse systems such as water-suspensions, airborne chip streams, rheologically complex coating formulations and fluidized beds of particles are examples. The uses of novel technologies in electronics, micro-, mini- and large scale computers in business and technical control widen the direct result of research in pulp and paper industrial, academic and semi-academic laboratories.

CHAPTER 4

ENHANCED ROLE OF RENEWABLE FIBER RESOURCES--AN OVERVIEW OF PRODUCT SUBSTITUTION

Today about 98 percent of the fiber requirements of the U.S. paper industry comes from the forest. The remainder is mainly other vegetable fibers, i.e. cotton linters, bagasse, and flax. Only minor amounts of nonrenewable fibers (mostly asbestos and glass) are consumed. Some paper products, however, are meeting strong competition from nonrenewable materials, i.e. plastic films for wrapping and molded plastic containers for milk, etc.

Specific information is needed on product substitution that can be incorporated into the perturbation of specific fiber product flow. This type of information is not readily available and represents an area requiring research and study. Published work should be searched for information indicating trend of substitution. Specific dependence upon potential impact should be studied by one of the three methods illustrated below.

APPROACHES FOR STUDY AND FORECASTING

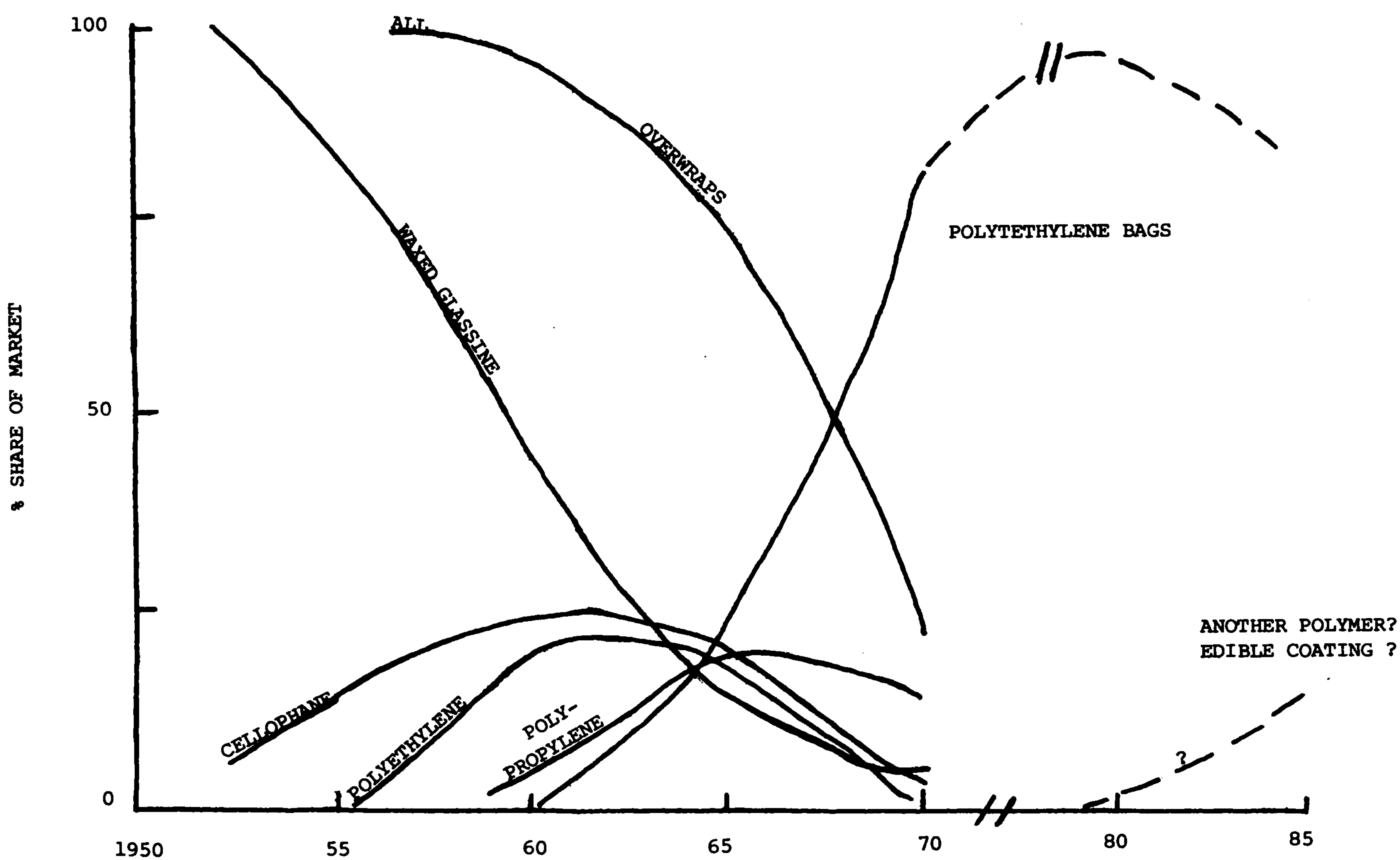
Most approaches to forecast substitution fall into three general categories as listed below. The first is the easiest to perform, but obviously is least certain. The last category builds the best overall understanding about the issue, but takes considerable effort to accomplish.

1. Intuitive Approaches

   - Based on historical perspective and intuitive forecast
   - Useful for recognizing that a cycle will probably occur and for thinking about substitutes
   - Limited by available data base and the perceptivity of the forecaster
   - Example: "Bread Packaging Life Cycles" (Figure 2)

FIGURE 2

BREAD PACKAGING LIFE CYCLES



Source: Developed for CORRIM by G. L. Carlberg, Weyerhaeuser Co., Tacoma, Washington.

2. Empirical Mathematical Approaches

- Based on historical perspective and assumption that past relationships will continue in the future
- Useful for major product categories and long-range planning, but not for new products
- Requires that the substitution has been under way for many years; does not define reason for substitution
- Example: Synthetic vs. Natural Fibers - consumption data and projections using a substitution model. This model, by Fisher and Pry (1971), illustrates a mathematical approach to forecasting substitution of natural fibers by synthetics (see Appendix 2).

3. Cost Performance/Market Analysis of Competitive Products

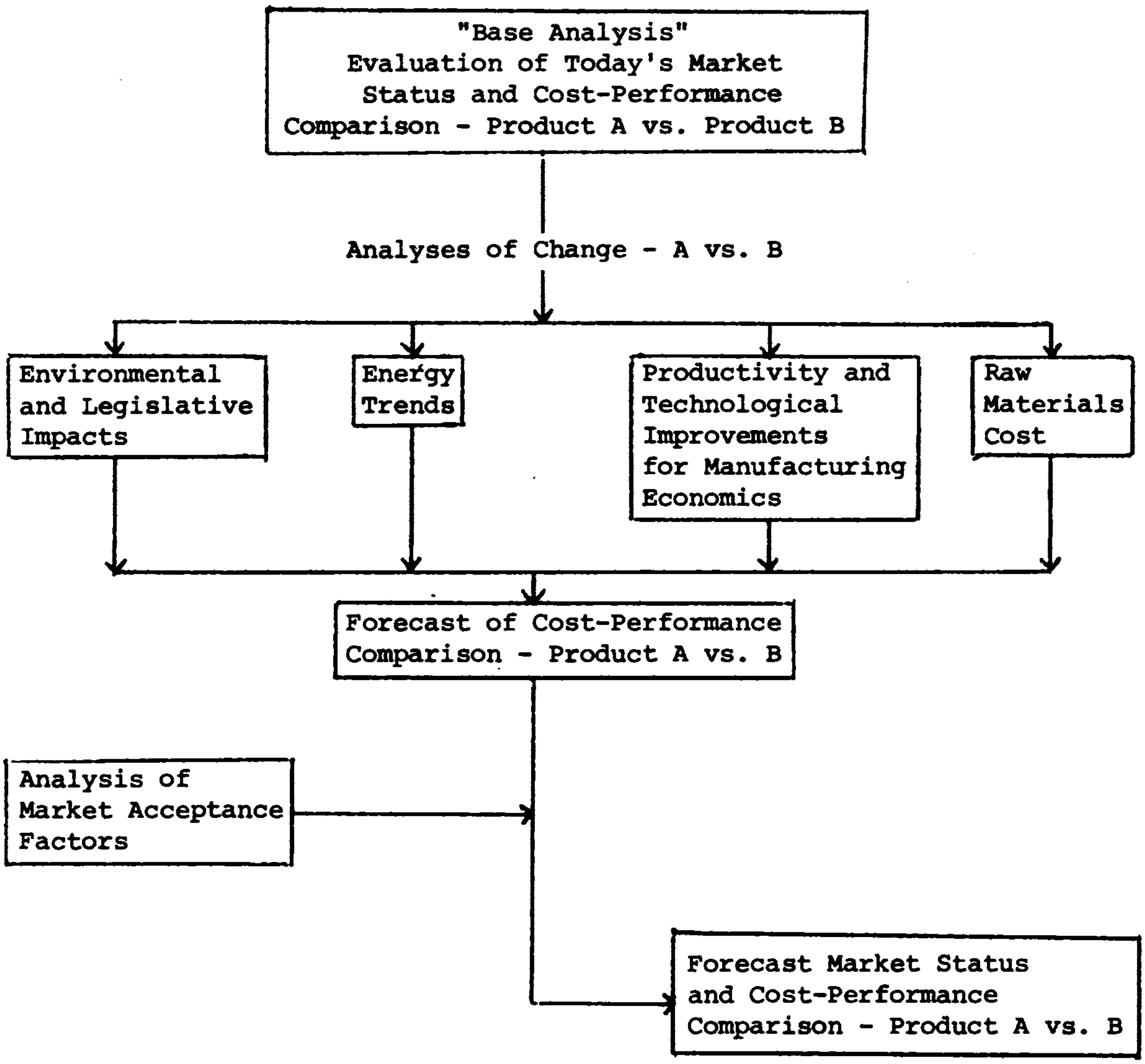
- Involves a base analysis of current status of competitive products and a detailed forecast of technical, environmental, economic and market trends. Figure 3 presents a scheme for incorporating the various forces of change which are fundamental to the rate and extent of substitution of one product for another.
- Accommodates fundamental cost or market situations which disrupt simple trend extrapolation.
- Considers all factors to and including final end-use (i.e., is a total system approach).
- Example: "Half Gallon Milk Packaging" (Figures 4,5). Note: For half gallon size, paperboard will remain less costly and since the package is acceptable to the consumer, one can forecast minimum penetration for plastics. Other sizes have different cost and acceptance comparisons.

EXAMPLES OF SUBSTITUTIONS AFFECTING PULP, PAPER, AND PAPERBOARD

Following is a list of some obvious cases of substitution involving fibrous products. The data in parentheses gives 1973 fiber product volumes in 1,000's of tons over the percent penetration of nonfiber product.

FIGURE 3

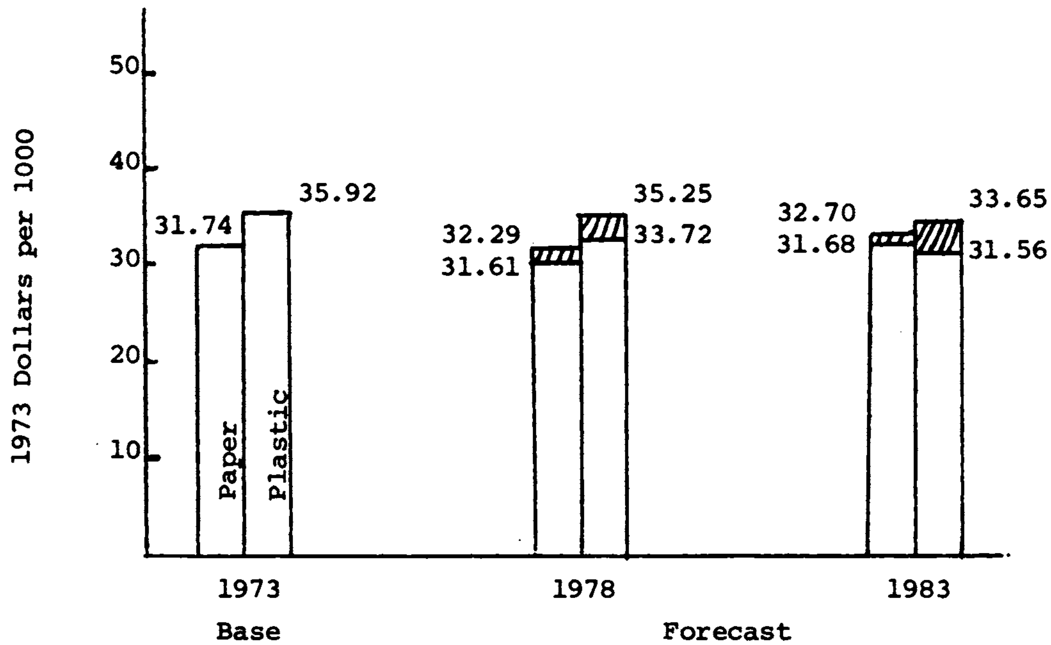
A SCHEME FOR ANALYSIS OF SUBSTITUTION OF COMPETING PRODUCTS



Source: Developed for CORRIM by G. L. Carlberg, Weyerhaeuser Co., Tacoma, Washington.

FIGURE 4

FORECAST OF COMPARATIVE ECONOMICS FOR NEW CAPACITY TO PRODUCE 1/2 GALLON MILK CONTAINERS



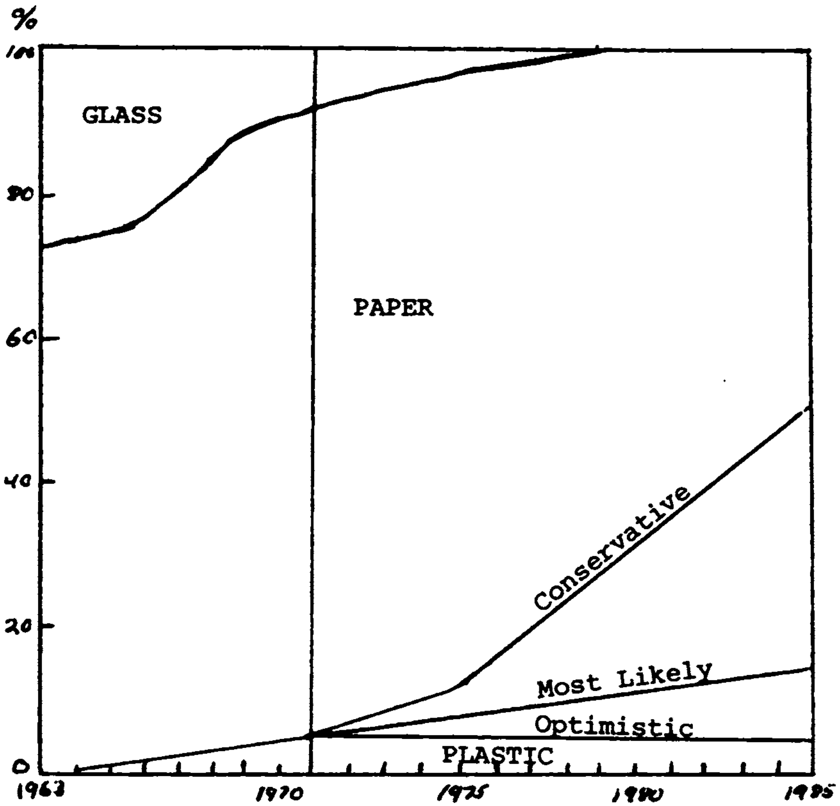
	1983 Container Price Would Rise by......
If no technological cost reduction is made in HDPE manufacture	$2.71/thousand
If ethylene price is 3 cents per pound higher	2.44
If bleached kraft container board has no technological cost reduction	2.14
If real pulpwood price doubles	2.45

Overall, molded HDPE bottles seem likely to remain slightly more expensive than a coated paperboard carton, although the price gap should narrow when HDPE resin returns to cost-based pricing. This forecast is, however, quite sensitive to all important assumptions.

Source: De Bell and Richardson, Inc. (1974).

FIGURE 5

HALF GALLON MILK PACKAGING



Assumptions

- Paper has replaced glass (despite higher cost) because it is non-returnable, lighter and unbreakable.
- Paper has resisted replacement by plastics because it is lower cost and provides acceptable performance.
- Plastics will not penetrate this size unless its price becomes lower.
- Our upper limit forecast for plastic hinges on a major cost breakthrough with no retaliation by paper. We feel this has a probability of no more than 5%.
- The influence of conversion to plastic gallons will not significantly influence conversion to plastic half gallons.

Source: Unpublished, internal study by Weyerhaeuser Company, Tacoma, Washington.

1. Fiber products that have lost a share of the market:

- Coated paper bread overwrap vs. plastic film bag (0/100 percent)
- Glassine food packaging vs. plastic films (236/large)
- Paper grocery sack vs. plastic sack (850/nil)
- Paper shipping sack vs. plastic sack (110/4 percent of units)
- Corrugated container vs. corrugated tray/shrink film (16,900/small)
- Paperboard milk carton vs. blow molded plastic bottle (871/20 percent)
- Coated printing paper vs. plastic paper (3,800/nil)
- Printing paper vs. electronic media (13,500/small)

2. Fiber products that are gaining a share of the market:

- Pulp in disposable diapers vs. cotton cloth diapers (270/32 percent penetration for disposables)
- Nonwoven fabric from pulp vs. fabrics from synthetic fibers or rayon (400/?)
- Composite oil can body vs. steel or aluminum can (205 total for all fiber can stock/75 percent for this use)

CHAPTER 5

IDENTIFICATION OF EDUCATIONAL ROLES AND NEEDS

The educational implications related to the future needs of the pulp and paper industry will be determined by: (1) the nature of the industry in the future, (2) the form and character of the educational programs of our colleges and universities at the time under consideration, and (3) the interaction between these two groups of organizations. The following statement has been taken largely from a report of the Technical Association of the Pulp and Paper Industry (Jahn 1973).

THE INDUSTRY

The pulp and paper industry has manpower problems that are peculiar to it. It is considered a mature, prosaic industry concerned with cost reduction and internal efficiency. It also is labelled with an inaccurate, poor image that dwells upon bad pollution, destructive logging, and wastes. The constructive strides taken by the industry in these areas need to be emphasized, as well as the positive role of paper as a basic element of civilization and society's needs. There is need for greater exposure of high school students to professional people in the industry who can explain these and other aspects of job satisfaction.

The pulp and paper industry also does not, in the eyes of engineers and scientists, easily fit the conception of an engineering and science-based industry. The product, the processes, and the wood and fiber raw materials are heterogenous, and their properties are difficult to deal with in terms familiar to engineers and physical scientists, such as a mathematically predictive framework. Also, the industry is essentially "non-proprietory" in its technology, leaving much of the research on process and product development to the suppliers of equipment and chemicals. The total R&D expenditure of the pulp and paper industry is meager in relation to its size, and as a result, the size of the technical manpower aggregate is relatively small compared to many engineering and science-based industries. There is a tendency for over-recruitment in good years and a failure, not only to absorb new scientists and engineers in lean years, but to dispense with the services of those already employed.

This situation handicaps the recruitment of engineers and scientists by the pulp and paper industry. A basic policy effort is required by management to improve the image of technical jobs in the eyes of young people. This includes (1) a competitively attractive starting salary, (2) improved job responsibility along professional lines, and improved status, (3) attractive future salary increases that are competitive 10 or more years after starting with other industries, (4) open lines of advancement in responsibility and authority, (5) opportunities for upgrading skills and education, (6) job security, and (7) stabilized recruitment, i.e., avoiding over-recruitment in good years and providing some type of buffer capacity in lean years, such as keeping new graduates working on development problems related to the industry in university and institute laboratories (as is informally done in at least one European country).

An important fact is that the industry is moving towards greater production, towards more automation and computer control, away from the art of the process and towards greater technical refinement and efficiency, towards greater empathy with social and environmental needs, as well as towards larger sizes, mergers and internationalization. These factors all emphasize the necessity for intensive research and development within the companies and cooperation with other pulp and paper companies, for joint efforts with machinery, instrument and chemical companies, and with universities and research institutes. Teamwork will be essential involving specialists in different disciplines learning to work with each other to solve broad problems.

The pulp and paper industry has the good fortune of being based upon a renewable resource. The future state of the industry will depend upon the health of our forest crops and how well they are managed. The industry will also depend upon the suitability of its conversion systems in terms of economics, energy supplies and the environment. Finally, its success will depend upon how well it adapts to social and technological change and to the solving of its human problems. The future training of our manpower will need to be directed with these considerations in mind.

THE UNIVERSITY AND ITS PRODUCT

Institutions of higher learning in the U.S. and all over the free world are under stress from a variety of forces, such as social, political and economic changes, fiscal and budgetary problems, and market fluctuations for graduates. These all greatly affect educational policy, the strength and quality of programs, as well as the morale of faculty and students. The effects of population, such as changes in birth rate, shifts in sizes of age groups and other population patterns is a major governing force with respect to enrollments in our universities and the supply of scientific and engineering manpower.

Today both public and private colleges and universities face difficult fiscal problems. Federal and state governments and the private sector of the economy all are hard-pressed financially. As a result some government agencies and state legislators have over-reacted to the declining job situation and have cut support for some programs rather indiscriminately. There is danger that support may be reduced below the level needed to sustain sound programs over a period of time. Where reductions and adjustments are necessary, they should be done with deliberate care or the effect will be harmful to the institutions, to industry, and to society in the years ahead.

Due to increasing costs, both to the university and to the student, more programs will be operated on a tri-semester or twelve months basis. The co'op system involving on-the-job experience may also become more common and will financially help the student. Three calendar years of co'op education is about equivalent to two years of a regular nine months academic program.

Changes in social attitudes towards our institutions, culture, and way of doing things have had a greater impact upon our universities than upon other institutions. These are pervasive and are of evolutionary character. Already changes in educational patterns in various universities have come about, such as open admission policies, free choice of courses with no fixed curriculum, open admission to courses, mini-courses, and a no-grading system. [Present indications are that this trend is now slowing down.]

Curricula based on strong disciplines, such as the natural sciences, mathematics and engineering cannot readily adapt to such permissiveness and lack of structure. The very nature of the subject matter and the interrelationship and building-block character of the courses require a structured program of learning. These social forces could, however, have beneficial effects on science and engineering programs, such as bringing some degree of flexibility and also bringing to the student a greater awareness of human behavior and social-economic-political problems.

In engineering there has been a gradual lengthening of the curriculum, both informally by the student taking an extra term or year to complete the four-year requirements or, formally, by the introduction of a five-year program. In engineering, the M.S. degree has become especially important, since the B.S. graduate is not yet equipped to deal with the more challenging problems in engineering development and design. This will become even more true in the years ahead. This is also true in mathematics and the physical sciences. In mathematics, persons with an M.S. degree are sought by industry for work in statistics, operations research, systems analysis and computer technology. A four-year program is becoming less able to provide a person with the means to tackle the increasing complexity of developments in science and technology. A greater portion of our students in the future must go beyond the four-year program to meet the basic requirements in science and engineering.

Interdisciplinary five-year programs have been developed and are likely to expand in the future, such as the integrated program between the engineering and business management schools at Dartmouth. A new combined engineering-management program at Syracuse University grants a Bachelor's degree after four years of study in industrial engineering and operations research and a Master of Business Administration degree after a fifth year in business management. Future company management will require an increasing awareness of the role of engineers and scientists in plant operation and R&D.

However, counter to this trend of longer study in the sciences and engineering, are proposals, such as that of the Carnegie Commission on Higher Education, to bring about a reduction in the time to earn a Bachelor's degree. Some institutions are seriously considering the shorter program. This is not likely to affect the overall science and engineering curricula, other than by a possible restructuring with two degrees.

There has been an enormous expansion of the junior college, i.e., two-year college concept in the U.S., also commonly termed community colleges. The programs are a mix of terminal programs, namely paraprofessional and technician programs training the student for a career at the end of two years of study, and of regular college programs that the student is expected to continue by transfer to a four-year college. These include pre-professional curricula for students expecting to transfer to engineering and the sciences. These two-year colleges are expected to play a larger role in the higher educational system over the years ahead, but will not basically alter the patterns in the sciences and engineering except that in many cases three years will be required for the Bachelor's degree, following the two-year associate degree.

A number of countries in Europe have specialized technical or paraprofessional schools, training persons for work in specific industries, including the pulp and paper industry. Education often takes place at different levels, such as in Germany, which has pulp and paper programs for technicians (shop foreman level), for applied engineers, for middle management (Graduierte Ingenieure) and for the Diplom-Ingenieure, who has a more theoretical and fundamental education and often finds position in top management.

In the sciences and engineering there is a trend away from specialization at the undergraduate level and towards greater depth in the principles of the discipline studied, such as chemical engineering or chemistry, etc., towards a solid base in the related areas of science and mathematics, and more knowledge of behavioral sciences and social-economic-political areas. The student in the future will have a better base to deal with problems relating to design, systems development, the environment, statistics and computer technology, as well as to understand human problems better and to work as a member of a team.

The specialized paper schools will continue to contribute to the industry in the future. Paradoxically, there is a trend in some of these schools away from specialization and towards a greater depth in the basic sciences, mathematics and chemical engineering. Also there are special problem courses and seminars designed to develop thinking along interdisciplinary lines and innovative approaches to problems. In at least two schools a B.S. degree in science can be obtained at the end of four years and a Chemical Engineering degree after the fifth year. Undoubtedly, in the future more of the specialization in some of these schools will be deferred to the masters program.

In 1970, the Academic Advisory Group of TAPPI (1972) Manpower Development Department completed a survey of the effectiveness of pulp and paper schools. While the survey is of a limited nature it reveals that the industry does recruit heavily from the pulp and paper schools. The industry also favors inclusion of courses that broaden the engineering coverage (process control, feed back circuitry, instrumentation, electronics, transport phenomena, statistics and probability theory) as well as nontechnical courses, especially those related to finance, labor relations, and sociology.

It is obvious that the desires of the industry to include the wide spectrum of courses in the curriculum is not possible within the four-year time span. Hence, the tendency already mentioned above of a discipline-oriented basic four-year curriculum followed by a fifth year concentration in chemical engineering, or in specialization in pulp and paper courses, in business management and finance, or in other options.

Although graduates of pulp and paper schools can and do take employment outside the industry, the percentage is rather small. As students, they already consider themselves oriented towards the industry and, therefore, they form a pool of technically trained personnel that the pulp and paper and allied industries can count on. A survey (1971 unpublished report, Department of Paper Science and Engineering, SUNY College of Environmental Sciences and Forestry, Syracuse, N.Y.) made of 850 graduates in paper science and engineering showed that 86 percent were employed by the pulp and paper and allied industries. Another 8.5 percent of these graduates were employed as chemists outside the pulp and paper and allied industries. Although the future paper science and engineering students will be less specialized and more broadly educated, they will still be oriented towards the industry.

COOPERATION BETWEEN INDUSTRY AND HIGHER EDUCATIONAL INSTITUTIONS

The pulp and paper industry, perhaps more than any other industry, has cooperated with higher educational institutions in the U.S., the German Federal Republic, France, Great Britain, Japan, the Scandinavian and other countries. This is especially true with respect to the specialized paper schools (see above) and pulp and paper industry oriented programs in engineering colleges. In some cases, this amounts to direct support, such as for the educational program of the Institute of Paper Chemistry. Indirect support is also given the programs of the several paper schools of the U.S. through the establishment of industry supported foundations which grant scholarships to students and, in some cases, provide other support as well. The industry, through TAPPI, has also solicited the interest of chemistry and chemical engineering departments in directing their graduates to the paper industry. In several European countries, there is close cooperation between the pulp and paper industry and a number of educational institutions.

Cooperation between industry and higher educational institutions will continue to grow over the next decade. It will broaden beyond the specialized schools and programs to basic programs in the physical sciences, engineering and management, with increasing emphasis on graduate study and on continuing education programs.

EDUCATIONAL IMPLICATIONS AND SUMMARY

The direction that the industry is going and what it will be in the 1980s and later has strong educational implications. To operate this large and complicated industry successfully and profitably will require a very able technical staff. How will such a staff be best organized? What types of scientists and engineers will the industry need and seek? Among most top people asked in technical management and among those responding in higher education, the answers to these questions are almost unanimous and the picture that evolves is outlined below.

A multidisciplinary task force or team approach will be necessary. It will deal with planning, operation, research and development, problem identification, problem solving, environmental and social considerations, etc. Available to this team will be well trained specialists in various disciplines. The areas will include: statistical experimental design, evolutionary operations, instrumentation, computerized equipment design, materials science, environmental science, as well as the conventional disciplines such as chemistry, chemical engineering, mechanical engineering, electrical engineering, physics, biology, forestry, economics, marketing and psychology or human behavior.

Technicians and technical assistants will be required to support the team effort. These will include both graduates of two-year colleges and of four-year colleges. The teams must also have generalists, including the team leader. The team leader generally will come from within the ranks of the team and be promoted on the basis of ability and should have some knowledge of economics and be cost conscious and, of course, be able to grasp quickly the interrelationships of the disciplines as a part of the total team effort. The leader and other generalists should also be concerned with the long-term interactions of change, both on the industry and on society in general. Preferably all members of the team should have a systems approach. They should understand clearly the overall efficiency of a process to the industry, as well as to the welfare of the employees, the ecology and society in general. Task forces should be flexible to meet varying demands and problems. Their size, composition and the number of disciplines and specialties represented will correspond to the occasion.

The industry will need technical persons who are professional scientists, engineers and specialists with the following general qualifications:

A sound education in a basic discipline, preferably chemical engineering, chemistry, a chemistry-chemical engineering combination, or in mechanical engineering. He must be well grounded in chemistry, physics and mathematics. More professionals will also be required who have majored in other basic disciplines, especially in the biological sciences. Following four years in a given discipline, the graduate should then take a fifth year or a graduate program to develop further his discipline or a specialty, such as statistics, computer science, polymer science, management, etc.

A general knowledge of economics and of social and human relations and problems in addition to his in-depth education in his basic science or engineering discipline. Imaginative, versatile and flexible persons, capable of understanding and dealing with diversity and rapid change.

To back up the task force and to carry out technical as well as maintenance operations throughout the mills, there will be a great need for technicians with various levels of education, including the B.S. degree level. One group will be graduates of one-year (certificate) or two-year college (AAS degree) programs. They will be paraprofessionals who have studied in a specific field, such as chemical technology, electronics, monitoring and control methods, analytical techniques, etc., as well as in pulp and paper technology, coating techniques, etc.

The second or higher group will be drawn increasingly from the graduates of four-year programs in science or engineering. These young professional graduates will fill higher level technical, control and operating positions, where their knowledge of mechanics, chemistry, electronics, instruments, unit processes, biology, etc., will be needed throughout the mills to keep them running smoothly, as well as on R&D teams.

The technician of the future will come, for the most part, as now, from the basic disciplines in science and engineering. However, after completing the B.S. degree, most will take a fifth year or a graduate program for further in-depth study of their discipline or to specialize in a chosen area. Included in their education, however, should be the following:

1) some amount of multidisciplinary team-teaching so that the student may learn the team approach while studying,

2) emphasis on the systems approach rather than the present state of the industry and use industrial processes only to illustrate engineering and scientific principles,

3) courses to give perspective to the student's discipline and to deal with the changing world, such as in economics, marketing, and those concerned with social, human and environmental problems, both on the national and international levels,

4) more emphasis on applied mathematics and automation,

5) thorough knowledge of the newest techniques of recording, storage and retrieval of scientific and technical information, and

6) teaching the student how to learn and instilling in the student the desire to learn effectively on the job and throughout life.

Some technical management people, particularly in Europe and Japan, recommend that advanced study or graduate work should come only after 2-3 years of industrial experience and should be supported by the industry. In the U.S. and Canada, this is not often the case; the student desiring graduate work generally continues directly on to a graduate degree following the B.S. degree.

The doctorate program in the U.S. is being critically examined, with respect to educating persons for industry. There is a real need to produce broader and more creative persons who are flexible in outlook, capable of working on interdisciplinary teams and prepared to work on problems that need to be solved.

Finally, a strong effort should be made in the future to design educational programs on all levels to provide a better base for future studies. This should encompass the entire system, i.e., from an associate degree or technician training upward, and especially for programs in continuing education.

There is great need for continuing education programs in the future because of the increasing tempo of change, that can bring whole lines of endeavor into obsolescence. There will be a continual need for updating and retraining technical personnel, including new knowledge on recording, retrieval and storage of information. Also frequent opportunity should be given personnel to acquire expertise in a new specialty such as automation, data techniques, instrumentation, electronics, etc. These programs should be frequently available to all technical persons during their working years, with all avenues open to the ambitious.

Continuing education programs can either be in-house or extramural. It takes a large organization to develop its own in-house continuing education program. Most paper companies will cooperate with universities or other institutions. This will be done either by having guest lecturers at the plant or, if near an institution, by sending the technical personnel there. Many special courses designed for industry people are given at universities for short periods of time (few days to 2 or 3 weeks). Greater advantage of these programs will be taken by companies in the future, by giving time to those persons who can profit by taking such courses.

Excellence in the scientific disciplines and technical subjects must remain a major objective of the future pattern of education in our technological society. But the objectives must be broader. The scientist and engineer must understand and appreciate the concepts and methods of conservation of materials and energy, appreciate the biological base of our renewable forest resources and of the environment, and have some understanding of social and economic questions. These are essential to becoming a good team worker and ultimately a task force leader.

Finally, the goals of higher education should include the professional education of leaders, knowledgeable about the mechanisms of decision-making and with finely-honed judgment in fields transcending our normal disciplines and constraints.

CHAPTER 6

RECOMMENDED RESEARCH, ITS COSTS AND RETURNS, AND TIME SCHEDULE

The paper industry naturally needs to conduct research in many fields to remain viable and to compete effectively with other industries in serving the needs of man in general and of the U.S. in particular. In general, we may classify these needs of the pulp and paper industry along the following lines:

(A) The need to offer substitute materials based on wood and other vegetable fibers for materials based on the exhaustible metal and petrochemical raw materials.

(B) Enhancing the efficiency of fiber raw material use--from the forest, in conversion processes, and in recycling.

(C) Enhancing the efficiency of utilizing capital in our capital-intensive industry,

(D) Enhancing the efficiency of producing and using energy in our industry.

(E) Meeting the increasingly costly demands of keeping the environment wholesome.

(F) Matching the properties of our products to the demands made on them in manufacture and in their end use.

(G) Minimizing operating costs while meeting all requirements set in above six items.

To fulfill the above needs, the following projects are among the most important ones which the industry is, or should be engaged on:

(1) Use of the whole tree--instead of only a portion, as at present--but without introducing deleterious materials in our processes or products, and the wider use of little-used species.

(2) Perfection of non-sulfur, non-chlorine pulping and bleaching to obtain 60 percent yield and 90 percent brightness pulp of acceptable mechanical properties.

(3) Recovery systems of chemicals which are not as hazardous as the explosion-prone systems we have.

(4) Refiners using less energy to achieve the beating of pulp.

(5) Develop means for broader and better use of the properties of high-yield pulps through refining and paper making research.

(6) Economical closing-up of the water system of integrated pulp-and-paper mills, such as by reconditioning of white waters for reuse.

(7) Perfecting conversion and recovery processes with maximum use of waste and heat by-products.

(8) Extruding a uniform sheet directly from a high-consistency headbox into a press at economically high speed.

(9) Eliminating mass and water streaks in paper making.

(10) Making low basis-weight, high-opacity sheet economically at high speeds.

(11) Sheets with barriers against water vapor, oil or other gases and liquids at low costs to compete with high performance organic films and metallic foils.

(12) Specialty papers for non-impact printing by photographic, electronic and/or photoelectronic means.

(13) Shipping containers that meet performance requirements at minimum cost vs. those manufactured to comply with specifications based on design regulations.

(14) A truly "disposable nonwoven" system whereby the ultimate user does not have to worry about how to dispose of his so-called "disposables" when he uses them on a massive scale in hospitals, hotels, etc.

In the following matrix, column letters A to G correspond to the seven primary needs outlined above and row numbers 1 to 14 to the projects. The matrix shows how each project serves to fulfill one or more needs of the industry.

	A	B	C	D	E	F	G
1		X		X			
2		X	X	X	X		
3			X		X		X
4				X			X
5		X	X	X	X	X	X
6		X	X	X	X		X
7		X	X	X	X		X
8		X	X	X			X
9			X	X		X	X
10		X				X	
11	X					X	
12	X					X	
13	X		X	X		X	
14	X				X	X	

It is difficult to estimate costs required. At present, the industry is spending about 0.6 percent of its sales dollar (or some 9 percent of its capital outlays) on research. Much of this is probably in maintaining present day equipment and technology shipshape. If one assumes 60 percent of the present expenditure is on innovative processes and products, this will amount to some $\$150 \times 10^6$ in 1975 dollars. To achieve accelerated results so that many, if not all, of the above suggested items would be ready for commercial implementation by, say, 1985, would require that this sum should be increased to $\$450 \times 10^6$ in 1975 dollars. If we add the cost of "maintenance research" of $\$100 \times 10^6$ (in 1975 dollars), then the total bill for 1975 research would increase from its present estimated value of $\$250 \times 10^6$ to, say, $\$550 \times 10^6$, i.e., from its present 0.6 percent of sales up to 1.3 percent of sales. If the cost keeps pace with inflation, most of the results could be achieved by 1985.

The above values are for R&D. The commercial implementation of the newly developed processes and products would, of course, require capital investment in the hundreds of millions of dollars. But that is another challenge for the industry--how to find the capital required to meet energy, environmental and innovational demands made on it in the next ten years.

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APPENDIX I

Reliability of Forecast World Demand for Paper and Paperboard

J.L. Keays

One indirect measure of reliability can be obtained from an analysis of previous forecasts for paper and paperboard consumption--by comparing the forecast with the actual consumption figures. In 15 of the 16 forecasts for which data were examined, the projected value was lower than the actual value, the shortfall ranging from 5 to 70 percent. Consistent projection shortfall would suggest the presence of a systematic error in all forecasting demand for paper and paperboard, since random error would be expected to give either high or low projections. There are a number of obvious reasons why the estimates are low, including unrealistically low estimates for population growth, increase in GNP, shifting distribution of disposable income, and per capita consumption of paper and paperboard. Undoubtedly some part of the shortfall results from the conservative nature of economic forecasters, who probably believe that it is safer to underestimate than to overestimate (a). It is believed that some fairly large part of the extent to which forecasts fall short of reality arises from a lack of knowledge on which to predict the effect of those technological or social changes which result in increased consumption of paper. This accounts for perhaps 15 percent shortfall in projection analyses. On this basis, it is suggested that the true world production of paper and paperboard in the year 2000 might well be, in actual fact, closer to 475 million tons, that is, 415 plus 15 percent, than to the 415 million tons developed in the present analysis (b). Documentation of the thesis that projection analysis of the type used does not allow for accelerated innovation in the pulp and paperboard field is beyond the scope of the present analysis, but a number of examples could be cited illustrating the general principle involved. Where projections for paper and paperboard demand are based on demographic trends, or derived from estimates for trends in GNP, disposable income, etc., it is certain in most cases, and highly probable in all other cases, that allowance has not been made for a vastly increased demand for disposables--i.e., bedding, hospital gowns, dresses, curtains, and miscellaneous items of apparel. It is not possible to predict realistically the future demand for disposables in the form of paper or paper-plastic or combinations of paper with other fibres, since there are insufficient data for statistical analysis. However, it is certainly conceivable, and not unrealistically possible, that within 30 years a billion people (the combined population of North America, Europe, and the Soviet Union) will consume an average of 50 pounds per person per year in the form of disposables. This would amount to 25 million tons of production. In short, the projection for world demand for paper and paperboard by the year 2000 could be low by 25 million tons, or 6 percent, because of a single type of development in wood-fiber use, the effects of which can now be seen only in the faintest outline.

Another example, not related to innovation but related to a changing society, could be cited in the field of potential newsprint consumption. If 10 million commuters in the United States were to use commuter trains, either from choice or from necessity, this would represent four billion commuter trips per year, and if each commuter bought one additional newspaper weighing 1 pound, this would consume an additional 2 million tons per year of newsprint.

In the field of communications papers, to take another example, if the possession of a library were to become a prestige symbol (or a cultural necessity), 20 million families each purchasing a thousand pounds of books, would increase book-paper consumption over say 10 years by 10 million tonnes.

There may, of course, be numerous other examples of increased paper and paperboard consumption resulting from the development of new products or end uses which could only be discussed *a posteriori* since they have not yet been envisaged (c).

Notes

(a) The social advantage of so doing can be questioned, since as much loss to a given economy could result from something not being done (such as not putting in a mill because of a low forecast of demand) as from what is done (such as to put in a mill which is forced to operate short of productive maximum because of an unrealistically high forecast).

(b) The higher figure has not been used, but there is no reason to suppose that a forecaster is in a better position in 1975 than he was in say 1950 to predict unforeseeable changes in paper and paperboard use. It might be argued that a simple graphic projection of the production curve for paper and paperboard would include the missing 15 percent, since technological and social change has gone into the creation of the curve on which the projection is based. However, this would assume a constant rate of acceleration, which is not necessarily a valid assumption.

(c) In the realm of pure speculation, mention might be made of at least one future potential for massive use of wood fiber. If it were possible to develop from wood fiber a set of dishes which met <u>all</u> the requirements of the user, and which were readily disposable without washing, there might be a market arising from:

1,000,000,000 people,
200 days per year,
2 meals per day,
1/4 pound of disposable dishes per person per meal,

to give a total potential market of 50 million tons per year of wood fiber. The saving in fuel required to heat hot water would be appreciable and the fuel value of the discarded fiber dishes probably even more so.

APPENDIX II

A SIMPLE SUBSTITUTION MODEL OF TECHNOLOGICAL CHANGE*

J. C. FISHER and R. H. PRY

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Introduction

For people who attempt to forecast the future, there is a continuing need for simple models that describe the course of unfolding events. Each such model should be based upon easily understood assumptions that are not available for unconscious or invisible tampering by the forecaster in his efforts to make the future what he wants it to be. The model should be easy to apply to a wide variety of circumstances, and should be easy to interpret. It is our purpose to describe such a model and, by way of example, to apply it to a few illustrative forecasts.

If one admits that man has few broad basic needs to be satisfied--food, clothing, shelter, transportation, communication, education, and the like--then it follows that technological evolution consists mainly of substituting a new form of satisfaction for the old one. Thus, as technology advances, we may successively substitute coal for wood, hydrocarbons for coal, and nuclear fuel for fossil fuel in the production of energy. In war we may substitute guns for bows and arrows, or tanks for horses. Even in a much more narrow and confined framework, substitutions are constantly encountered. For example, we substitute water-based paints for oil-based paints, detergents for soap, and plastic floors for wood floors in houses.

The view of advancing technology as a set of substitution processes may seem evolutionary or revolutionary, depending upon the time scale of the substitution. Regardless of the pace of the change, however, the end result to the user is almost always to allow him to perform an

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*From M.J. Cetron and C. Ralph (eds.) (1971) Industrial Applications of Technological Forecasting to be published by John Wiley & Sons, Inc. (Printed by permission of the publisher in Technological Forecasting and Social Change 3, 75-88, 1971).

existing function or satisfy an ongoing need differently from before. The function or need rarely undergoes radical change. Whenever exceptions to this view are found, the notion of competitive substitution as a model for technological change does not apply.

The Model

The model is based on three assumptions: (1) Many technological advances can be considered as competitive substitutions of one method of satisfying a need for another. (2) If a substitution has progressed as far as a few percent, it will proceed to completion. (3) The fractional rate of fractional substitution of new for old is proportional to the remaining amount of the old left to be substituted.[1]

When a new method is first introduced, it is less well developed than the older method with which it is competing. It therefore is likely to have greater potential for improvement and for reduction in cost. Our second assumption is based upon the idea that any substitution that has gained a few percent of the available market has shown economic viability, even without the improvement and cost reductions that will come with increased volume, and hence that the substitution will proceed to 100 percent.

Experience shows that substitutions tend to proceed exponentially (i.e., with a constant percentage annual growth increment) in the early years, and to follow an S-shaped curve. The simplest such curve is characterized by two constants: the early growth rate and the time at which the substitution is half complete. The corresponding fraction substituted is given by the relationship

$$f=(1/2)\,[1+\tanh\,\alpha(t-t_0)]$$

where α is half the annual fractional growth in the early years and where t is the time at which $f=1/2$. This equation can be derived from our third assumption, which in the mathematical form is

$$(1/f)\;df/dt-2\,\alpha(1-f).$$

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[1]A special form of Pearl's law; cf. Raymond Pearl, The Biology of Population Growth (New York: Alfred A. Knopf, 1925).

Before proceeding with some examples of the application of the model, a few useful characteristics of the S-shaped expression $f=(1/2)[1+\tanh\alpha(t-t_0)]$ will be developed. First, recall that $f=1/2$ when $t=t_0$. Thus t_0 signifies the point in time when the substitution is half complete. It will be convenient, in addition, to characterize a substitution by its "takeover time" defined as the time required to go from $f=0.1$ to $f=0.9$. This time is inversely proportional to α.

$$t=t_{0.9}-t_{0.1}=2.2/x.$$

A more convenient form of the above substitution expression (1) is

$$f/(1-f)-\exp 2\alpha(t-t_0)$$

This expression allows one to plot the substitution data in the form of $f/(1-f)$ as a function of time on semilog paper and fit a straight line through the resulting points, as illustrated in Fig. 1. The slope of the line is 2α, the time t_0 is found at $f/(1-f)=1$, and the takeover time is easily measured as the time between $f/(1-f)=0.11$ and $f/(1-f)=9$. The resulting curve can then be replotted on linear graph paper for display.

It will be readily recognized that the model contains at least one obvious flaw: all substitutions in reality start at a specific point in time, whereas the model predicts that all substitutions began in the infinite past. In practical circumstances, this is of little consequence, however, since the model, by our first assumption, is not to be applied to substitutions prior to their achieving a magnitude of a few percent, at which time a definite growth pattern is established and the very early history has little effect upon the trend extrapolation.

Applications

Synthetic vs. Natural Fibers. Table I shows the history of the U.S. consumption of natural and man-made or synthetic fibers since 1930. Wool, silk, and flax have been lumped together under "all others." The fraction f of synthetic to total fiber is listed in this table. The function $f/(1-f)$ vs. time has been plotted in Fig. 2. This indicates a half substitution date of 1969 and a takeover time of fifty-eight years, from an $f=0.1$ in 1940 to $f=0.9$ in 1998. If one wishes to use this projection to forecast the total use of synthetics or natural fibers, two additional pieces of information are required: projections of population growth and of per capita fiber consumption in the

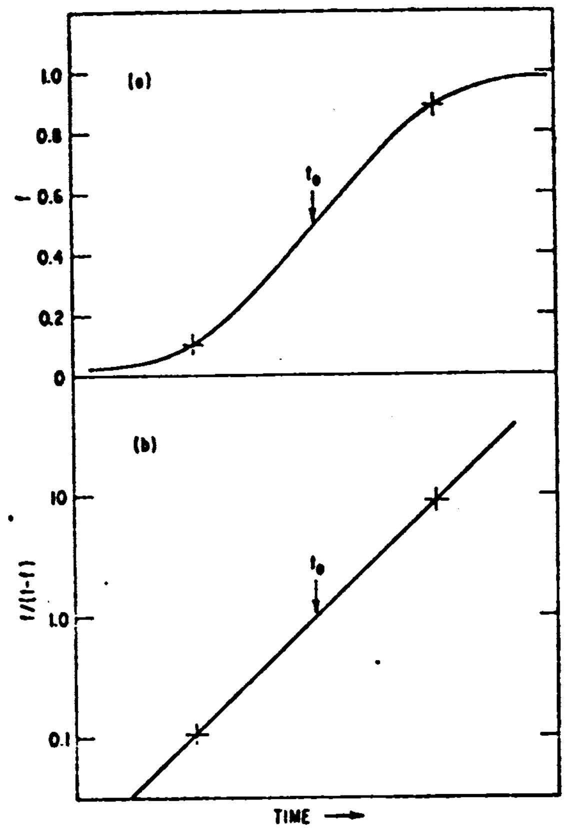


Fig. 1. General form of the substitution model function.

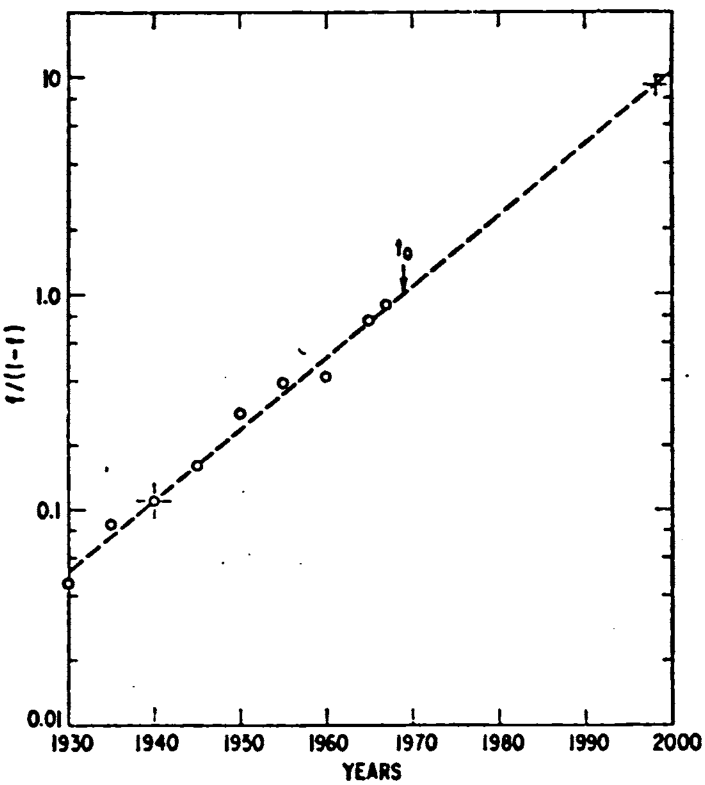


Fig. 2. Synthetic for natural fiber substitution vs. years—substitution model fit to data.

Table I

Mill Consumption of Natural and Synthetic Fibers

Year	Synthetics $\times 10^9$ lbs.	Synthetics lbs. per capita	Cotton $\times 10^9$ lbs.	Cotton lbs. per capita	Other Natural $\times 10^9$ lbs.	Other Natural lbs. per capita	Total per capita	Fraction Synthetic
1930	0.12	1.0	2.62	21.3	0.36	2.88	22.66	0.044
1935	0.27	2.2	2.76	21.7	0.50	3.97	27.87	0.079
1940	0.50	3.7	3.96	30.0	0.47	3.55	37.25	0.10
1945	0.85	6.1	4.52	32.3	0.65	4.66	43.06	0.14
1950	1.82	10.1	4.68	30.0	0.66	4.34	45.34	0.22
1955	1.90	11.5	4.38	26.5	0.433	2.62	40.62	0.28
1960	1.89	10.4	4.19	23.2	0.423	2.37	35.97	0.29
1965	3.62	18.6	4.47	23.0	0.40	2.07	43.67	0.43
1967	4.24	21.3	4.42	22.2	0.32	1.65	45.15	0.47

United States. Per capita consumption is listed in Table I and shown in Fig. 3, including a linear trend projection into the future. Combining these curves with the Bureau of the Census population projection, assuming 1962-1966 fertility levels, a forecast of synthetic and all natural fibers for the United States through the year 2000 is obtained and shown in Fig. 4. This forecast suggests a substantial increase in consumption of synthetics and a decline in the consumption of natural fiber. The degree of concern this should cause the natural fiber producers depends upon one's confidence in the forecast.

Plastic vs. Leather. A similar example is the substitution of plastic for leather. Everyday experience suggests that plastic materials have been substituting for leather in the United States. The per capita consumption of leather has undergone a steady decline since about 1930, but we were not able to find data on the consumption of plastic leather-substitutes. However, assuming a constant per capita consumption of the combined materials over the past few decades, it is possible to deduce the fraction of plastic for any given year. Figure 5 shows the substitution

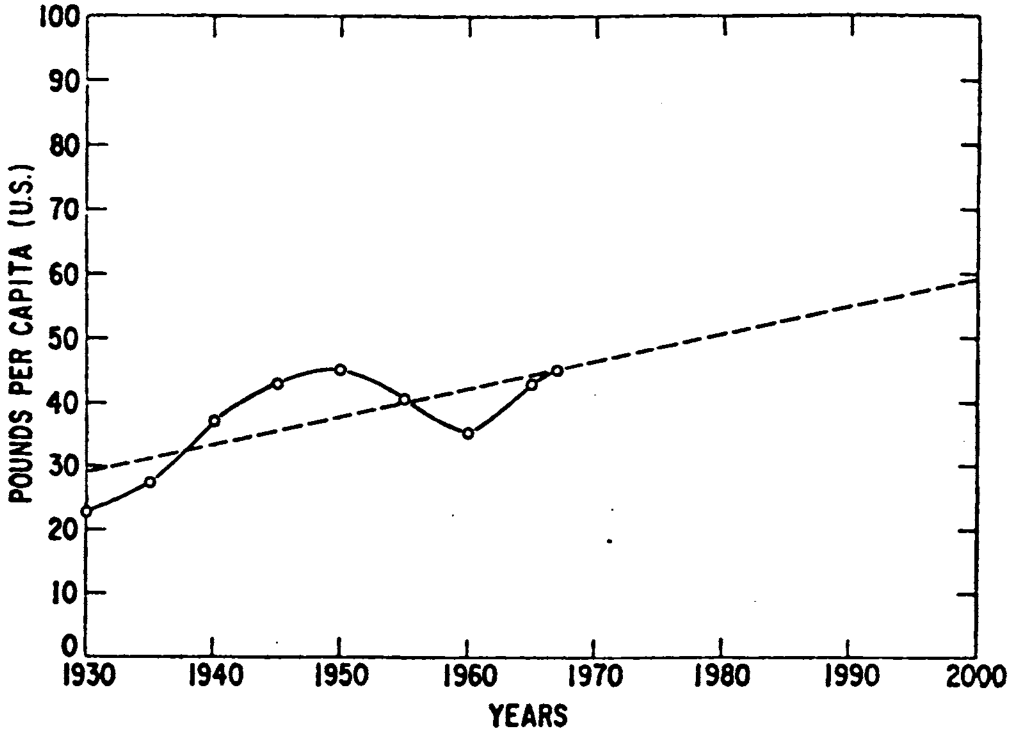


Fig. 3. Total per capita U.S. fiber consumption vs. years—data and straight-line projection.

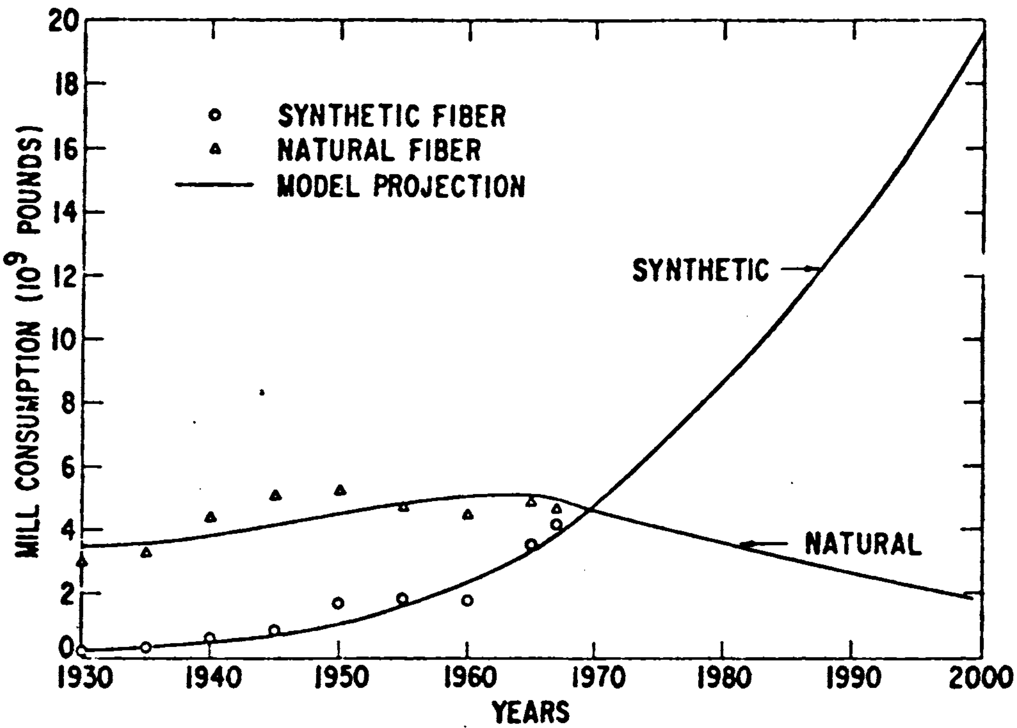


Fig. 4. U.S. fiber consumption vs. years—data and projection using the substitution model.

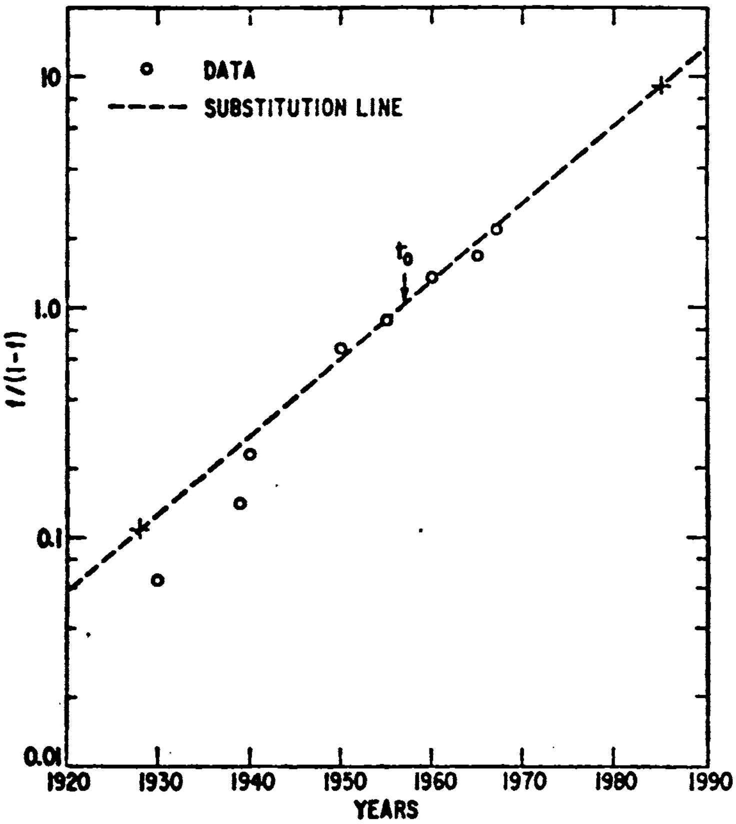


Fig. 5. Synthetic for natural leather substitution vs. years—substitution model fit to data.

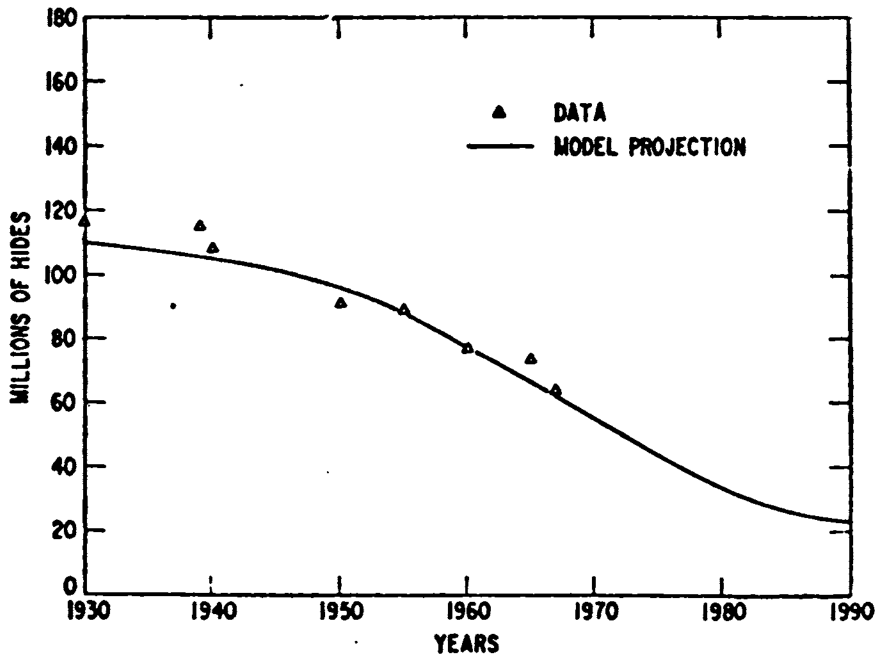


Fig. 6. U.S. consumption of tanned animal hides vs. years—data and substitution model projection.

curve generated in this way. If the curve in Fig. 5 is projected ahead, assuming a constant per capita consumption of combined leather and plastic substitutes, and using the same population projection as in the former fiber example, one obtains the curve of Fig. 6. This shows the forecast total of tanned animal hides to be sold in the United States as a function of time. Again, if one believes the model, a rapid and continuing reduction in the sale of leather products will take place. As illustrated in these two examples, the proposed substitution analysis model can be used not only to forecast expanding opportunities, but to point to areas where additional attention may be needed to adjust to potential adverse changes.

Some of the principal advantages of this substitution analysis can now be seen. First, the analysis is simple to perform and not open to much subjective judgment by the forecaster. Second, the various elements of the forecast are separated; i.e., the fractional substitution competition, the per capita consumption, and the projected population growth. This not only allows, but demands, that independent projections be made for each. The substitution model is fatalistic in the sense that it projects a specific and undeviating future based upon past events. This is not to suggest that a particular future is inevitable, but that, in a normal competitive environment where no large forces are discontinuously brought into play, the future is predictable from past events. [The remaining portion of this paper is omitted.]

SECTION B

PAPER AND TEXTILE PRODUCTS FROM PLANT FIBERS OTHER THAN WOOD AND COTTON

CONTENTS

SECTION B

PAPER AND TEXTILE PRODUCTS FROM PLANT FIBERS OTHER THAN WOOD AND COTTON

INTRODUCTION

Plant fibers other than wood and cotton are used for paper and paperboard and for textile products. These include several types of imported fibers such as sisal, henequen and jute. Many other nonwood vegetable fibers are used in papermaking, particularly outside the U.S. and the potential for future use is great. Therefore, these fibers can be considered raw material sources for both the pulp and paper and the textile industries, depending upon the properties of the fibers from the different species of plants.

In the late 1950s the U.S. Department of Agriculture evaluated new crops for fiber and industrial use in order to promote increased domestic fiber production. Highest rated were kenaf, roselle, sorghums, bamboo and crotalaria. Kenaf regularly produces 10 tons of dry matter/acre annually, and under best conditions, as much as 20 tons/acre (Miller 1975). However, the U.S. has large amounts of unused fibers mainly in the form of cereal straws. As recently as 1950, the U.S. produced as much as 650,000 tons of paper pulp from cereal straws, mainly wheat (Miller 1973). As many as 50 mills were in operation. They were unable to compete with wood due to the economic and technical problems of collection and storage of the straw. With the greatly increasing demand for paper products, this once important source of cellulose may again be needed.

NONWOOD PLANT FIBERS FOR TEXTILES

Reference materials systems and activities are given in the materials flow charts for jute and kenaf (Figure 1) and sisal and henequen (Figure 2). These materials are primarily used to manufacture textiles and textile-related

FIGURE 1

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES -- JUTE & KENAF

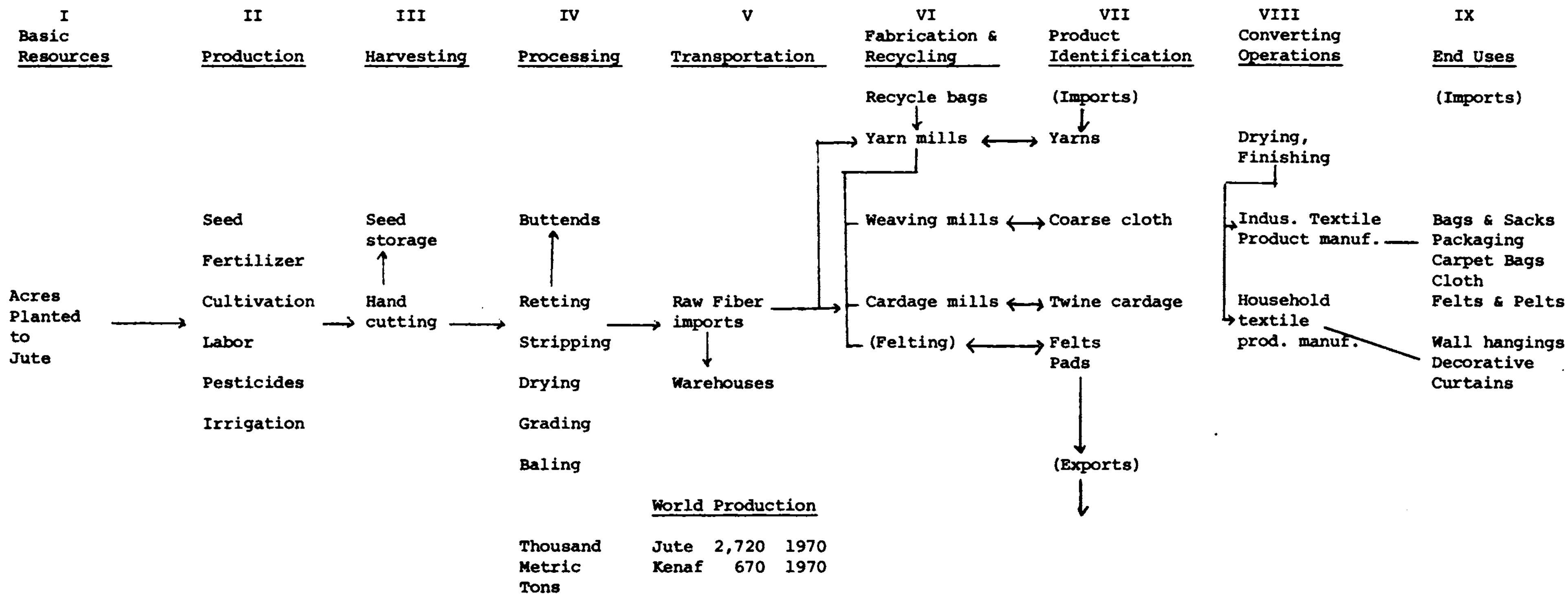
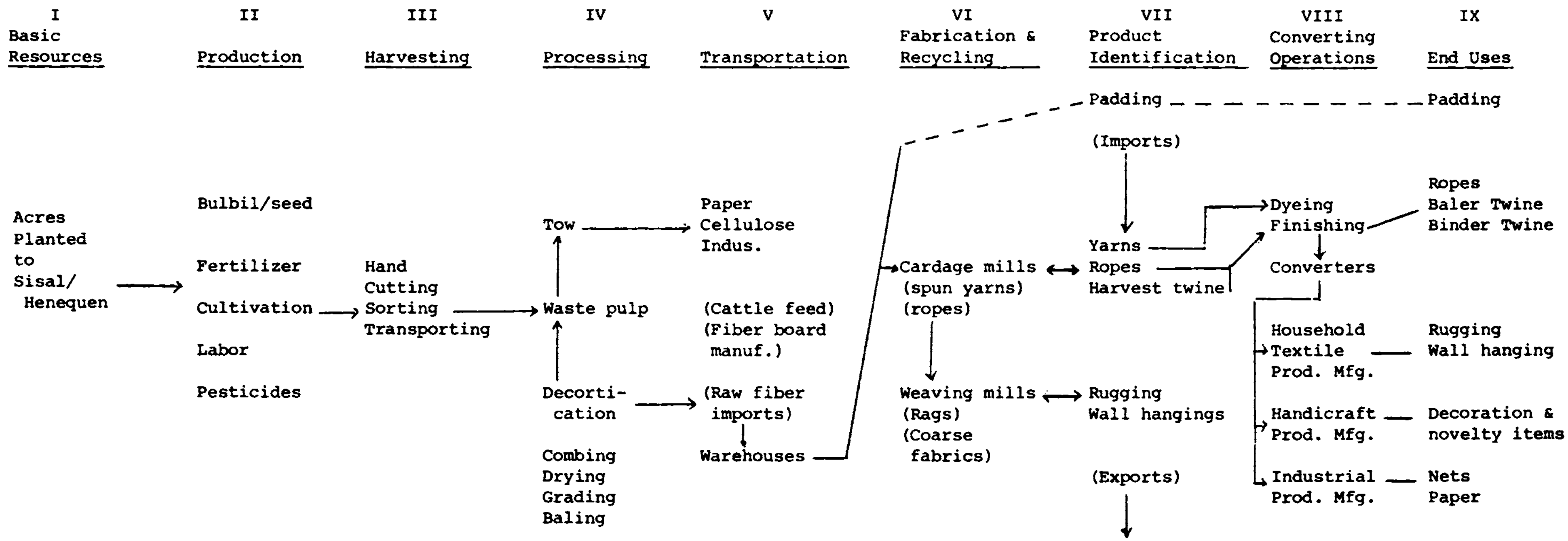


FIGURE 2

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES -- SISAL & HENEQUEN



Sisal & Henequen
Imports - Thousand metric tons
1972

	Raw fiber	Manufactures
Total Western Europe Devl. Countries	311.7	59.3
Total U.S.	50.0	147.7
Total Japan	20.0	-

World Production

Sisal	493-658	Range 1956-72
Henequen	122-167	Range 1956-72

products, such as rope, twine, etc. These raw materials are all imported into the U.S. RMS systems were not developed for bagasse and other fibers used for paper, since from the processing stage on, the activities follow the same trajectory as previously given for paper products from wood (see Section A).

Over 100,000 tons of vegetable fibers other than cotton were imported into the U.S. in 1972, as indicated in Table 1. The major types of fiber imported are sisal, henequen, jute, abaca and kapok. Most of these imported fibers are used for making bags, sacking, carpet backing cloth, packaging cloth, household furnishings, felts and padding, nets, ropes, twine and to a small extent, paper. The latter is mainly tea bag and filter paper made from abaca.

NONWOOD PLANT FIBERS FOR PAPER

The availability in the continental U.S. of cereal crop by-product fibers suitable for papermaking is estimated to be 68.3 million metric tons, using present collection methods (see Table 2), compared to 885 million tons for the world (Atchison 1973). However, the total amount of fiber by-products from crops in the U.S. (includes Hawaii and Puerto Rico) exceeds 500 million short tons (d.b.) (Miller 1975), of which cereal straws make up 130 million short tons and bagasse over 5 million tons. The estimate by Joseph E. Atchison Consultants, Inc. for 1974 for bagasse is somewhat lower, namely 4.4 million metric tons for the 50 states plus Puerto Rico. Their estimate for available seed flax straw, 500,000 metric tons, is lower than the USDA estimate (Table 3) and is based on yield per acre planted.

The collection of these agricultural by-products would involve a separate and costly operation with present equipment. A suitable solution to the storage problem also needs to be developed.

World production of nonwood plant fiber pulp for paper and board is over 7 million tons or about 5 percent of all pulp production (Atchison 1974). In the U.S. the totals (1972) are estimated to be (in air dry metric tons):

bagasse	- 218,000
cotton linters	- 115,000 for dissolving pulp
cotton linters	- 45,000 for paper pulp
rags, abaca, hemp, flax seed straw, sisal, etc.	- 187,000

The estimated nonwood plant fiber pulp consumption for paper and board in the U.S. for 1972 totals 453,000 metric

TABLE 1

IMPORTS OF VEGETABLE FIBERS (EXCEPT COTTON) AND SILK

1972

Flax	1,127	long tons (2,240 lbs)
Hemp	34	" "
Sunn	103	" "
Jute	13,182	" "
Abaca or Manila	21,002	" "
Sisal & Henequen	49,206	" "
Istle or Tampico	151	" "
Crin	22	" "
Kapok	11,037	" "
Coir	3,692	" "
Other Vegetable Fibers	4,771	" "
Silk, raw	553	1000 lbs
Silk, waste	1,586	" "

JUTE AND HARD FIBERS

Imports for Consumption in USA and World Production

1972

	USA Imports	World Production
Jute, raw	13,608 m. tons*	2,766,942 m. tons
Abaca, raw	21,319 " "	75,751 " "
Sisal & Henequen (raw) (raw)	49,896 " "	740,270 " ""

*2,204.6 lbs.

SOURCE: U.S. Department of Agriculture, Foreign Agricultural Service. Import data compiled from reports of U.S. Dept. of Commerce.

Est. jute and jute goods consumption in USA in 1971 was 389.2 metric tons (from IBRD).

TABLE 2

ESTIMATED AVAILABILITY OF SPECIFIC NONWOOD PLANT FIBROUS RAW MATERIALS - 1972

RAW MATERIAL	POTENTIAL WORLDWIDE AVAILABILITY WITH PRESENT COLLECTION METHODS (BDMT)	POTENTIAL TOTAL AVAILABILITY IN CONTINENTAL U.S. WITH PRESENT COLLECTION METHODS (BDMT)
1. Sugar Cane Bagasse	55,000,000	2,400,000
2. Wheat Straw	550,000,000	50,000,000
3. Rice Straw	180,000,000	1,000,000
4. Oat Straw	50,000,000	8,000,000
5. Barley Straw	40,000,000	5,000,000
6. Rye Straw	60,000,000	2,000,000
7. Seed Flax Straw	2,000,000	500,000
8, Grass Seed Straw	3,000,000	1,000,000
Subtotal Straw	885,000,000	68,300,000
9. Bast Fibers		
a. Jute - mainly from India and Bangladesh	4,425,000	-
b. Kenaf and Roselle - mainly from India and Thailand	1,674,000	-
Subtotal Bast Fibers	6,099,000	-
10. Leaf Fibers		
a. Sisal	648,000	-
b. Abaca	92,000	-
c. Henequen	164,000	-
Subtotal Leaf Fibers	904,000	-
11. Reeds	30,000,000	-
12. Bamboo	30,000,000	-
13. Papyrus	5,000,000	-
14. Esparto Grass	500,000	-
15. Sabai Grass	200,000	-
16. Total Cotton Staple Fiber	13,500,000	3,000,000
17. Total Second Cut Cotton Linters	1,000,000	250,000
ESTIMATED TOTAL	1,027,203,000	73,150,000

Source: Joseph E. Atchison Consultants, Inc., New York, N.Y.

TABLE 3

AVAILABLE AGRICULTURAL FIBER RESIDUES

1972

	Millions Short Tons
Cereal straws	132.4
Wheat	85.1
Rye	2.0
Oats	24.5
Rice	3.3
Barley	17.5
Rye grass straw	.6
Flax straw	2.2
Bagasse	5.5
Corn stalks	125.0
Soybean stalks	26.0
Grain sorghum stalks	20.0

Source: U.S. Department of Agriculture, Agricultural Research Service.

tons. The different types of pulp produced are shown in Table 4.

For increased utilization of crop by-products in the U.S., better collection and storage methods are required. Preferably the straws should be cut close to the ground and stored in bulk, to avoid the expensive baling operation. Projections for the utilization of crop by-products in the U.S. are practically impossible to do. There is, however, strong potential for the use of these fibers as the demand for fiber products rises. An efficient collection and storage method is essential to the utilization of this now wasted resource. From the standpoint of maximum utilization of renewable resources, Joseph E. Atchison (private communication; July 25, 1975) believes that the government could wisely finance the development of a good method of collecting and storing straw that would make it economical to use as a raw material for paper.

POTENTIAL ENERGY USE

An alternative use for crop by-products is for energy. A comparison of the fuel value of bagasse and cereal straws with fossil fuels is shown in Table 5. According to Atchison (private communication; July 25, 1975), these materials have a fuel value about equivalent to two barrels of fuel oil. Therefore, they have a fairly good fuel value and may have some potential in the future because they are renewable annually. Bagasse is currently used for fuel in sugar refineries.

General Motors Corporation (Green 1975) has also carried out a study on the energy potential from agricultural field residues. Among the conclusions of this study are:

> "Agricultural residues left in the field each year in the form of stalks, leaves, and husks after the edible grains and materials are removed, amount to almost one-half the heating value of the coal produced in the United States annually. The potential technology available for increasing the total agricultural production in the U.S. and a growing demand for food permit a reasonable anticipation that within twenty years crop residues left in the field will be equivalent in heating value to that of all U.S. coal produced in 1972.
>
> "From the viewpoint of conservation of energy, two-thirds of the agricultural residues should be removed from the field for energy uses. We are considering further the dilution of coal with agricultural residues as fuel for power

TABLE 4

ESTIMATED TOTAL NONWOOD PLANT FIBER PULP CONSUMPTION IN THE UNITED STATES IN 1972 FOR PAPER AND BOARD

	AMOUNT CONSUMED (MT)
Bleached Bagasse Pulp	36,300
High Yield Mechanical Type Bagasse Pulp for Wallboard	181,500
Cotton Linter Pulp	45,400
Rag Pulp (Bleached)	45,400
Flax Pulp	36,300
Abaca Pulp	14,500
Rag Pulp for Roofing Felt	99,400
TOTAL	453,800

"The above data supplied by Joseph E. Atchison, President of Joseph E. Atchison Consultants, Inc., New York, N.Y."

TABLE 5

EQUIVALENT FUEL VALUE OF BAGASSE AND OTHER FIBROUS RAW MATERIALS AS COMPARED TO FOSSIL FUELS

GENERAL DATA USEFUL FOR CALCULATIONS

FUEL VALUES

	FUEL HIGHER HEATING VALUES	MODERN BOILER HEAT EFFICIENCY
Coal	12,000 Btu/lb as is	85%
Oil (Bunker C)	18,000 Btu/lb as is	85%
Gas*	1,000 Btu/ft^3 std.	85%
Bark		
Hardwood	7,600-8,800 Btu/lb bone dry (8,200 av.)	Depends on moisture content of bark
Softwood	8,500-9,600 Btu/lb bone dry (9,050 av.)	Depends on moisture content of bark
Wood		
Hardwood	8,200-8,900 Btu/lb bone dry (8,700 av.)	Depends on moisture content of wood
Softwood	8,400-9,900 Btu/lb bone dry (9,050 av.)	Depends on moisture content of wood
Bagasse	8,000-8,400 Btu/lb bone dry (8,200 av.)	Depends on moisture content of bagasse
Cereal Straw	8,000 Btu/lb bone dry	Depends on moisture content of Straw

EFFECT OF MOISTURE CONTENT OF REFUSE FUEL ON HEAT EFFICIENCY OF A MODERN BOILER

MOISTURE CONTENT OF FUEL AS FIRED (%)	BOILER HEAT EFFICIENCY (%)
0	78
10	76
20	74
30	72
40	68
45	66
50	64
55	61
60	57
65*	52

*Boiler manufacturers indicate this is the maximum moisture content for good operation of a refuse burning boiler without the use of auxiliary fuel.

Note: Fuels should not be equated for cost on the Higher Heating Value only. In the case of the refuse fuels, the boiler heat efficiency at the moisture content of the fuel also enters into the conversion of monetary value of one fuel to that of another. Then from the related monetary values the physical equivalencies of the fuels can be calculated for any given situation.

MOISTURE IN BARK AND WOOD RESIDUES

METHOD OF PREPARATION	MOISTURE (%)
Kiln dried	8-12
Air dried	15-25
Drum barked, dry handled	35-50
Drum barked, wet handled	45-65
Hydraulic barked	60-75

*In the U.S. system the calorific value of gas is expressed at 60°F and 30" Hg., whereas in the metric system the value is expressed at 0°C and 760 mm of Hg.

"The above data supplied by Joseph E. Atchison, President of Joseph E. Atchison Consultants, Inc., New York, N.Y."

boilers to reduce SO_2 emissions. Also, we are studying gasification of field residues to determine the economics and quality of gas which can be produced.

"Some plastics can be produced from field residues; to this extent petroleum and natural gas become available for other uses.

"For benefits to many segments of the country, investigations on converting agricultural field residues to liquid fuels for supplementing gasoline should be considered further for support by a number of organizations, possibly including the Federal government.

"It is not anticipated that agricultural residues would totally displace coal, natural gas, petroleum, or nuclear energy; however, it is clear from the technological point of view that agricultural residues can be effective supplements to traditional fuels.

"Uses of agricultural residues are environmentally favorable. New uses of residues may even encourage the production of more food with better economics for the World's hungry."

The basic twin problems to be overcome in the use of agricultural residues for energy or any other use are the same as for the production of fiber for paper, namely, the economics and technology of (1) collecting a bulky, low-density material from vast areas and (2) storage facilities to provide a year-round operation based on a once-a-year production of raw material. This requires research and engineering ingenuity.

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SECTION C

THE TEXTILE INDUSTRY

CONTENTS

CONTENTS

SECTION C

THE TEXTILE INDUSTRY

INTRODUCTION

From ancient times the renewable fibers, especially flax, silk, cotton and wool, have provided the basic materials for clothing, carpets, tents, wall hangings and other textile products. This continued to be the situation down through the centuries, until recently. During the past 25 years, the synthetic fibers have become formidable competitors to the natural fibers. This has been primarily the result of a massive research and development effort and an aggressive marketing program on the part of the petrochemical industry. Cheap and plentiful natural gas and petroleum were contributing factors.

It is usual to point out that the petrochemicals consume such a small part of our total petroleum needs that changes in demand for synthetic versus natural textile fibers would have little effect on overall U.S. petroleum consumption. This is correct as far as it goes, but Bowling (1975) points out that, "The real impact of a shift to petroleum based materials vs. renewable resource based materials may be more closely related to the proportion of petrochemicals consumed than to petroleum consumed. For example: man-made fibers consume approximately 1 percent of petroleum, but this is 29 percent of the petrochemicals. Consequently, changes in man-made fiber production have a major impact on availability of petrochemicals for other products. The expansion of petrochemical capacity to meet additional demands not only requires additional petroleum but requires considerable time for plant construction and large capital expenditures. These factors tend to increase the cost to consumers of not only energy but final end products.

"The recent Arab oil embargo illustrates the economic impact of marginal changes in both petroleum and petrochemicals. Additionally, the marginal change impact will likely increase as the world demand for petroleum increases and as the supply continues to decrease.

"Exports of agricultural products have been essential to help pay for the increasing costs of imported petroleum.

Cotton is a major agricultural export item. Production of agricultural fibers not only reduces somewhat the dependency on petroleum imports but helps to pay for the imported fuel through improved balance of trade."

The primary cause of lower cotton and wool consumption during the recent past has been the falling price level of the synthetic fibers, which, in turn, was brought about by the willingness of the chemical industry to conduct research, promote and market its tailor-made products aggressively enough to generate volume production. This was the major factor in bringing about price reduction for these heavily promoted products competing with commodities.

The growth in synthetic fibers is greater than the GNP growth but by 1980 this growth is expected to begin to parallel GNP growth. A recent study (Dudley 1974) projects total fiber consumption for textiles in 1985 at 82-90 lbs. per capita and cotton consumption at 14-18 lbs. per capita. Some gain in cotton per capita consumption is expected thereafter, estimated at 15-20 lbs. for the year 2000.

A unique feature of both cotton and wool is that their production is closely associated with the production of food and high quality protein. For each pound of wool there is produced about 3.22 lbs. of meat and for each pound of cotton, 1.75 lbs. of cottonseed, an important food source. With the present awareness of the need to feed a growing world population, the ability to produce both food and fiber from the same acreage is an important consideration.

In Table 1 on "Fuels and Electric Energy Consumed by the Textile Industry" data are given for the quantity and cost of purchased fuels by weaving mills using cotton, wool and synthetics, as well as for all textile mills. Other data on energy and other factors are given in the individual chapters.

The net energy required to produce a pound of cotton is 5 to 7 times less than for man-made fibers (National Cotton Council 1974) (see Appendix I to Chapter 1 on "Cotton"). The kilowatt-hours required to produce one pound of cotton fiber plus 1.75 lbs. of cottonseed are 3.36 compared to 16.32 to 20.42 for the man-made fibers. The net energy figure for the cotton fiber only is 2.86 kilowatt-hours per pound.*

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* For each pound of cotton lint there is also produced 1.75 lbs. of cottonseed which represents about 15 percent of the value. The net energy, therefore, on the basis of value, to produce one pound of cotton fiber becomes 2.86 kilowatt-hours.

TABLE 1

ELECTRIC ENERGY AND FUELS CONSUMED
BY TEXTILE INDUSTRY

1971

Code	Industry group and industry	Kilowatt-hours equivalent	Total cost	Fuel oil						Standard error of estimate (percent)[1] for column–	
				Total		Distillate		Residual			
				Quantity	Cost	Quantity	Cost	Quantity	Cost	B	D
		(billions)	(million dollars)	(1,000 barrels)	(million dollars)	(1,000 barrels)	(million dollars)	(1,000 barrels)	(million dollars)		
		Col. A	Col. B	Col. C	Col. D	Col. E	Col. F	Col. G	Col. H		
	All industries, total	3,332.4	5,360.6	245,667.2	989.3	104,940.8	453.4	140,726.4	535.9	1	1
22	Textile mill products	81.6	159.7	11,202.4	48.0	4,648.0	20.7	6,554.4	27.3	1	1
2211	Weaving mills, cotton	8.8	14.5	508.1	2.1	183.5	.9	324.6	1.2	1	6
2221	Weaving mills, synthetics	9.2	16.7	952.4	4.1	391.8	1.6	560.5	2.5	2	1
2231	Weaving and finishing mills, wool	3.1	6.6	742.7	3.1	202.4	.9	540.3	2.2	5	8
2241	Narrow fabric mills	1.1	2.1	178.7	.7	65.1	.3	113.6	.4	8	19

Code	Industry group and industry	Bituminous coal, lignite and anthracite		Coke and breeze		Natural gas		Other fuels	Fuels not specified by kind	Standard error of estimate (percent)[1] for column–	
		Quantity	Cost	Quantity	Cost	Quantity	Cost			J	N
		(1,000 short tons)	(million dollars)	(1,000 short tons)	(million dollars)	(billion cu. ft.)	(million dollars)	(million dollars)	(million dollars)		
		Col. I	Col. J	Col. K	Col. L	Col. M	Col. N	Col. O	Col. P		
	All industries, total	61,392.6	658.1	13,742.8	317.6	6,454.4	2,559.9	377.5	458.2	1	1
22	Textile mill products	1,545.8	20.5	(S)	(Z)	100.7	53.3	9.7	28.3	1	1
2211	Weaving mills, cotton	354.5	4.3	(S)	(Z)	11.8	5.5	.1	2.6	1	1
2221	Weaving mills, synthetics	267.6	3.4	(S)	(Z)	12.4	6.3	.2	2.7	1	1
2231	Weaving and finishing mills, wool	31.8	.6	-	-	2.3	1.2	.6	1.1	4	10
2241	Narrow fabric mills	3.8	.1	-	-	1.2	.7	.1	.6	27	9

Source: 1972 Census of Manufactures, U.S. Department of Commerce.

Wool most probably requires even less energy than cotton, so that natural fiber production is much less energy-consuming than the production of man-made fibers.

A recent study (National Cotton Council 1974) of the amount of energy required to spin the fibers into yarns, weave or knit the yarn into cloth, and finish the cloth, showed that processing cotton into cloth did not involve any significant energy penalty, and that cotton's advantage in fiber production remained intact up to the finished product. This study took into account the different processing waste percentages and fabric weights for each class of textile fiber. Cotton was assigned an average processing loss of 11-1/2 percent and man-made fibers 1-1/2 percent. The average weight of cotton broadwoven fabric was 0.30 lb./sq.yd., compared to 0.26 lb./sq.yd. for man-made fabrics. These factors were included in the energy requirement to assure that cotton and the man-made fiber fabrics were compared on an equal "replacement" basis.

REFERENCES CITED

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3 National Cotton Council of America (1974a) Textile Fibers and Energy Consumption - An Update, Memphis, Tenn.

4 National Cotton Council of America (1974b) The Energy Crisis and Textile Fabrics - Some Considerations. Memphis, Tenn.

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CHAPTER 1

COTTON

INTRODUCTION

The cotton plant provides a relatively pure cellulose fiber of excellent morphological structure. It is a superb fiber whose virtues as a luxury fiber for spinning into textiles were recognized thousands of years ago by ancient Egyptians, Hindus, Pueblo Indians, Incas and others. Flax, wool and silk were the other major renewable fibers of early history. Cotton came into its own on a volume production scale in the U.S. with the invention of the cotton gin in 1793. Thereafter, cotton played a greater role in the economy and politics of the world than any other commodity. The relative importance of its role is now reduced by competition from synthetic fibers, but it is still a major agricultural and industrial commodity of worldwide importance.

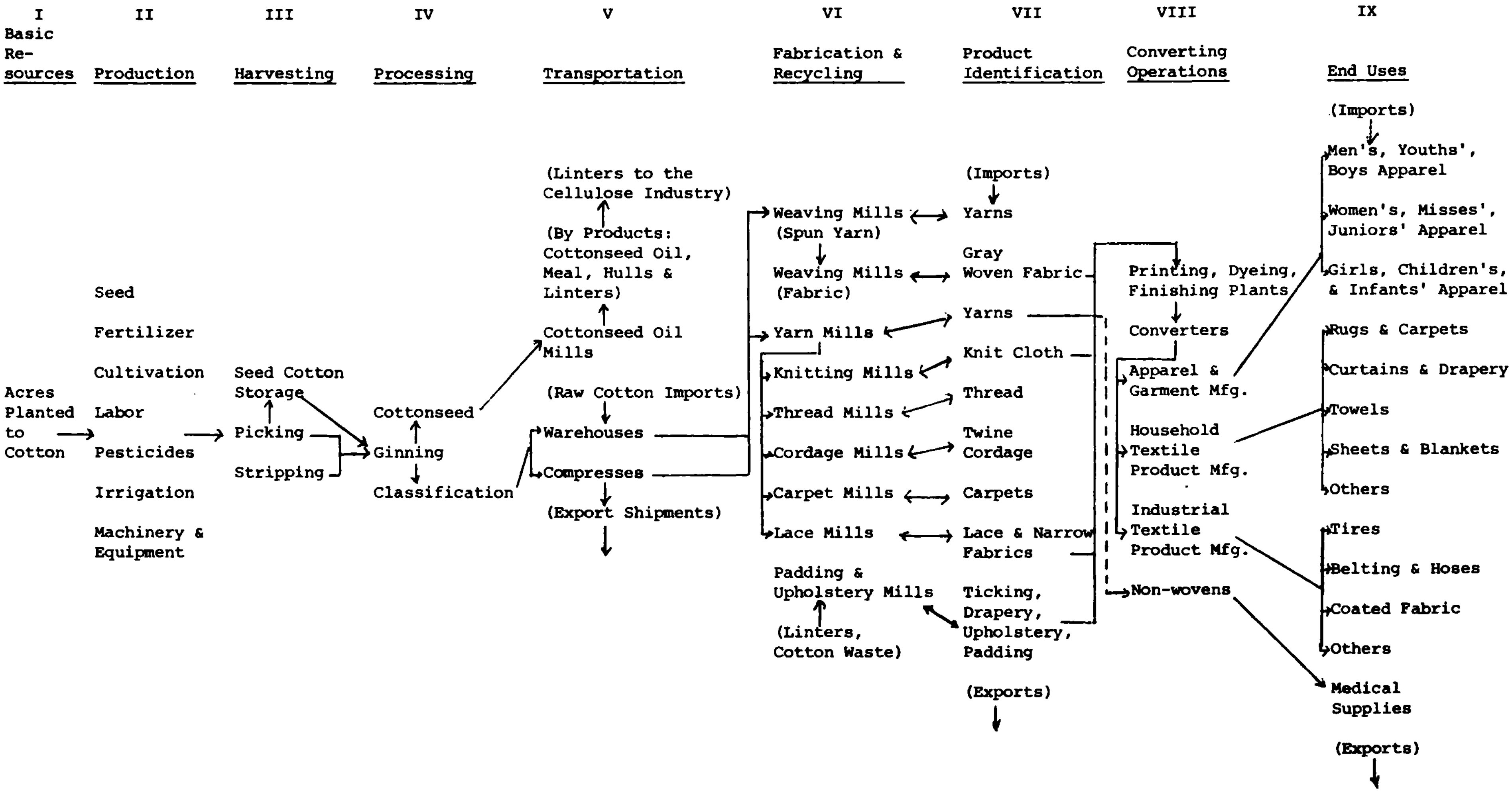
The materials flow for cotton production and manufacture is based on data for the year 1972. In addition to the data presented in outline form, the relationships are also shown on a flow chart in the form of a reference materials system (RMS) (Figure 1).

On the chart, the nonwovens are indicated as only coming from yarns, because the Census data only provides information on nonwovens as coming from this source. This will provide the best statistical information available on this item.

Projections for 1985 and 2000 are listed in tabular form. Following the data is a brief explanation of the assumptions and methodology used in each computation. The agricultural industry of the U.S. has the capability to produce the amount of cotton which will be demanded in the marketplace. Therefore, the demand projection is of critical importance in projecting the quantity and cost of production and processing, as well as the end product quantities to be consumed.

FIGURE 1

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES -- COTTON



The projected per capita demand for the low, medium, and high scenarios for 1985 and 2000 were used as a framework to develop the breakdown of the materials flow chart information up to the fabrication level. Beyond this point the number of technological, economic, and political changes that could occur is tremendous and their identification and determination of effect complicated. The total end result would likely be little different from the total figure for projected demand. It is suggested that the material flow data be extended proportionately through the end uses.

The materials flow projection for cotton production and consumption for 1985 ranges from 10.9 to 12.8 million bales for low to high economic scenarios. Comparable projections for the year 2000 range from 13.3 to 16 million bales. These levels of cotton consumption, and the cotton production to provide for this consumption, can be considerably altered by technological developments, resource availability and efficiency, environmental impact, and by government policy and administration. The research that is provided and the management of the above functions will determine the future availability of cotton as a renewable resource.

The perturbations likely to occur, which would significantly influence cotton's future availability as a renewable resource, are so closely interrelated with research, technology, economics, and regulatory aspects that they are discussed jointly with respect to each perturbation.

MATERIALS FLOW FOR COTTON PRODUCTION AND MANUFACTURE 1972

OUTLINE

I. Cotton Production--Basic Resources Through Bale Processing and Transportation

A. 1972 Base Data

Acres planted to cotton--14 million; acres harvested--12.98 million
Seed used--180,000 tons
Fertilizer--1.5 billion pounds nutrient materials
Labor--307 million man-hours
Pesticides--112 million pounds active ingredients
Irrigation--3.44 million acres irrigated
Picking--9.32 million bales machine picked
Stripping--3.95 million bales stripper harvested
Ginning--13.27 million bales ginned (495.7 lbs. average net weight)
Cottonseed--5.44 million tons produced

B. Energy Consumption

Total fuel and electricity used through ginning--3.30 kWh/lb. lint (no energy allocated to seed)*

C. Labor Requirements

Total labor used through harvesting--307 million man-hours
Total labor used in ginning--11 million man-hours

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* See Appendix I, "Textile Fibers and Energy Consumption - An Update", National Cotton Council of America, Memphis, Tenn., June 1974.

D. Cost Per Unit, Annual Basis

	U.S. Average Cost Per Bale-1972
Labor	$ 21.16
Power and Equipment	39.46
Seed	3.99
Fertilizer	9.94
Pesticides	14.44
Custom Services	10.23
Irrigation	10.08
Interest	2.53
Land	30.97
General Overhead	11.33
Subtotal	$154.13
Less Cottonseed Value	-19.64
Plus Ginning Charges	21.35
Total Cost per Bale of Lint	$155.84

E. Co-products and By-products

For every bale of cotton lint produced, there are also produced about 825 pounds of cottonseed.

In 1972, 4.26 million tons of cottonseed were crushed at cottonseed oil mills. By-products totaled: 1.92 million tons of cottonseed meal; 1.05 million tons of hulls; 760.6 million pounds of linters; and 1,355.2 million pounds of crude cottonseed oil.

Each acre of cotton produces annually some 16.5 tons of oxygen, while removing 22.7 tons of carbon dioxide from the air.

F. Production, Imports, and Exports

Cotton lint: 13.27 million bales produced
74,000 bales imported
3.3 million bales exported

Cottonseed: 5.44 million tons produced
10,000 tons exported

Cottonseed Products:

Oil: 1,355.2 million pounds produced
475.7 million pounds exported

Meal and Hulls: 2.97 million tons produced
4,000 tons imported
40,000 tons exported

Linters: 761 million pounds produced
32 million pounds imported
102 million pounds exported

II. Cotton Product Production--Fabrication Through Converting

A. 1972 Base Data

Weaving mills and yarn mills--3.8 billion pounds of raw cotton consumed, average processing loss 12-1/2 percent

Yarn production--
- 3.34 billion pounds, total
- 2.55 billion pounds, weaving yarns (except carpet)
- 616 million pounds, machine knitting yarns (except carpet)
- 19 million pounds, carpet and rug yarns
- 32 million pounds, cordage and twine
- 66 million pounds, thread
- 57 million pounds, all other uses (including tufting)

Gray cloth production--
- 5665.9 million linear yards, cotton broad-woven goods
- 550 million pounds of cotton knit fabrics
- 83 million pounds of narrow cotton fabrics

Cotton linters--
200.3 million pounds, mattresses and bedsprings
108.9 million pounds, padding and upholstery
83.3 million pounds, upholstered furniture

Cotton waste--
- 146.2 million pounds, padding and upholstery
- 74.6 million pounds, textile waste processing

Cloth finishing--5398.8 million linear yards finished cotton broadwoven

Apparel and garments--1.48 billion pounds of cotton materials

Household textile products--1.27 billion pounds of cotton materials

Industrial textile products--524 million pounds of cotton materials

B. Energy Consumption

Yarn production--2.58 kWh/lb.
Gray cloth production--2.96 kWh/lin. yd.
Cloth finishing--3.32 kWh/lin. yd.

C. Costs of Production

Yarn production:
- $0.442 per pound yarn for materials
- 1.3¢ per pound yarn for fuel

Gray cloth production:
- $0.266 per linear yard for materials
- 1.1¢ per linear yard for fuel

Finished fabric production:
- $0.089 per linear yard for materials

0.8¢ per linear yard for fuel

D. Production, Imports, Exports

Yarn: 3.34 billion pounds produced
39.4 million pounds imported
17.9 million pounds exported

Cloth: 2.5 billion pounds produced
313 million pounds imported
174 million pounds exported

III. Cotton End Uses

A. 1972 Base Data

Imports--536,800 cotton bale equivalents (480#) of cotton manufactures
Men's, youths' & boys' apparel--2.26 million c.b.e.'s
Girls', children's & infants' apparel--471,940 c.b.e.'s
Women's, misses' & juniors' apparel--708,900 c.b.e.'s
Rugs & carpets--105,520 c.b.e.'s
Curtains & drapery--395,490 c.b.e.'s
Towels--713,100 c.b.e.'s
Sheets & blankets--638,280 c.b.e.'s
Other household uses--974,320 c.b.e.'s
Tires--25,660 c.b.e.'s
Belting & hoses--65,710 c.b.e.'s
Coated fabric--253,440 c.b.e.'s
Other industrial uses--716,800 c.b.e.'s
Medical supplies--120,120 c.b.e.'s
Exports--195,900 c.b.e.'s of cotton manufactures

PROJECTIONS FOR 1985 AND 2000

Projection summaries for cotton for the years 1985 and 2000 are given in Tables 1 and 2, respectively. These cover demand, exports, inputs for production, energy consumption, labor requirements, cost of production and co-products and by-products.

TABLE 1

COTTON PROJECTION SUMMARY FOR 1985

	Low	Medium	High
Per capita cotton demand (lbs.)	14	16	18
Population (1,000,000)	235	235	235
Domestic demand (millions of 480-lb. bales)	6.86	7.85	8.83
Exports (millions of 480-lb bales)	4.00	4.00	4.00
Total demand (millions of 480-lb. bales)	10.86	11.85	12.83
Yield per harvested acre (lbs.)	515	515	515
Abandonment (%)	5	5	5
Planted acreage (millions)	10.13	11.04	11.96
Harvested acreage (millions)	9.62	10.49	11.36
Inputs for production			
Fertilizer (millions nutrient lbs.)	1,116	1,217	1,317
Fuel (million gallons)	246	268	290
Pesticides (million lbs. active ingredients)	68.5	74.7	80.9
Seed (tons)	126,587	138,014	149,441
Labor (million man-hours)	127	139	150
Irrigated acreage (millions)	3.30	3.59	3.89
Harvesting (millions of 480-lb. bales)	10.87	11.85	12.83
Ginning (millions of 480-lb bales)	10.87	11.85	12.83
Cottonseed (millions tons)	4.48	4.89	5.29
Energy consumption			
Total energy consumed through ginning (billions BTU)			
Fuel	31,920	34,774	37,629
Fertilizer	2,051	2,237	2,421
Pesticides	783	854	924
Irrigation	13,038	14,184	15,370
Ginning	1,669	1,819	1,970
Total	49,461	53,868	58,314
BTU per lb. lint	9,488	9,470	9,469
Kw. hr./lb. lint	2.781	2.776	2.775
Labor requirements			
Total labor through harvesting (million man-hours)	127	139	150
Total labor used in ginning (million man-hours)	9.47	10.33	11.19

COTTON PROJECTION SUMMARY FOR 1985 (Cont'd)

	Low	Medium	High
Cost of Production			
Total cost per harvested acre of producing lint and seed	$250	$322	$413
Cost of producing a pound of lint adjusted for seed value at $150/ton	.36	.50	.67

Co-products and by-products

For every 480-pound bale of cotton produced, it is assumed that there are also 825 pounds of cottonseed. Historical yield relationships between the tons of cottonseed crushed and derived products are as follows:

Product	Percentage
Oil	16.4
Meal	46.3
Hulls	23.6
Linters	9.2
Loss	5.6
	100.0

Sources: National Cotton Council of America, Economic Research Division.

U.S. Department of Agriculture (1972) Economic Research Service, Fats and Oils Statistics, Statistical Bulletin, No. 489.

TABLE 2

COTTON PROJECTION SUMMARY FOR 2000

	Low	Medium	High
Per capita cotton demand (lbs.)	15	17.5	20
Population (1,000,000)	264	264	264
Domestic demand (millions of 480-lb. bales)	8.26	9.64	11.02
Exports (millions of 480-lb. bales)	5.0	5.0	5.0
Total demand (millions of 480-lb. bales)	13.26	14.64	16.02
Yield per harvested acre (lbs.)	540	540	540
Abandonment (%)	4	4	4
Planted acreage (millions)	12.28	13.56	14.83
Harvested acreage (millions)	11.79	13.01	14.24
Inputs for production			
Fertilizer (millions nutrient lbs.)	1,368	1,510	1,652
Fuel (million gallons)	286	316	346
Pesticides (million lbs. active ingredients)	60.9	67.2	73.5
Seed (tons)	153,514	169,454	185,395
Labor (million man-hours)	128	142	155
Irrigated acreage (millions)	3.46	3.82	4.18
Harvesting (millions of 480-lb. bales)	13.26	14.64	16.02
Ginning (millions of 480-lb. bales)	13.26	14.64	16.02
Cottonseed (millions tons)	5.64	6.22	6.81
Energy consumption			
Total energy consumed through ginning (billions BTU)			
Fuel	37,123	41,017	44,911
Fertilizer	2,514	2,775	3,036
Pesticides	696	768	840
Irrigation	13,671	15,093	16,516
Ginning	2,035	2,248	2,460
Total	56,039	61,901	67,763
BTU per lb. lint	8,804	8,809	8,812
Kw. hr./lb. lint	2.58	2.58	2.58
Labor requirements			
Total labor through harvesting (million man-hours)	128	142	155
Total labor used in ginning (million man-hours)	8.26	9.12	9.98

COTTON PROJECTION SUMMARY FOR 2000 (Cont'd)

	Low	Medium	High
Cost of production			
Total cost per harvested acre of producing lint and seed	$311	$496	$783
Cost of producing a pound of lint adjusted for seed value at $190/ton	.41	.75	1.28

EXPLANATION FOR COTTON PROJECTIONS TO 1985 AND 2000

Per Capita Cotton Demand

Cotton consumption on a per capita basis has been trending downward since 1942 when per capita consumption was 40.2 pounds. Per capita consumption in 1972 was 19.9 pounds, and the 1970-74 weighted average was 18.95 pounds. An economic analysis (Dudley 1974) projected per capita cotton consumption from 14-18 pounds for 1985. This range was selected for use in this projection.

The range for the year 2000 was increased to 15-20 pounds. The primary reason for the higher range was the 155 percent increase in real per capita income between the year 1972 and 2000 given in the economic parameters.

Exports

Exports were taken to be 4 million bales in 1985 and 5 million bales by 2000. These estimates are based on the assumption that foreign countries will continue to have an increasing level of demand for feed and food crops, and this will constrain cotton production.

Yields

Yield per harvested acre is projected to be 515 pounds by 1985 and 540 pounds by 2000. The 1972 average was 507 pounds, whereas the 1972-74 weighted average was 489 pounds. The increases are only modest and are based on the assumption that cotton production will continue to be concentrated in the hands of the more efficient producers, and that new technology will be adopted to increase yields.

Fertilizer

The application rate of fertilizer was assumed to remain about the same in the future. Cotton acreage has received 116 pounds of nutrients per acre (U.S. Department of Agriculture 1974a)--58 pounds of nitrogen, 32 pounds of phosphates (P_2O_5), and 26 pounds of potassium (K_2O).

Fuel--(Gasoline, Diesel, and L. P. Fuel)

Cotton used 26.7 gallons per acre of these fuels in 1973, and a USDA report projected a usage rate of 26.9 gallons by the year 1980 (U.S. Department of Agriculture 1974b). There is an emerging trend toward minimum tillage and fuel conservation due to the recent price increases and expected increases for the future. There is also a trend toward the use of more diesel-powered equipment, which is more efficient than gasoline. For these reasons, fuel usage by 1985 was taken to be 95 percent of the 26.9 gallons, or 25.56 gallons per harvested acre. For the year 2000, another improvement in fuel usage was assumed, and the rate was taken to be 24.28 gallons per harvested acre (95 percent of 25.56). The percentage breakdown on fuel for 1985 and 2000 was 75 percent diesel, 5 percent gasoline, and 20 percent L. P. fuel.

Pesticides

A survey of pesticide usage by farmers in 1971 indicated that 9 pounds of active ingredients were used on each acre of cotton (Andrilenas 1972). These pesticides were: .02 pounds of fungicides, 1.59 pounds of herbicides, 5.96 pounds of insecticides, and 1.52 pounds of defoliants and fumigants. The application rate per acre varied greatly from region to region. Application rates per planted acre were made to 1985 and 2000 based on two assumptions. First, acreage has been shifting away from areas that are the heaviest users of pesticides. This trend is expected to continue. Second, new varieties of cotton will likely be available that will reduce the use of certain classes of pesticides, and better management systems will likely be employed that will also reduce the pesticide usage per acre. The 1985 application rate utilized was 6.76 pounds per planted acre (65 percent of the 1971 rate in each region for insecticides and 95 percent for other pesticides), and the rate for the year 2000 was 4.96 (50 percent of the 1971 rate for insecticides and 90 percent for other pesticides).

Seed

Seed usage was taken at the historical average of about 25 pounds per planted acre.

Labor (Production)

The hours of labor per harvested acre in 1972 was 15.55. An improvement of 15 percent was used to arrive at a figure of 13.22 hours/harvested acre for 1985. An improvement of 30 percent over the 1972 level was assumed for the year 2000--giving a rate of 10.89 hours/harvested acre. The reasons for the improvements are the trend toward minimum tillage and expected improvements in both herbicides and insecticides.

Irrigated Acreage

Irrigated acreage is currently about 28 percent of the total cotton acreage in the U.S. This acreage is expected to increase to 32.5 percent by 1985, but decline to 28.2 percent by 2000. The reason for the decline is the falling water table in the High Plains of Texas.

Cottonseed

The relationship between the pounds of cotton lint and cottonseed was taken to be 1.72 pounds of seed per pound of lint 985 and 1.77 pounds of seed per pound of lint in the year 2000. The increase is expected because of the increasing level of demand for protein and the expanding uses of seed. It will be possible for cotton breeders to alter the lint-seed ratio. In the past, they have attempted to lower the ratio, but future expectations are for this to be reversed.

Energy Consumption

The following Btu equivalents were taken per unit of input:

Input	Btu/Unit 1985	Btu/Unit 2000
Fuel (gallon)	129.8	129.8
Fertilizer (pound)	1,838	1,838
Pesticides (pound)	11,430	11,430
Irrigation (acre)	3,951,096	3,951,096
Ginning (bale)	153,540	136,480

Labor Requirements

Production (see Labor)

Ginning

Ginning required 1.25 man-hours per bale in 1972. There is an emerging trend toward more automation in the ginning process, and this will reduce the labor requirement. High-speed gins with automatic compression and strapping will utilize modules of cotton rather than wagon loads.

Man-hour efficiency was, therefore, projected to improve to .872 man-hours/bale in 1985 (a 30 percent improvement over 1972) and to .623 man-hours/bale in 2000 (a 50 percent improvement over the 1972 level).

Cost of Production

The cost of producing an acre of cotton lint and the associated seed was $193 in 1972, $268 in 1974, and is estimated to be $279 in 1975. The cost per harvested acre increased 54 percent from 1964 to 1975, but the largest portion of the increase occurred between 1973 and 1974 as the cost of inputs escalated to a much higher level. Cost is typically expressed on a per pound of lint basis, so the usual method is to subtract the value of the cottonseed from the total cost and then divide by the yield to obtain the per pound cost of producing lint. The 1972 total cost per acre was projected to 1985 and 2000 by a 2 percent, 4 percent, and 6 percent compound rate, corresponding to the low, medium, and high categories. Cottonseed was valued at $150/ton in 1985 and $190/ton in the year 2000.

RESEARCH

An examination of the current research being conducted on cotton and on future cotton research needs was performed in 1973-74 by scientists from all segments of the cotton community. Their findings were published in The 1973 National Cotton Research Task Force Report, a study by the National Cotton Council of America.

Cotton research can be classified into three major categories: cotton pests; production and processing; utilization and marketing. Expenditures on cotton research in 1972 were $30 million and required 492 scientific man years. Specific research expenditures and scientific manpower within each category is presented in Table 3. Financial support of $30 million represented approximately 1.13 percent of the value of cotton lint, cottonseed, and government payments in 1972. Research manpower and financial support is approximately equal in each of the three major research areas. Insect control, breeding and improvement, and fiber and cottonseed utilization subcategories received primary attention.

Broadly stated, the Task Force study showed that cotton needs intensive research in five areas:

TABLE 3

RESEARCH INVESTMENTS FOR COTTON

Research Program	Research Manpower		Financial Support[2]	
	SMY[1]	% of Total	Public % of Total	Producers % of total
Cotton Pests	(160)	(33)	(37)	(16)
Insects	102	21	26	6
Disease & nematodes	41	8	8	6
Weeds	17	4	3	4
Production & Processing	(152)	(30)	(30)	(48)
Breeding & improvement	99	20	19	33
Mechanization & management	46	9	10	13
Pollution & dust	7	1	1	2
Utilization & Economics	(180)	(37)	(33)	(36)
Fiber & cottonseed	151	31	27	30
Marketing & economics	29	6	6	6
Totals	492	100%	100%	100%

[1]SMY - Scientific Man Years

[2]State Experiment Station and USDA funds were $29,522,000 in 1972, while producer commodity groups and grower associations contributed $1,219,000 in 1972.

Source: National Cotton Council of America (1973).

1. To increase efficiency in producing, handling, and processing.
   Increased efficiencies are needed in all operations of the cotton industry to keep it viable and strong. In production, for example, greater efficiency to reduce costs is essential in meeting fiber price competition and in providing incentives to produce adequate supplies.

2. To improve, preserve, and deliver quality.
   The improvement and the protection of cotton are necessary to facilitate efficiencies in processing operations, and to meet more stringent quality specifications for both old and new products.

3. To develop new and improved products.
   New products and new performance qualities are the fundamental basis of man-made fiber competition with cotton. Increased research is especially needed to (a) improve the processing efficiency and performance characteristics of cotton in knitting and nonwoven application and (b) impart such key functional properties as durable press and flame retardancy to knitted, woven, and nonwoven fabrications without sacrificing other desirable qualities such as comfort.

4. To enhance the quality and processing of cottonseed and its products for food, feed, and industrial uses.
   For each pound of fiber produced, the cotton plant yields nearly two pounds of cottonseed with a feed roughage-vegetable oil-protein ratio of about 2:1:1. Accelerated research is necessary to further improve and develop these uses--especially to meet increased world needs for protein foods and feeds.

5. To meet special requirements relating to worker safety and health, consumer protection, and environmental quality.
   Public concern in recent years about pollution, safety, health, and related matters is resulting in increased government standards and regulations which affect significantly many cotton industry operations and products. A stepped-up, concerted, coordinated research effort is necessary to provide the industry with practical methods and procedures for solutions to many new problems of

this nature. Problems relating to byssinosis, fabric flammability, pollution and waste control, pesticides, and noise control are especially urgent.

The 1973 Cotton Task Force also identified eight high priority research concerns for the future. These were as follows:

1. Modify fiber properties to meet requirements of new textile technology.
2. Improve fiber use for specific end-uses such as fire retardant fabrics and knitted fabrics of cotton or high level cotton blends.
3. Pest management research for improved and lower cost insect, disease, and weed control resulting in increased productivity. This area would include nutrition, mass rearing and sterilization of the boll weevil for use in an eradication program and the development of integrated pest management systems for control of diseases, weeds and insects.
4. Cottonseed research for food and feed that would improve cottonseed and products made from cottonseed.
5. Energy conservation in cotton production by the development of cultural and chemical practices to reduce energy requirements in cotton production, harvesting, and processing activities without reducing productivity.
6. Reduction of the pollution potential in cotton production and processing. Specific areas designated were the dust-particulate matter from ginning and processing, chemical residues from fiber-textile processing, and pesticide residues, residuals and container disposal.
7. An improved information system that would provide data on supply, demand, and prices for cotton, cottonseed, man-made fibers, and textiles.
8. Improved cotton plant efficiency that would result in an increase in the quantity and improve distribution of the plant components into yield of fiber and seed.

These eight categories were the research areas the Task Force felt were critical research needs for the future. Table 3 summarized the research investment for cotton by research programs for 1972. The total USDA and state experiment station expenditures were $30 million, but total research funds from all sources combined are estimated at about $40 million. This compares to research expenditures by the man-made fiber industry of approximately $150 million per year. This gap is obviously a great obstacle for cotton.

Recognizing the need for expanded research, the Task Force identified priority areas and recommended a 40 percent increase in the level of Scientific Man Year activity. Table 4 identifies the recommended increases for the same research program categories that are presented in Table 3. The largest percentage increases are recommended for pollution, dust, marketing, and economics.

Changes since 1972 in the energy situation and in the governmental regulation area will have a major impact on the direction and emphasis that are needed in cotton research. The increased cost of energy in 1973, 1974, and into 1975, has greatly increased the cost of producing cotton. Cotton requires more energy to produce than other competing crops, although not as much as synthetic fibers require on a pound-for-pound basis. In order to compete for scarce resources at the production level and also to compete in the textile market, cotton will need to develop cultural and chemical practices to reduce production energy requirements.

TABLE 4

SUMMARY OF COTTON RESEARCH ACTIVITY IN RESEARCH PROGRAM AREAS AT CURRENT AND RECOMMENDED LEVELS OF SCIENTIFIC MAN-YEARS (SMY) OF EFFORT

Research Program	Research Manpower Current SMY Effort	Research Manpower Recommended SMY Effort	Percent Increase
Cotton Pests	(160)	(208)	(30)
Insects	102	115	13
Diseases and Nematodes	41	63	54
Weeds	17	30	76
Production and Processing	(152)	(217)	(43)
Breeding and Improvement	99	118	19
Mechanization and Management	46	54	17
Pollution and Dust	7	45	543
Utilization and Economics	(180)	(266)	(48)
Fiber and Cottonseed	151	206	36
Marketing and Economics	29	60	107
TOTALS	492	691	40

SOURCE: National Cotton Council of America (1973)

PERTURBATIONS

The potential for change is great in an industry as large and complex as cotton. Of all the fibers used in our society, more cotton is consumed than any other textile fiber, and more cotton is exported than any other fiber. Cotton serves the apparel, domestic, and industrial goods markets. It is produced by the farmer and processed, sold, or stored by ginners, cottonseed crushers, cotton merchants, cooperatives, warehouses, and textile manufacturers. The perturbations that may occur are numerous. Some changes which presently appear likely to occur and which could have a major impact on the industry are discussed here.

For cotton to continue as a viable renewable resource through 1985 and 2000, it must maintain a price low enough to compete with other fibers in textile products, yet high enough to compete with other agricultural crops for land resources. Success, understandably, will require that costs be minimized.

Opportunities exist to reduce the cost of producing, processing, and manufacturing cotton goods, as well as to improve its utility to the consumer. Additionally, we have societal problems of significance, such as energy shortages, regulatory functions, and national defense, which must be considered. The perturbations which follow cover first the production functions, then processing and fabrication, followed by societal concerns.

Cotton Production

There are several research categories that offer potential and should become reality within the 1985-2000 time frame or before. Among the more promising areas are minimum tillage, insect resistant cotton, modular system of seed cotton handling, and high speed automated ginning.

Minimum Tillage

Minimum tillage is a system that is modified from the conventional tillage system in order to reduce the traffic through the field and thereby reduce the energy inputs and the cost of production (Reeves 1975). Soil preparation entails two major objectives: (1) break up impermeable soil layers, and (2) provide an adequate seedbed. The amount and type of tillage required to provide an adequate seedbed is a function of the soil type, the climatic conditions, and the weed and grass problems. The conventional tillage system varies from state to state, but on the average requires 10.66 trips through the field. These operations generally include shredding, pre-plow disking, plowing or chiseling, 3 or 4 post-plow diskings, bedding, 1 or 2 bed conditionings, planting, and 2 to 4 cultivations.

Minimum tillage systems would eliminate some of these operations and the average number of trips through the field could be reduced to 7.64, or a savings of 3.02 trips. Fewer trips would effect savings in labor, fuel, equipment maintenance, and equipment depreciation.

Research at the Delta Branch of the Mississippi Agricultural and Forestry Experiment Station has determined that minimum tillage, in addition to lowering the cost per acre by about $6, would increase average yield about 5 percent (Cooke and Spurgeon 1974). Using an average yield on light textured soils in the Mississippi Delta at 700 pounds of lint per acre would translate into an additional 35 pounds of lint and 60 pounds of cottonseed. Valuing lint at 45 cents a pound and seed at $120 per ton would mean an additional $19.35 to income. The reduction in production cost added to the increased revenue indicates it would be about $25 an acre more profitable to use the minimum tillage method rather than the conventional seedbed preparation. Problems still need to be worked out through research to make minimum tillage applicable to varying soil and climate conditions.

Another variation of the conventional tillage system is the No-Till system (Progressive Farmer 1975). This system eliminates plowing and cultivation operations and relies on chemicals for weed control. There are herbicides under review that can make this a real possibility on the heavier clay type soils. The potential cost savings may be $20 to $25 per acre.

In general, it appears that minimum tillage and variations of minimum tillage may represent a 5 to 10 percent potential reduction in production cost.

Insects and Plant Breeding

Insect control is one of the most important factors in efficient cotton production. Losses in yield and quality to insects, plus the cost of control methods, are expensive. The potential advantages from most other improved production practices may be greatly reduced or completely nullified unless insects are controlled. The best control measures available depend heavily on the use of chemicals and require careful management and strict attention to details such as species and abundance of insects and mites present, production potential of the crop, and proper timing and thorough application of insecticides. Yet these measures, even when correctly applied, fall far short of being adequate.

No less than 100 species of insects and spider mites are known to attack cotton, 47 of which are economically important pests in one or more states. The crop is subject to attack from the seedling state to complete maturity. The insects and mites involved represent an extremely wide variation in biology, ecology, host-plant relationship, feeding habits, and in the nature and extent of damage to cotton. About half of the species occur throughout most of the Cotton Belt, and the others are more or less confined to either the Rain Belt or the irrigated West.

It is estimated that during the past 50 years, insects have destroyed an average of about one bale of cotton for every eight bales harvested--or the equivalent of one entire crop out of every nine planted. In 1967, it was estimated that yield and quality losses were averaging about $350 million annually and that farmers were spending no less than $150 million annually for insecticides and their application (National Cotton Council 1967). These costs and losses together averaged around $500 million annually. This was at the mid 1960s price levels, so the amount would be higher at today's higher fiber prices and chemical, machinery, and labor costs. Thus, even moderate success in developing more efficient and inexpensive methods of insect control can reduce the cost of cotton production.

The development of insect resistance to insecticides is a severe and growing problem. Adequate insect control now requires more insecticide applications and the process of genetic selection for resistance to insecticides is speeded up accordingly. Furthermore, modern production practices have extended the growing season for cotton. Thus one or more additional generations of insects are subjected to chemical application each year. The expanded use of broad spectrum insecticides during a prolonged cotton growing season greatly reduces the populations of parasites and predators. Such reduction often allows increased populations of certain pest species that are usually suppressed and sometimes completely controlled by parasites and predators. This applies particularly to the bollworm, tobacco budworm, spider mites, and aphids. This situation requires the use of more insecticides throughout the growing season.

It is now quite clear that the future of conventional chemical control, as currently practiced, is seriously threatened and could prove disastrous to the cotton industry unless new approaches can be developed soon that are not wholly dependent upon present procedures. There is good reason to believe that new approaches will be developed through comprehensive research programs. Cotton pest management programs encourage producers to take full advantage of naturally occurring beneficial insect populations and to time insecticide applications carefully using pest population numbers and the appearance of economic damage as key indicators. This system replaces the practice of applying insecticides on a time table and thereby cuts costs and reduces the insecticide load.

New varieties of cotton that possess higher levels of insect resistance will likely be on the market in the near future. Seed men hope that within two to three years they will be able to offer varieties with higher levels of insect resistance. Within five years they may be able to unlock some mysteries that will permit breeders to develop varieties with excellent resistance to most serious cotton pests. The resistant varieties will not solve all insect problems, but they will permit more flexibility in management of the cotton crop and will result in lower production costs.

It is of course difficult to specify what the cost saving potential might be because one must consider both improvements in yield (eliminate a portion of the 10 percent yield loss) and a lowering of the production cost by using less chemicals, machinery and labor. It might be reasonable to expect a fourth of the yield loss to be eliminated (lowering of the loss to 7-1/2 percent) and the elimination of 50 percent of the insecticide treatments. In fact, the shifting of acreage to areas that have less insect problems will lower the insecticide load. This has been the trend of recent years and will likely continue into the future; so a 50 percent reduction in insecticide use on cotton does seem reasonable. In 1971, insecticide use on cotton was 73.3 million pounds of active ingredients which represented 47 percent of the total farm use of insecticide on crops. A 50 percent reduction from this level would yield significant environmental benefits. In terms of improvement in the cost of producing cotton, insect resistant cotton would reduce the per pound cost of production by 5 to 10 percent. This would occur if the yield loss is reduced to 7-1/2 percent and the insecticide cost is lowered 50 percent.

Plant Diseases

Direct yield losses from plant diseases increased steadily from 10.65 percent in 1956 to 16.91 percent in 1961 and since then have remained relatively constant at about 15 percent (National Cotton Council 1967). In addition to these yield reductions, direct losses are sustained from lowered lint and seed quality and from cost of chemicals used for disease control. Indirect losses occur from (a) the substitution of resistant varieties which, on disease-free soil, do not equal the yield and quality of otherwise adaptable but non-resistant varieties; (b) long-time rotations which permit the use of cotton (the highest profit crop in the rotation) too seldom; (c) the use of cultural practices which reduce efficiency of other operations; and (d) the effects of using poor quality planting seed.

Quality losses, costs associated with chemical applications, and indirect losses approach the magnitude of the direct yield losses from plant diseases. While it is unrealistic to assume that development of adequate controls for each disease would eliminate all of this loss, most authorities agree that adequate exploitation of the potentials of modern science and technology could reduce these costs and losses. A rough figure might fall around 5 percent improvement in the cost of producing a pound of lint--which would be a combination of cost reduction and yield improvements.

Processing

Ginning and Marketing

A substantial sum is added to the mill cost of cotton after harvesting. The main components of this off-farm cost are in ginning, warehouse-compressing services, marketing costs, and transportation.

In many areas, harvesting proceeds so rapidly that it outruns the capacity of gins; and seed cotton must be stored on gin yards in trailers or other containers for appreciable time periods. Use of the cotton module builder or cotton ricker eliminates the bottleneck at the gin by allowing farmers to store their seed cotton as it is picked. This means they do not have to wait for trailers and can operate their pickers at full capacity during suitable weather. The more rapid harvest will eliminate some yield loss which normally results from weather problems. Also, by eliminating the need for many expensive trailers, these systems of seed cotton handling can reduce cost.

Greater automation of all stages in handling and storing seed cotton at the gin and gin yard can lead to reduced labor costs in the overall ginning operation. Labor costs will undoubtedly be an increasingly important element of total ginning costs because of changes in federal wage regulations recently enacted. If, for example, automatic lifting equipment is employed to dump a whole trailer of cotton into a hopper, the necessity of employing a person to operate a "suck pipe" to unload each trailer is eliminated.

Automatic feeding systems for cotton modules also reduce the labor requirement.

The primary function of the ginning operation is separating the cotton lint from the seed. There are opportunities for cost savings in ginning and related operations. In recent years, the charges for ginning a bale of cotton have averaged around $25 throughout the Cotton Belt. This is equivalent to slightly more than 5 cents per pound of lint. Actual costs of ginning vary considerably, however, from gin to gin, and are to a considerable extent volume-dependent. While the average number of bales handled by gins is around 3,000 in a normal year, some new high capacity gins can turn out 5 or 6 times that quantity. While most gins can be operated profitably, it is almost self-evident that those handling less than 3,000 bales per season, if equipped to cope with machine-harvested cotton, stand a good chance of losing money at prevailing prices for ginning.

It is highly desirable that the cost of producing and processing cotton be reduced not only on the farm, but at every stage in the path which cotton takes from the farm to, and through, the spinning mill. Ginning represents a prime example of a processing operation that is amenable to significant cost reductions. One of the obvious approaches to lower cost is through arrangements that increase the volume of cotton available to a given gin. Various methods for accomplishing this have been suggested: central ginning, gin-yard storage of seed cotton, the transport of cotton from greater distances and high speed automated ginning. The primary function of these types of changes would be to lower the labor and energy requirements to gin and compress cotton.

The entire complex of seed cotton storage, ginning, and compression, etc., offers substantial opportunities for cost savings. From a total cost of producing a pound of cotton, this combined area could potentially represent a 5 to 10 percent improvement in the cost of producing a pound of lint.

Cottonseed

Cottonseed is one of the major oilseeds of the world. Its availability has been dependent on the demand for cotton fiber due to its lesser economic importance. Historically, (Table 5), in the U.S. cottonseed has accounted for only 14 percent of the gross revenue from cotton production.

TABLE 5

VALUE OF SEED AND LINT PRODUCTION

Year Beg. Aug. 1	Lint 1000 Dollars	Seed 1000 Dollars	Total 1000 Dollars	Seed Contri-bution Percent
1964	2,258,491	293,840	2,552,331	11.5
1965	2,106,088	284,412	2,390,500	11.9
1966	997,467	261,008	1,258,475	20.7
1967	953,820	177,406	1,131,226	15.7
1968	1,212,021	234,492	1,446,513	16.2
1969	1,054,981	167,254	1,222,235	13.7
1970	1,121,622	229,607	1,351,229	17.0
1971	1,419,624	240,874	1,660,498	14.5
1972	1,798,960	267,136	2,066,096	12.9
1973p	2,795,153	495,915	3,291,068	15.1
Average	1,571,823	265,194	1,837,017	14.4

Source: U.S. Department of Agriculture (1974c)

The ratio of seed volume to lint has been relatively constant (Table 6) so that projections of future availability of cottonseed may be derived from projections of demand for cotton fiber. The economic relationship between seed and fiber may be altered due to the increasing importance of cottonseed as a supplier of food. Since 1969, the value of cottonseed has more than tripled, rising from just $15 per acre to $50 in the 1974-1975 season. This dramatic increase reflects the demand for cottonseed products.

TABLE 6

YIELD OF SEED AND LINT PER HARVESTED ACRE OF COTTON

Year Beginning Aug. 1	Lint Pounds	Seed Pounds	Total Pounds
1964	517	888	1,405
1965	527	894	1,421
1966	480	829	1,309
1967	447	803	1,250
1968	516	913	1,429
1969	434	736	1,170
1970	438	729	1,167
1971	438	739	1,177
1972	507	831	1,338
1973	519	825	1,344
Average	482	819	1,301

Source: U.S. Department of Agriculture (1974c)

Growth in the economic importance of cottonseed would have an impact on cotton economics in that the returns from cotton production would be enhanced--making cotton more competitive with other crops for land resources.

The shortage of protein foods is commonly stressed in analyzing the world food situation. Food and Agriculture Organization of the United Nations estimates that the protein deficit will reach 10 million tons by 1980. With world population expected to increase from 3.86 billion to 6.0-7.1 billion by the year 2000, the deficit can be expected to increase unless new or additional sources of protein are developed (University of California Food Task Force 1974).

The potential exists for cottonseed to help alleviate the protein shortage. World production of cottonseed reaches 24 million metric tons annually. Approximately 20 percent of this is crude protein, which represents 5 to 6 percent of the world's available protein (Jones 1974). Although cottonseed represents a significant protein resource, it has largely been unavailable for human consumption due to the presence of a phenolic toxin in the pigment glands of the kernel called gossypol. To produce a food-grade protein from cottonseed, a process for removing the gossypol is a prerequisite (Hoffpauir 1972). There are at least two potentially feasible ways of accomplishing this--one is glandless seeds which have no gossypol, and the other is utilization of the Liquid Cyclone Process (Gardner et al. 1973). Glandless seed was developed in 1954 but has yet to achieve significant production, though considerable experimentation is in process (Miravelle 1971). The Liquid Cyclone Process (LCP) was developed recently by the USDA Southern Regional Laboratory to remove the gossypol-containing pigment glands and produce a food-grade protein flour for human consumption. The LCP system involves: (1) drying of the cottonseed meats followed by grinding and extracting the oil; (2) pumping the residual cottonseed meats slurry under pressure through a liquid cyclone which fractionates the slurry; (3) the overflow fraction obtained produces a high protein flour essentially free of gossypol.

It is envisioned that cottonseed flour will be used as an additive or fortifier in meat, breads, cakes, candies, cookies, and beverages. Cottonseed protein has a bland taste, unlike soy's "beany" taste, and is more dispersible in water than soy. Cottonseed also has a high protein efficiency ratio of 2.4. The protein texturizes well, making it a potential meat extender and substitute.

The LCP system offers a means of achieving the untapped potential of cottonseed protein. It is important to note, though, that production of food-grade protein requires prime quality seed. Over the last three years, only about 1/3 of the cottonseed crop in the U.S. is graded prime quality (USDA 1974d). This suggests a need for research to improve seed quality and thus assure a dependable supply of food-grade raw material.

The large potential world demand for protein, when combined with the recent progress in converting cottonseed to protein for human consumption, illustrates an area of excellent payoff opportunity for research and product development.

Fabric Forming Systems

Approximately 75 percent of U.S. mill cotton consumption goes into woven fabrics, about 20 percent into knits, and 5 percent into yarn applications such as cordage, thread, tufting yarns, etc. These consumption relationships become significant when viewed in light of current consuming capacities in weaving, knitting, and other systems.

During 1973, for instance, approximately 10.2 million bale equivalents of all fibers were consumed in woven fabrics. Of that total, cotton accounted for about 55 percent, or 5.6 million bales. During 1973 and the first half of 1974, when the U.S. textile economy was still strong, weaving capacity was strained. Spokesmen for textile mills and machinery manufacturers have suggested that mill plans for loom purchases are few and that they will be primarily for replacement of old looms. Hence, near term additions to weaving capacity are expected to be marginal. This means, of course, that there are serious capacity restraints on the principal consuming system for cotton.

Looking to the future, several things relating to the broad subject of "fabric forming systems" would be helpful to cotton:

Expansion of weaving capacity--Of total spun and filament yarns consumed in 1974, weaving accounted for 44 percent, knitting for 25 percent, and all other (tufting, tire cord, thread, cordage, etc.) for 31 percent. Because 3/4 of cotton consumption goes into woven fabrics, expansion of weaving capacity would facilitate cotton's growth. In time, it seems likely that consumer demand will make it attractive from the standpoint of profitability to add weaving capacity. But for the near term, price competition created by excess knitting capacity may tend to adversely affect profitability and discourage purchasing of new looms.

Research to improve cotton's processing and functional characteristics for knitting--Although "other" (tire cord, tufting, thread, cordage, etc.) follows weaving in order of importance (31 percent of fiber consumption in all yarns), cotton's opportunities for improving its competitive status in this sector through research seem minimal. Most of cotton's disadvantage in "other" yarns centers on its strength-to-bulk ratio where improvement seems unlikely. Knitting, on the other hand, accounts for about 1/4 of fiber consumption in all yarns and, here, cotton's chances for improving upon its present 22 percent market share seem reasonably good. Research is needed to improve both the processing efficiency of cotton for certain knitting machines and the functional characteristics of knitted cotton fabrics and products. The research needs outlined (National Cotton Council 1968) (in Appendix 2) are still valid. To the extent that improvements can be made in cotton's processing and functional properties for knits, its opportunities for expanding consumption will be broadened.

Research to improve cotton's qualities for nonwoven fabrics--To this point, all the discussion involving fabric forming systems has centered on those systems which consume yarns. A number of fabric forming systems, broadly termed "nonwovens," consume fiber in stock form. Nonwovens have experienced exceptional growth in recent years, but staple cotton usage in nonwovens has been minimal.

Analysts project growth of nonwovens over the next decade at about 15 percent annually. Improvements in processing and in functional properties of cotton for nonwoven fabrics would substantially broaden its consumption base (see Appendix III [National Cotton Council 1969] for the nature of improvements needed).

Cotton's chances of competing seem especially good in those nonwoven systems and end use markets currently dominated by rayon. It seems unlikely that rayon staple capacity will expand very much in the years ahead. Any new producing capacity would require substantial increases in rayon prices to cover higher production costs. Hence, the supply capabilities of rayon for an expanding market seem limited. Cotton, with some improvements through research, could represent a good alternative fiber source.

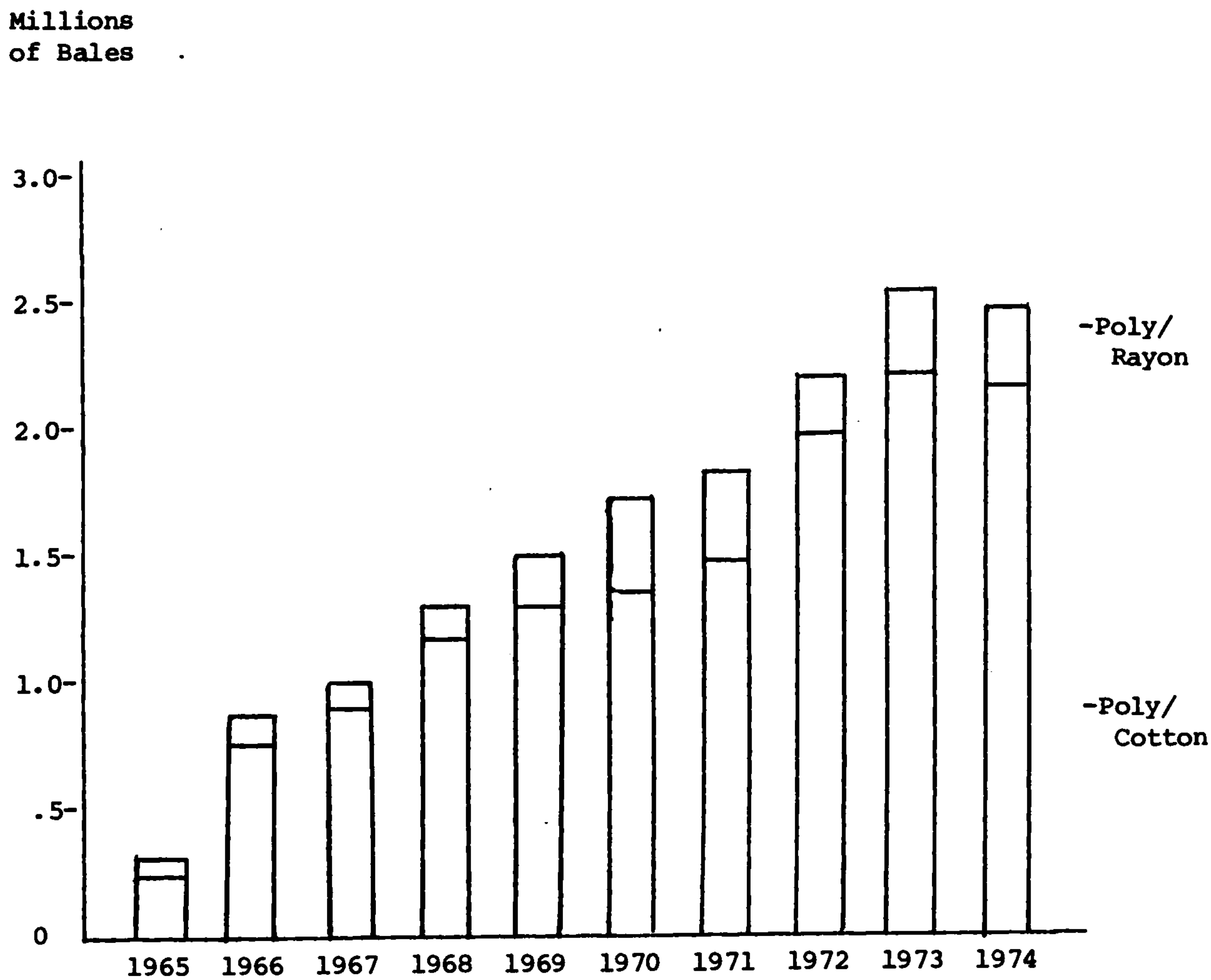
Durable Press

The impact of no-iron textiles (durable press) on interfiber competition is unparalleled in recent history. From 1965 to 1974, production of polyester/cellulosic blends --the principal fabrics for durable press finishing--increased from less than half a million bale equivalents to about 2.5 million bale equivalents (Figure 2). These blends, most of which contain cotton, are consumed primarily in markets which, until the advent of durable press, were dominated by 100 percent cotton. Easily a million and a half bales of cotton have been displaced over the past decade by durable press blends alone. Other types of no-iron synthetic fabrics--notably 100 percent polyesters--have competed in traditional cotton markets to a lesser degree, but it is probably safe to assume that competition from all types of durable press fabrics has cost cotton two million bales of domestic market.

Technology to impart high quality durable press properties to 100 percent cotton fabrics would improve cotton's competitive position in the domestic market. Objectivity would not permit one to conclude, however, that high quality durable press properties in 100 percent cotton fabrics would allow cotton to regain <u>all</u> the volume which has been lost to durable press competitors. Whereas losses can be attributed primarily to cotton's lack of durable press properties, other factors have subsequently become significant as well. For example, polyester staple now is priced competitively with cotton; this plus the fiber's mill processing efficiency and consumer acceptance would make it

FIGURE 2

POLYESTER/CELLULOSIC WOVEN FABRICS
FINISHED FOR DURABLE PRESS



Source: U.S. Department of Commerce.

difficult for cotton to regain all its durable press-related losses. But cotton's gain potential would, nevertheless, be impressive. While no one can precisely quantify what a competitive durable press finish would mean for cotton, the gain potential might well approach a million bales in the domestic market alone.

Research efforts continue to be funded to improve upon current cotton durable press technology. Presently, a high quality finish is being marketed for heavy weight cotton fabrics. This should help cotton hold major markets for such heavy fabrics as denims, corduroys, etc., and perhaps make some marginal competitive gains. But similar technology will have to be developed for medium and light weight fabrics if a real competitive impact is to be made.

Flammability

Flammability may well be to interfiber competition in this decade what durable press was in the previous one. Already the Consumer Product Safety Commission has promulgated flame retardance standards on a number of textile products, and by 1985 chances are good that most apparel and home furnishings and many industrial textiles will be affected by flame retardance standards.

When standards were promulgated for children's sleepwear (sizes 0-6x), cotton's market share plummeted from 66 percent to 6 percent in one year. What happens when standards are set for other textile end uses depends upon:

- specific requirements of standards,
- timing of standards implementation, and
- state of flame retardance technology--by fiber or fabric type--at time of implementation.

Based on conventional measures of functional and aesthetic requirements, there are no completely satisfactory flame retardant fabrics. If present technology for flame retarding cotton can be improved and adapted to a broad range of fabric types, cotton will not only be able to ward off competitive losses but it should be able to make substantial competitive gains in many markets.

Currently, the most difficult fabric types to make flame retardant are the popular polyester/cellulosic (principally polyester/cotton) blends. These blend markets are, therefore, vulnerable. Should they be lost, cotton volume would decline sharply--unless the blend losses were to 100 percent cottons, which would mean a substantial gain to cotton. In woven and knitted fabrics combined, more than 1.75 million bale equivalents of man-made fiber are consumed annually in polyester/cellulosic blends. Broadly speaking, that is the gain potential for cotton, assuming a competitive flame retardant finish that is adaptable to a wide range of fabric types. But, realistically, it is not likely that all this market would go to cotton, even though most of the blended fabrics are "cotton-like" in hand* and appearance. A good flame retardant finish for 100 percent cotton--competitive functionally, aesthetically, and economically--might effect domestic market gains for cotton ranging from 500 thousand to one million bales.

If flame retardant properties and durable press could be imparted in a single finishing step, cotton's potential for competitive gains would be further enhanced. Some researchers believe this may be possible. An ammonia finishing chamber currently is used to impart durable press to heavy weight cotton fabrics, and ammonia chambers are used as one of several ways of applying flame retardance finishes to cotton. With additional research, the two functional properties may prove to be compatible via one finishing system. Another possibility is the mandatory flame retardance standards in major markets for polyester/cellulosic blends could result in a shift toward higher cotton content blends. The ammonia finish presently used on 100 percent cotton to impart flame retardance can also be applied to higher cotton content blends, which, in addition to flame retardance, have some durable press properties as well. The polyester/cellulosic blend market is big enough that a change in blend levels from the present average of about 45 percent cotton to 65 percent cotton would add approximately a half million bales to cotton consumption.

Flame retardance technology--regardless of fiber--is in its infancy. Demand for the property, whether mandatory or voluntary, will almost certainly become enormous. Outstanding success or complete failure of a fiber in the domestic marketplace may well hinge on how well the fiber can compete in this one functional requirement. Continuing research on flammability is essential to maintaining cotton as a viable renewable resource.

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* 'Hand' refers to a combination of properties or characteristics of textile materials which can be distinguished by the sense of touch, such as smartness, crispness, weight, flexibility, and resiliency.

WORLD TRADE AND THE EXPORT MARKET

The long-range outlook for U.S. cotton exports depends primarily on future trends in foreign production and consumption of cotton. Future developments in the following three aspects of the foreign cotton situation could effect a significant change in the trend in foreign production

and consumption of cotton and, therefore, in U.S. exports of cotton.

1. Political Decisions -- Countries with a central plan for production, such as USSR, account for more than 40 percent of foreign cotton production and consumption. If current trends continue in both the centrally planned countries and the rest of the foreign world, the centrally planned countries will account for more than one-half of foreign cotton production and consumption within ten years; and the centrally planned countries as a whole will become net exporters of cotton. Obviously, therefore, any decisions affecting either the cotton production or consumption trends in these countries will have a significant impact on the demand for U.S. cotton exports.

2. Economic Considerations -- Many foreign countries produce cotton primarily for the export market in order to earn foreign exchange for purchasing food and other essentials. However, as the world demand for food and feed crops continues to increase, creating upward pressure on prices of these crops, many cotton producers around the world are finding it more profitable to switch to these crops where they have the options. A major switch from cotton in only a few of the larger cotton exporting countries would substantially reduce the amount of foreign cotton available to compete with U.S. cotton in the export market.

3. Technology -- More than three-fourths of the acreage planted to cotton in the foreign non-communist world currently has average production of less than 200 pounds of cotton lint per acre. Any technological breakthrough that provided a substantial increase in the yields of cotton on these 38 to 40 millions of acres would obviously have a major impact on the world export market for cotton. Likewise, improved production efficiency in the U.S. would make our cotton more competitive in world markets. The U.S. production of cotton is highly mechanized and capital intensive. Many foreign producers have small fields and capital shortages which make mechanization both difficult and very costly.

The U.S. cotton export market's future potential will depend upon cotton's ability to be price competitive in the world market and to maintain effective marketing services.

ENERGY

The U.S. cotton industry, like all of America, is vitally concerned about our nation's energy problem. Cotton farmers, ginners, warehousemen, merchants, cotton spinners, and cottonseed crushers committed the cotton industry to a continuing all-out energy conservation program starting in early 1973. Cotton shares the problems of energy availability along with the rest of U.S. agriculture. Cotton is a major crop in 14 states; cotton exports earn substantial foreign exchange; and cotton is the leading fiber of our nation's textile industry. In addition, cotton is a valuable food crop, yielding about 825 pounds of high protein cottonseed from each acre of cotton.

National leaders, recognizing the need for maximum agricultural food and fiber production, took the position that the nation's interest would be served best if agriculture was given priority for 100 percent of its energy needs. Consequently, agriculture was granted top priority in all categories of the mandatory fuel allocation regulations. The importance of this action to cotton was recognized by Carter and Kopacz in their article "Cotton and the Energy Crisis: What Does the Future Hold?" (1974) in which they stated:

> "The key factor in domestic and foreign usage of cotton is the competition from man-made fibers. Shortage of petrochemical feedstock and energy to convert them into synthetic fibers, plus skyrocketing petroleum prices, have forced man-made fibers into a tight supply situation. Cotton production, however, along with all agricultural production, was put among the most essential services on fuel needs in the regulations of the Mandatory Petroleum Allocation Program. Provisions are made to help assure farmers, their suppliers, and product processors of adequate quantities of fuel. A system also has been established for small percentages of set-aside of most fuel to provide for emergency situations within the allocation program. The synthetic fiber industry does not have such assurances of feedstock and energy supplies."

Recent legislative actions have continued the policy of channeling energy resources into agriculture. Numerous bills have been introduced to establish improved energy priorities for agricultural processing and input production. Fertilizer manufacturers are scheduled to receive natural gas and petroleum products. Farming operations have been granted exemption from energy excise taxes under several proposals. Carter and Kopacz (1974) asked Bruce Hannon of the Center for Advance Computation, University of Illinois, to compare the energy and labor usage of cotton and man-made fibers. From his results, they conclude:

> "Based on these data (Dr. Hannon's), it is easy to see that a decision maker, in allocating energy resources to various industrial sectors, would easily select production of cotton to meet fiber demands because it is less costly in energy and increases employment."

At the current time, the inherent value of cotton production to the U.S. economy seems to be recognized by energy policymakers. However, it is conceivable that future energy programs might discriminate against the natural fiber as a renewable resource. In the event that energy rationing becomes necessary, a high fuel priority for agriculture and/or cotton will be necessary to insure adequate food and fiber production. An adequate allocation of fuel for textile manufacturers is needed for the processing of fibers. Such an allocation is also important to our economy because of the high level of labor intensity in the textile industry. Lack of these priorities could hamper production efficiency and lower output. As pointed out in the introduction to "Section C, The Textile Industry," the production of cotton fiber is much less energy demanding than production of man-made fibers. The latter require 5 to 7 times the energy needed for cotton production on a unit basis [see Appendix I]. The present energy consumed as raw materials and in the fiber production processes is 3.36 kilowatt-hours per pound of cotton fiber plus 1.75 lbs. cottonseed. The net energy for the fiber alone is 2.86 kilowatt-hours.

A recent study (National Cotton Council 1974) shows that the processing of cotton into cloth requires no significantly different energy than the man-made fibers. Cotton's energy advantage in fiber production remains intact to the finished product.

As shown by the projections for 1985 and 2000, cotton energy use is expected to show substantial improvements on a per-unit basis. Estimates of the materials flow for renewable fiber resources show cotton achieving a 15 percent energy savings by 1985 and a further 7 percent reduction by 2000. More efficient production methods will increase yields and reduce energy requirements per pound of cotton, thereby partially off-setting the rising cost of energy inputs. Minimum tillage, high capacity gins, selective chemical applications, and other cultural practices will allow the cotton farmer to improve fuel efficiency and increase energy conservation.

The importance of energy to our nation's future cannot be underestimated. Renewable resources, like cotton, food, and fiber, should be a major building block in any national energy policy. The comment of Carter and Kopacz (1974) provide a succinct conclusion of energy's role in cotton's future:

> "In summary, it is generally recognized that the energy problem is a long term problem and cannot be solved merely by additional supplies of petroleum or by use of other nonrenewable fuel resources. We have ample warning that these finite resources will be depleted in time, and it is essential that technology be applied to develop energy alternatives, preferably from renewable resources. Agriculture in general, and cotton production in particular, should continue to receive ample supplies of energy for economic and political reasons. On a practical basis, cotton fiber is a renewable and biodegradable raw material for the production of textiles and, if you will, a superior alternative for manmade fibers. In addition, the cotton plant also provides a high protein food and feed for man and animal. Based on our limited knowledge of the present energy crisis--we would suggest that prospects for increased usage of cotton and cottonseed products are indeed bright."

ENVIRONMENT

Material resources and the quality of our environment must be considered jointly. Depletion of reserves and pollution have the same cause--failure to manage the flow of materials as a cycle. The National Commission on Materials Policy (1973) stated, "A national policy for the management of energy and materials is needed to transform this open-ended process of wastage into a substantially closed system." Because cotton is a renewable resource which derives much of its energy from the sun and because it is biodegradable, cotton fits well this "closed system" concept.

The National Commission on Materials Policy (1973) makes two further findings which define the environmental market impact on fibers. With respect to growth rate,

> "Major deviations from the historic trends are seen in synthetics, both fibers and plastics. These materials will probably experience a considerable decline in their growth rate, having recently risen from a low base. Their precipitous growth was achieved primarily by displacing other materials, and the projection assumes a slower future development for these materials."

The cost impact of environmental enhancement will affect market price and, therefore, the balance among fibers in the marketplace. The National Commission on Materials Policy (1973) stated:

> "Some materials will experience price increases as a result of expenditures needed to comply with effluent standards; others will be affected very little or not at all.
>
> "Although the trend toward synthetics may continue under current policies, it should be noted that the environmental impact of the industrial processes involved in their manufacture are quite different from those arising from the treatment of natural fibers. Thus environmental concerns may in future alter the market balance between these fibers. Disposal of synthetic products also is relatively difficult because many resist oxidation or dissolution by natural processes."

Although cotton requires inputs of fertilizers, pesticides, and other agrichemicals for cultivation, the relative energy input is far less than for fibers derived from petroleum.

GOVERNMENT REGULATIONS

The area of governmental regulation is a topic of great interest and concern to the cotton industry--from the producer level through the textile mill level. Federal authorities have placed restrictions on the use of selected chemicals, placed safety guarding and shielding requirements on agricultural equipment, placed dust standards on textile mills, and promulgated flammability standards for textile products. While these regulations are imposed in the interest of society and our environment, some may not be reasonable and all have the impact of increasing cost. Cautious judgment in standards promulgation and implementation is needed. These regulations could have considerable impact on cotton markets by the years 1985 and 2000. As an example, consider the quantitative estimates for costs of flammability regulations, air pollution control in cotton gins, the DDT cancellation, and cotton dust standards in textile mills.

Flammability standards affect consumers and farmers, but most of the cost of new flammability standards for textile products falls on consumers. The National Cotton Council estimates that children's sleepwear prices are about a dollar per garment higher because of the regulations, and this amounts to more than $115 million per year additional expenditure by consumers for a less comfortable product. The impact on the cotton farmer is not insignificant, either. As a direct result of the regulations, children's 0-6x sleepwear market dropped from 66 percent in 1972 to 6 percent in 1973.

A Louisiana study shows the cost of meeting the air pollution regulations for cotton gins in that state amount to $2.22 per bale annually in a medium-sized gin (St. Clergy 1975). If this is typical for the nation as a whole, the annual cost would be about $27 million, that would have to be passed on to farmers. The study points out that it is not economically feasible for many small gins to invest the amount required. Closure of these gins would mean a longer average haul for seed cotton, adding a further unknown cost to growers.

A 1969 USDA study showed that elimination of DDT as a pesticide in cotton would cost about $55 million per year at 1969 prices if yields could be maintained (Cooke et al. 1969). The price of the leading replacement, methyl parathion, is up 55 percent since 1969, labor is up 56 percent, and farm machinery up 40 percent, according to government figures. Therefore, a 50 percent increase in the $55 million figure seems fully justified. This would mean a cost of $83 million at today's prices. Testimony in the recent Louisiana case, asking for limited use of DDT, indicated that yields are not being maintained in that state in the absence of DDT, and the additional loss figure was put at $13 million in that state alone. Thus, the total cost undoubtedly is much higher than $83 million.

Another area is OSHA regulations on cotton dust levels in textile mills, imposed in 1971. While this is not a direct cost to the farmer, it is related directly to the use of a major farm product for which substitutes are readily available. Therefore, it adds to the cost of processing cotton and puts it at a competitive disadvantage with other fibers, thus reducing markets.

The capital cost to textile mills for cotton dust control equipment has been estimated at $960 million, plus $53 million a year for operation and maintenance of the equipment, testing, etc. A new standard is being considered that would require capital expenditure of $1,440 million. With capital outlays amortized over ten years and interest at 9 percent, the total annual cost would be $230 million for the present standard, or about 6.8 cents per pound of cotton used. It is not at all inconceivable that in the long run this annual cost might be forced back on the farmer in terms of lower value of his cotton as compared with substitutes that do not have the problem.

Farmers are threatened with additional regulatory costs when OSHA issues its standards on the guarding of farm and gin machinery; these are expected momentarily. Further down the road, worker protection from excessive noise and heat is expected to be required. We do not yet know what the classification of pesticide uses will cost, since these regulations have not been fully spelled out. Flammability standards are very likely to be applied to additional textile uses.

The annual cost impact of the government regulations discussed above will have great impact on cotton producers, textile manufacturers, and on the consumers of the goods. In addition to annual costs, capital investment funds must be used to meet regulatory requirements rather than used for production maintenance and capacity expansion. This seriously impairs the opportunities of cotton as a renewable resource.

It is recognized that some regulations are needed and are essential to the welfare of our society. However, excessive regulation can be so expensive, as well as restrictive, that the viability of the cotton industry could be seriously eroded in the near future.

COTTON AND NATIONAL DEFENSE

A major concern of any society is security. The ability to mobilize adequate defense forces when needed is essential to security. A strong viable cotton industry is important to the U.S. defense capability.

Stephen J. Kennedy's study, <u>The Changing Capability of the Textile Industry to Support National Defense</u> (1973), shows that the textile industry would be confronted with severe manufacturing and <u>fiber shortage</u> problems if mobilization were required for our defense. The Arab oil embargo and the energy crisis which followed closely Kennedy's publication illustrate the validity of his study.

In the study's conclusions on raw materials, it states:

> "...looking into the 1980-85 time frame, the assessment of the energy outlook which has been made by the Committee of the U.S. Energy Outlook of the National Petroleum Council, and published in December 1972 by the U.S. Department of the Interior, has placed the entire situation with respect to supplies of petroleum and gas in a context which requires reassessment as to the necessity of using man-made fibers drawn from these raw materials.
>
> "In view of the seriousness of the potential balance of trade deficit in energy fuels that may exist by that time, and its consequences upon the military, political and economic security of the United States, it must be anticipated that too great dependence upon fibers drawn from petrochemical feedstocks could present undesirable hazards to the military services from a supply standpoint.
>
> "Accordingly, the desirability of keeping open all options with respect to the utilization of cotton in military textiles should be recognized and continued as a policy of the Department of the Army and the Department of Defense."

The importance of defense to our society is illustrated by the fact that more funds are budgeted for defense than any other item. In view of the importance of cotton and the textile industry to defense, Congressman Sisk appointed a Cotton and Textile Defense Capability Committee to study and to make comments and recommendations. See Appendix IV for the committee's comments on the study's conclusions.

The Kennedy (1973) study conclusion on needed research with comments by the Cotton and Textile Defense Capability Committee were as follows:

Conclusion #11 (A) A broad-based research and development program to develop alternate textile materials which will be in consonance with industry's capabilities for large scale production within the projected time frame, 1980-85, and yet which will meet all critical and essential technical requirements, should be undertaken as a matter of priority.

(B) In view of the rapid changes taking place in the industry on the one hand, and the need for prudent reserve about too great a commitment to man-made fibers based upon oil, of which a large part will have to be imported in the time frame suggested, such a research and development program should proceed along several lines simultaneously, including especially the upgrading of the performance of cotton textiles or limited mixtures of other fibers with cotton. The support of industry and the U.S. Department of Agriculture should be obtained on as broad a base as possible to assure the availability of materials conforming to all military needs.

Comment: The Committee whole-heartedly endorses the foregoing. For a variety of reasons, some of which are peculiar to the industry segment involved, the research and development support in the clothing and textile area has been inadequate to keep pace with the military's needs. The Committee also notes that this problem is compounded by the many recent technological changes in the industry, and the unique requirements of military textiles that prohibit ready interchange with items acceptable to the civilian sector. To resolve this, the Committee recommends support of a research and development program, managed by the Army, as further outlined in Appendix B. In preparing this recommendation program, the Committee notes that it offers the potential of not only alleviating future mobilization problems, but of improving the technological posture of the industry with subsequent advantages to the economy. The Committee also notes that within the Department of Defense, the pressures of many high priority programs frequently leave little emphasis on clothing and textile research. Inasmuch as the DOD procures clothing and textile items to the extent of approximately $500,000,000 per year, the Committee recommends that the research and development in this area be assigned a higher priority, commensurate with the mobilization problem noted, and the concomitant beneficial effects to the economy.*

The research recommendations of the Cotton and Textile Defense Capability Committee included $20 million for improving the textile industry mobilization support capability, including improved methods of using cotton, a renewable resource, for defense textile needs.** This research funding is needed to aid in maintaining the technological base of the U.S. textile industry as well as to maintain cotton as a viable industry to facilitate national security.

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* Appendix IV. Cotton and Textile Defense Capability Committee Comments on Kennedy study conclusions.

** For the Cotton and Textile Defense Capability Committee's research recommendations see Appendix B of the Committee's comments on the Kennedy study conclusions, (in Appendix IV).

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Appendices

Appendix I	"Textile Fibers and Energy Consumption - An Update." National Cotton Council of America, Memphis, Tenn., June, 1974.
Appendix II	"Quality Considerations and Research Needs". From "Cotton in the Knitting Industry." National Cotton Council of America, Memphis, Tenn., June, 1968.
Appendix III	"Nonwoven Textiles - A Market Survey." National Cotton Council of America, Memphis, Tenn., Feb., 1969.
Appendix IV	"Conclusions of the Report* Entitled "The Changing Capability of the Textile Industry to Support National Defense." Summarized by Arlie L. Bowling, National Cotton Council of America, Memphis, Tenn.

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* Kennedy, Stephen J. The Changing Capability of the Textile Industry to Support National Defense. U.S. Army Natick Laboratories, Natick, Mass., April, 1973.

APPENDIX I

TEXTILE FIBERS AND ENERGY CONSUMPTION--AN UPDATE

In January 1973, the National Cotton Council published a study entitled The Energy Crisis: Can Cotton Help Meet It? which showed that producing a pound of cotton requires only one-fifth as much energy as producing a pound of synthetic fiber. An update of these findings can now be made based on the following conditions:

(a) Man-made fibers have achieved efficiencies which are reflected in new Census data.
(b) Cotton has achieved efficiencies due to yield improvements.
(c) Cottonseed, as a co-product with cotton lint, should share part of the energy consumption previously attributed only to cotton lint.

Using data from the 1972 Census of Manufactures, cotton yields from the 1972 crop, and USDA data on cottonseed production, cotton's energy advantage was recalculated.

Man-made fiber energy consumption in the original study was based on 1967 data. 1972 Census data shows that volume of production increased significantly resulting in some economies of scale. Cotton yields in the original study were based on 1969 levels of 434 pounds. For 1972, cotton yields averaged 507 pounds, also resulting in greater energy consumption efficiencies. The new calculations of energy consumption in fiber production are presented in the following table:

Energy Consumed as Raw Materials and
in Fiber Production Processes
(kilowatt-hours per pound of fiber)

Cotton	Non-cellulosics	Cellulosics
3.36	16.32	20.42

For each pound of cotton lint, there is also produced 1.75 pounds of cottonseed, which represents approximately 15 percent of the value. Attributing some of cotton energy requirements shown above to cottonseed on the basis of value, the net energy required to produce a pound of cotton becomes 2.86 kilowatt-hours. Thus, non-cellulosic fibers require 5.7 times more energy than cotton, while cellulosics require 7.1 times more energy than cotton pound-per-pound. Therefore, the published cotton energy advantage of 5 to 1 is still accurate and quite conservative.

National Cotton Council of America
Economic and Market Research Department
June 1974

APPENDIX II

From Cotton in the Knitting Industry, National Cotton Council of America, Memphis, Tenn., June, 1968.

QUALITY CONSIDERATIONS AND RESEARCH NEEDS

Because of the large number of knitted end-use products and the variation in quality requirements from use to use, it is not feasible to present a complete end-use analysis of quality considerations and research needs. For this reason quality considerations are summarized under major headings of weft knitting and warp knitting, as shown in Table on the following page.

Considering the entire range of quality requirements, cotton is the most versatile of all the competing fibers. While improvement in any of the desirable qualities would tend to strengthen cotton competitively, trade sources say that many of cotton's current properties are adequate. Among them are:

Absorbency	Opaqueness	Pilling
Adhesive Qualities	Permeability	Seam Slipping
Bleachability	Washability	Soiling
Colorfastness	Resistance to:	Staining
Coolness	Clinging	Static Electricity
Non-irritating	odors	

Cotton, however, is competitively weak in a number of requirements, some of which are "major considerations." Trade sources suggest that cotton needs improvements in the following properties:

Bulk*	Quick Drying	Resistance to:
Dimensional Stability	Smooth Drying	Abrasion
Drape	Sheen	Fire
Elasticity	Strength	Linting
Hand	Warmth	Wrinkling
Light Weight	Sheerness	
	Slipperiness	

* Both low bulk and high bulk are important quality considerations for some end uses. See the following explanations under appropriate headings for additional comments about this property.

TABLE 1

QUALITY CONSIDERATIONS FOR WELF AND WARP KNIT

Weft Knit		Warp Knit	
Major Considerations	Other Important Considerations	Major Considerations	Other Important Considerations
Bleachability	Absorbency	Adhesive Qualities 2/	Absorbency 4/
Colorfastness	Adhesive Qualities 2/	Bleachability	Coolness
High Bulk 1/	Coolness	Low Bulk	Hand
Dimensional	Hand	Colorfastness	Permeability
Stability	Quick Drying	Dimensional	Resistance to:
Drape	Resistance to:	Stability	Abrasion
Elasticity	Abrasion	Drape	Clinging 3/
Non-irritating	Fire	Elasticity	Fire
Opaqueness	Odors	Light Weight	Odors
Permeability	Pilling	Non-irritating 3/	Pilling
Resistance to:	Seam Slipping	Opaqueness	Seam Slipping
Soiling 1/	Static Electricity	Quick Drying 3/	Soiling
Staining 1/	Strength	Resistance to:	Staining
Wrinkling	Warmth	Linting	Static
Sheen		Wrinkling	Electricity
Smooth Drying		Sheen	Strength
Washability		Sheerness	
		Slipperiness	
		Smooth Drying	
		Washability	

1/ For outerwear primarily.
2/ For fabric-to-fabric bonding.
3/ For underwear and nightwear primarily.
4/ Although an important consideration, many consumers are willing to forego this requirement in order to obtain other desirable qualities.

DIMENSIONAL STABILITY, SMOOTH DRYING, STRENGTH, AND RESISTANCE TO ABRASION AND WRINKLING

These qualities are all directly or indirectly related. Dimensional stability, smooth drying, and resistance to wrinkling are all qualities related to durable press or minimum care, while strength and abrasion resistance are sometimes affected by finishes designed to impart these qualities.

Dimensional stability has always been an important consumer quality requirement in knit products, but more recently, the entire range of individual qualities associated with durable press have become more important. The "durable press/minimum care" concept includes qualities of smooth drying and wrinkle resistance as well as dimensional stability.* However, dimensional stability is sometimes regarded as a major consideration in knit products for which the other durable press related qualities are thought to be less important considerations.

Dimensional stability is important in every type of knitting and in almost all end-use markets. Great strides have been made in developing finishes for dimensionally stabilizing cotton knits. Finishes currently available have played an important role in holding big cotton markets such as knit underwear, shirts, and blouses, and in gaining a foothold for cotton in outerwear markets such as women's dresses, suits, and skirts. Bonding of knit outerwear fabrics to acetate tricot has also been used as a means of improving dimensional stability of cotton knits. Despite the progress that has been made, producers are abandoning 100 percent cotton in favor of cotton blends and 100 percent synthetics because they say they get better dimensional stability from synthetics and blends than from 100 percent cotton.

While some have undoubtedly experienced difficulty in adequately controlling stability of cotton knits, others say they have little or no problem. Those who find currently available finishes adequate say that much of the shrinkage problem associated with cotton knits results from improper fabric construction and poor finishing practices. Some finishers resort to excessive stretching of the fabric during finishing as a means of gaining a few extra yards of finished fabric; then they attempt to set the fabric in this

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* Trade members believe that it is only a matter of time before durable pleats and creases will also become major considerations in durable press knits.

stretched state with poor quality resin finishes which eventually wash out and allow shrinkage to take place. While some industry sources say that cotton knits can be adequately stabilized, and some say they cannot, most agree that resins used to impart stability impair strength and abrasion resistance of the finished fabric.

The adequacy of present finishes for imparting dimensional stability to cotton knits may be debatable based on the foregoing comments. It is clear, however, that: (a) industry members, in comparing qualities of cotton versus competing materials, almost always call dimensional stability an advantage of synthetics and blends over 100 percent cotton; and (b) knit product manufacturers are turning to synthetics and blends in a broad range of products and citing better dimensional stability as a major reason for the switch. This suggests that cotton needs either research directed toward improving finishes for imparting dimensional stability to cotton fabrics or educational work to inform the trade about the better quality finishes available.

Widespread acceptance of durable press fabrics in woven goods has focused more attention on durable press in knits. Trade members feel that smooth drying and wrinkle resistance, although important already, will become more important in the future. Knits are inherently easy care but durable press, as such, is expected to play an important role in knit products, even to the extent of durable creases and pleats in knit apparel.

In knit fabrics, as in wovens, currently available finishes for durable press properties impair strength and abrasion resistance. Knitters have followed the lead of weavers in turning to polyester/cotton blends as a means of bolstering strength and abrasion resistance of chemically modified fabrics and products. This blending was not evident to any great extent in 1966 end-use consumption figures presented elsewhere in this report. However, the trend gained momentum in 1967 and significant inroads are expected to be made in 1968.

Trade members say that the cotton industry would be well advised to sponsor research directed toward improving finishes to impart durable press properties to cotton knits without seriously impairing strength and abrasion resistance. In cotton's favor, they say, are measures of wrinkle resistance and smooth drying inherent in knit constructions. Also, the natural elasticity of cotton knits lessens the effects of losses in strength and abrasion resistance on wear life of products. Because of these factors, they reason that possibilities of developing completely satisfactory durable press cottons are better in knits than in woven fabrics.

Improvements in cotton's properties of dimensional stability, wrinkle resistance, and smooth drying (while maintaining adequate strength and abrasion resistance) would strengthen its position in markets consuming close to a billion pounds of knitting yarn. Furthermore, predictions are that knits will command an increasingly larger share of the total textile market in the years ahead.

LOW BULK, LIGHT WEIGHT, SHEERNESS, SLIPPERINESS, NON-LINTING

These properties seem to be closely related and all are common to warp knits. Not only are these properties common to warp knits but they are largely confined to warp knits, principally tricots. Within the weft knit applications, cotton seems to be adequate with regard to these properties. However, disadvantages in low bulk, light weight, sheerness, slipperiness, and non-linting have resulted in almost total exclusion of cotton from tricot knit products. Trade members say that improvements in these properties would afford cotton an opportunity to compete in the tricot market, already consuming more than 200 million pounds of yarn annually and expanding rapidly.

To date, tricot fabrics have been confined largely to women's wear but trade sources believe that low bulk, light weight, non-linting cotton yarns could add the comfort factor to tricot knits necessary to move them into a wide range of men's and boys' garments, including tailored apparel.

The trade feels that economy is the major advantage tricot knits could claim over woven fabrics for such items as men's and boys' sport coats, suits, and trousers. Thus the cost of new or chemically modified knitting yarns should be such that economy over woven fabrics would continue to be an advantage of tricots.

While it has been possible to run cotton yarns on tricot machines, problems have been serious:

a. Cost of higher counts of cotton yarns cuts into the economy aspect of tricot knitting;
b. Strength is inadequate on high count cotton yarns fine enough to run on tricot machines;
c. High speed equipment operations cause excessive linting which "gums up" machines.

In view of market size and potential for expansion, trade sources suggest that research directed toward improving qualities in cotton yarns for tricot knitting and/or cooperative projects with machinery manufacturers to develop equipment more adaptable to cotton knitting yarns would be advisable.

SHEEN (LUSTER)

Some degree of sheen, or luster, is desirable in a broad range of knit products, including both white and colored goods. While processes are available for imparting sheen to cotton yarns and fabrics, trade members report that these processed yarns are too expensive for use in popular priced knit products. They say that research on low cost processes for imparting sheen to cotton goods is very important. Markets at stake include a very high percentage of the billion pound knit apparel market as well as many of the household and industrial uses.

RESISTANCE TO FIRE

While untreated cotton yarns and products are more combustible than wool and some of the synthetics, fire resistant finishes for cotton are available. It is felt by some that the melting characteristics of thermoplastic fibers and materials are actually more dangerous than flaming. However, producers are concerned primarily with meeting specifications for flammability as spelled out by the Flammable Fabrics Act. While current finishes will bring cotton knits within limits of the specifications, trade members suggest that additional research is needed to develop finishes for cotton that are more economical than those currently available.

Most of the suggestions for research on flammability came from sweat shirt manufacturers who are currently faced with the problem of meeting specifications of the Act. The scope of the Flammable Fabrics Act was broadened in 1967 to bring more textile products under its provisions. This broadening of scope plus the possibility of future expansions in coverage, further point up the need for intensified efforts on the part of the cotton industry in flammability research.

QUICK DRYING

Quick drying is an advantage claimed by synthetics. This quality is especially important in women's tricot underwear and nightwear but is often cited as a desirable quality in outerwear. Consumers like quick drying properties in no-iron clothing, particularly items of apparel suitable for travel.

DRAPE

Double knit cottons, as a rule, have good draping qualities. However, draping qualities of single knit cotton outerwear fabrics are sometimes inferior to wool and synthetics, according to the trade. Bonding these fabrics to acetate tricot lining materials has been one method of improving draping qualities but the trade suggests that improvement is needed in unbonded cotton knits.

ELASTICITY

Elasticity is an inherent quality of knitted products. A degree of controlled elasticity is desirable in a very broad range of knit apparel, household, and industrial products. In fact, elasticity is a major reason why knits have gained competitively against wovens in recent years.

For most applications, the elasticity of cotton is adequate insofar as "stretch" is concerned. After repeated stretching, however, cotton knits sometime assume an undesirable "baggy" appearance. This problem is not serious in cotton double knits or bonded cotton knits.

Cotton's disadvantage in elasticity seems to be most critical in men's and boys' hosiery where a high degree of stretch is desirable. Trade sources say that cotton's competitive position would be boosted in the whole range of knit products if improvements could be made in controlled elasticity.

WARMTH, HIGH BULK

Usually high bulk (or loft) is important in the same end uses as warmth. End-use applications include most men's, women's and children's fall and winter knit outwear. There is a marked difference in cotton's percentage share of spring and summer apparel as opposed to fall and winter apparel in most producers' lines. Wool and acrylics are cotton's principal competitors in knits where warmth and loft are major considerations. Trade sources say that cotton needs research directed toward developing a product suitable for year-round knit apparel.

HAND (TEXTURE, SURFACE INTEREST, NOVELTY EFFECTS)

Hand refers to properties or characteristics of textile materials which can be distinguished by the sense of touch, as smoothness, crispness, weight, flexibility, and resiliency. Hand embraces a combination of many properties as well as indefinable considerations which can be measured by the sense of touch. While difficult to describe the exact nature of hand, or to pinpoint the exact properties desired in hand, it _is_ regarded as an important consideration in knitted products.

Often a discussion about hand will prompt trade members to cite texture, surface interest, and novelty effects as additional important considerations, or to use these terms to describe what they mean by hand. While these terms suggest a somewhat broader meaning than hand (these are qualities that can be seen as well as felt) they seem to be closely related.

Hand, texture, surface interest, and novelty effects are often seen as advantages of wool and synthetics over cotton in knits. The very nature of the qualities implies that factors other than the properties of the _fiber_ are involved. Some of the qualities result from yarn alterations (such as texturizing filament yarns) styling innovations, and/or novelty approaches to fabric construction. Consequently, technical research efforts as well as educational and public relations may be required if cotton is to compete favorably in these areas.

APPENDIX III

Byron C. Cox, Jr., Market Research Service,
National Cotton Council of America (Feb. 1969)

NONWOVEN TEXTILES
A Market Study
Introduction

Beginning in early 1966, with Scott Paper Company's introduction of paper dresses made from their Dura-Weve nonwoven fabric, growing interest has developed in the area of nonwoven textiles. Although nonwovens have been in existence for many years, they have been relegated to small markets requiring specifically engineered fabrics.

The astounding consumer acceptance of Scott's paper apparel pointed up the fact that demand did exist for low cost, functional, limited use textiles. Consequently, tremendous research and development on nonwovens was spawned, especially in the area of disposable products. Now, disposable uses represent the largest potential for nonwoven fabrics.

The cotton industry should be vitally interested in nonwoven textile, particularly disposables. From one standpoint, serious losses for cotton will result from inroads by disposables--which consume virtually no staple cotton--in markets such as bed, bath, and table linen for the hospital and hotel/motel trade. Other textile markets, including medical apparel, work apparel, and diapers, are also vulnerable to the onslaught of nonwoven disposables.

On the other side of the coin is the potential for cotton consumption in these end uses via nonwoven fabrics. However, as mentioned above, cotton's present usage in nonwoven disposables is negligible. Industry sources indicate cotton is at a definite disadvantage because of the costs associated with cleaning and bleaching raw cotton in preparation for forming it into a nonwoven fabric, and because of cotton's lack of fiber length uniformity which affects its performance in the fabric forming process.

A market study is in progress to determine market size, fiber trends, and research opportunities for cotton in the nonwoven industry. The following summarizes some preliminary data gathered during initial field work. Revisions to these data along with expansion of detail concerning individual end uses will be made as work progresses.

This preliminary report is presented in two parts; first part dealing with the total nonwoven industry, and the second part with disposable nonwovens.

NOTE: Throughout this discussion, the term "cotton" will refer to staple cotton only, and will not include cotton linters and cotton waste.

- - - - - Description - - - - -

According to the American Society for Testing Materials, a nonwoven fabric is:

> A textile structure produced by bonding or interlocking of fibers, or both, accomplished by mechanical, chemical, or solvent means and combinations thereof. The term does not include paper, or fabrics which are woven, knitted, tufted, or those made by wool or other felting processes.

The major categories of nonwovens now in commercial production are described briefly as follows:

Dry Processes

FIBER BONDED FABRIC - a carded or garnetted fibrous web held together by an applied chemical binder. In some cases, thermoplastic fibers are used and the web is bonded by applied heat. One additional variation is a mechanical entanglement of cotton fibers by means of an alkaline bath.

SPUN BONDED FABRIC - a randomly arranged web of continuous filament synthetic fibers drawn from a spinneret, solidified, and heat sealed into fabric form.

NEEDLE PUNCHED FABRIC - a web of textile fibers held together by a needling process which interlocks the fibers. A variation is the Arachne process in which a fine denier synthetic filament yarn is knit stitched through the needled web to add strength and dimensional stability.

Wet Process

WET-LAY FABRIC - a fabric structure formed by dispersing textile-length fibers into a slurry and casting the mixture on modified papermaking machinery.

Combination Wet & Dry Process

TISSUE/FIBER FABRIC - a structure formed by sandwiching a non-interlaced scrim between layers of tissue, or by filling a non-interlaced scrim with a slurry mixture and allowing to dry.

Currently, fiber bonded fabrics rank as the number one fabric-forming process for nonwovens. However, during the past year, a flourish of interest has centered on the wet-lay system of producing nonwoven fabrics because it appears to offer the most economical method for large volume runs. Most of the largest U.S. paper mills are actively engaged in research on and/or test marketing of nonwoven fabrics made on papermaking equipment.

ALL NONWOVEN TEXTILES
- - - - - The Market - - - - -

SINCE 1960:

* Total fiber consumption in nonwovens has almost tripled, jumping from 100 million pounds in 1960 to 295 million pounds in 1968.

* Cotton consumption has more than doubled, from slightly less than 5 million pounds in 1960, to about 10 million pounds in 1968.

* Cotton's market share dropped from 5 percent in 1960, to 4 percent in 1968, due primarily to market expansion in areas where cotton was unsuitable from a price/quality standpoint.

TABLE 1

ESTIMATED FIBER CONSUMPTION IN NONWOVEN FABRICS, 1960 & 1968

Year	Total Fiber: Millions of Pounds	Total Fiber: Equivalent Bales	Percent Cotton	Cotton Bales
1960	100	233,000	5	11,500
1968	295	684,000	4	24,900

THROUGH 1980:

* Total fiber consumption will approximate 1 billion pounds with major markets being disposable goods, carpets, and shoes.
* Cotton consumption will increase very slightly.
* Cotton's market share will drop to about 1 percent as man-made fibers, especially rayon, capture most of the market expansion.

TABLE 2

ESTIMATED FIBER CONSUMPTION IN NONWOVEN PRODUCTS
BY MAJOR END USE, 1968

End Uses	Total Fiber 1/ Millions of Pounds	Equivalent 500-Lb. Bales	Percent Cotton	Equivalent Cotton Bales
TOTAL, ALL END USES	295	684,000	4%	24,900
Abrasives	5	12,500	0%	--
Apparel Uses	70	162,800	-- 2/	600
Disposable Apparel	19	45,200	0%	--
Disposable Diapers	27	64,300	1%	600
Interlinings	24	53,300	0%	--
Blankets	11	24,400	0%	--
Carpeting	58	128,800	0%	--
Face Yarns	38	84,400	0%	--
Backing, Primary & Secondary	20	44,400	0%	--
Electrical Insulation	4	8,900	0%	--
Filters	20	47,600	12%	5,700
Medical & Institutional Uses	47	111,300	1%	600
Disposable Flat Goods	21	49,400	0%	--
Headrest Covers	4	8,900	0%	--
Sheets	7	16,700	0%	--
OR & OB Drapes	5	11,900	0%	--
Bed Pads	5	11,900	0%	--
Sanitary Napkins	20	47,600	1%	500
Bandages & Supplies	6	14,300	1%	100
Ribbons & Tapes	26	61,900	0%	--
Shoes	9	19,300	0%	--
Substrate Material	3	6,700	0%	--
Lining Material	6	12,600	0%	--
Wall Covering Fabric	4	8,900	0%	--
Wiping Cloths	16	38,100	44%	18,000
Other	25	59,500	0%	--

1/ Excludes material such as Flote, fiberfill, wadding, batting, and felts.
2/ Less than one percent.

TABLE 3

ESTIMATED FIBER CONSUMPTION IN NONWOVENS
BY TYPE OF PROCESS, 1968
(Millions of Pounds)

		Processes				
	Total	Fiber Bonded	Spun Bonded	Needle Punched	Tissue/ Fiber	Wet-Lay
All End Uses	295	174	18	74	24	5
Abrasives	5	5	--	--	--	--
Apparel Uses	70	58	3	4	4	1
Disposable Apparel	19	13	1	--	4	1
Disposable Diapers	27	27	--	--	--	--
Interlinings	24	18	2	4	--	--
Blankets	11	--	--	11	--	--
Carpets	58	--	11	47	--	--
Face Yarns	38	--	--	38	--	--
Backing Fabric	20	--	11	9	--	--
Electrical Insulation	4	4	--	--	--	--
Filters	20	7	--	4	9	--
Medical & Institutional Uses	47	40	--	--	6	1
Disposable Flat Goods	21	16	--	--	4	1
Headrest Covers	4	3	--	--	1	--
Sheets & Pillowcases	7	4	--	--	2	1
OR & OB Drapes	5	4	--	--	1	--
Bed Pads	5	5	--	--	--	--
Sanitary Napkins	20	20	--	--	--	--
Bandages & Supplies	6	4	--	--	2	--
Ribbons and Tapes	26	26	--	--	--	--
Shoes	9	2	1	4	1	1
Substrate Material	3	--	1	2	--	--
Lining Material	6	2	--	2	1	1
Wall Covering Fabric	4	2	1	1	--	--
Wiping Cloths	16	14	--	1	1	--
Other	25	16	2	2	3	2

TABLE 4

ESTIMATED FIBER CONSUMPTION IN NONWOVENS
BY TYPE OF FIBER, 1968

Fiber	Million Pounds	Equivalent Bales	Percent
TOTAL, ALL FIBERS	295	684,000	100
Staple Cotton	11	24,900	4
Cotton Linters & Waste	36	83,100	12
Rayon	127	294,800	43
Acetate	13	30,300	4
Polyester	24	55,600	8
Nylon	28	65,300	10
Polypropylene	52	121,000	18
Other	4	9,000	1

- - - - - Quality Considerations - - - - -

Absorbency
Bulk*
Coolness
Dimensional Stability
Drape
Hand
Non-irritating
Opaqueness
Permeability
Resiliency
Strength

Resistance to:
Abrasion
Chemicals
Fire
Fraying
Heat
Linting
Mildew
Pilling
Static Electricity

* High and low bulk, depending on end use.

Preliminary findings suggest that cotton is competitive with rayon, the leading contender, with respect to these qualities. Cotton's disadvantages are, for the most part, cost related as indicated by the following recommendations for research.

- - - - - Research Needs - - - - -

* Reduce costs of cleaning and bleaching raw cotton.

* Improve fiber length uniformity of cotton, or develop production methods which do not require high degrees of uniformity in staple length.

* Develop process for bleaching nonwoven fabrics made from unbleached cotton fiber.

* Develop methods of retaining natural oils in cotton during bleaching process, or develop means of reducing friction and drag in the manufacturing process.

Industry representatives tell us that cotton is at a serious economic disadvantage for use in nonwoven fabrics. Costs related to fiber preparation, processing losses, and production speeds are considerably higher for cotton than for man-made fibers.

Most nonwoven end products are required to be bleached and free of all trash. Since the finished fabric is usually not bleached because of fabric degradation, the manufacturer must start with bleached stock. Total bleaching costs, including processing losses, amount to 10¢ per pound for raw cotton. This means that gray cotton fiber would have to be available at 15¢ to 18¢ a pound in order to compete on a clean fiber basis with bleached rayon staple which is available at 25¢-28¢ per pound.

In addition to cleaning and bleaching costs, there are other cost-related areas where cotton is at a disadvantage. In the fiber bonded process, production speeds are closely associated with fiber length uniformity. Cotton is not as uniform in length as man-made fibers which can be cut to exact staple length requirements. However, bleached cotton, even in uniform lengths, cannot be run at as high a speed as can the synthetics because bleaching removes most of the natural oils from the cotton fiber thus causing severe reductions in its lubricity.

DISPOSABLE NONWOVEN TEXTILES
- - - - - The Market - - - - -

While accurate estimates of total potential for disposable nonwoven textiles are not available at this time, some very crude calculations would place it near 20 million bales annually. About one-half of the total potential would be in institutional bed linen. Fiber consumption in reusable sheets and pillowcases for the hospital/motel industry approximates <u>100 thousand bales</u> annually. Practically all of this fiber is cotton since the "no-iron" concept has not made the penetration in these markets that it has in the consumer market. If nonwoven disposable sheets and pillowcases were used exclusively in the institutional market, about <u>10 million bales</u> of fiber would be consumed per year. Apparel for hospital and industrial use as well as other types of institutional linen serve to increase the total potential for nonwoven disposable textiles.

Generally speaking, disposable nonwovens are not competitive in price or quality with conventional textile materials at the present time. A competitive price would be one close to, or less than, the cost of laundering reusable woven goods one time. The qualities of appearance, hand, and drape usually are very poor in the disposable textile products now being offered. Most look and feel like paper. However, it would be myopic to think that these obstacles cannot be overcome.

Once disposables gain wide acceptance, the problem of ultimate disposal will become critical. No workable solution to this problem has yet been developed, but industry thinking is revolving around three major possibilities:

(1) Chemical or biological decomposition,
(2) Using for landfill, and
(3) Reclaiming the textiles and reprocessing the fiber.

Also, industry consensus is that some means of automated fabrication must be developed for disposables to become competitive in price with conventional textiles. The costs of cutting and sewing nonwoven fabrics is just as expensive as with conventional textile materials.

TABLE 5

ESTIMATED FIBER CONSUMPTION AND COTTON CONSUMPTION IN NONWOVEN DISPOSABLE TEXTILES, 1968

	Total Materials			
	Millions of Pounds	Equivalent Bales	Percent Cotton	Cotton Bales
DISPOSABLE USES, TOTAL	109	258,900	7%	18,000
Apparel	19	45,200	0%	--
Diapers	27	64,300	1%	600
Medical & Institutional Uses	47	111,300	1%	600
Headrest Covers	4	8,900	0%	--
Sheets & Pillowcases	7	16,700	0%	--
OR & OB Drapes	5	11,900	0%	--
Bed Pads	5	11,900	0%	--
Sanitary Napkins	20	47,600	1%	500
Bandages & Supplies	6	14,300	1%	100
Wiping Cloths	16	38,100	44%	16,800

TABLE 6

ESTIMATED FIBER CONSUMPTION IN DISPOSABLE NONWOVENS BY TYPE OF PROCESS, 1968
(Millions of Pounds)

	Total	Fiber Bonded	Spun Bonded	Needle Punched	Tissue/ Fiber	Wet-Lay
Disposable Uses	109	94	1	1	11	2
Apparel	19	13	1	-	4	1
Diapers	27	27	-	-	-	-
Medical & Institutional Uses	47	40	-	-	6	1
Headrest covers	4	3	-	-	1	-
Sheets & pillowcases	7	4	-	-	2	1
OR & OB drapes	5	4	-	-	1	-
Bed pads	5	5	-	-	-	-
Sanitary napkins	20	20	-	-	-	-
Bandages & supplies	6	4	-	-	2	-
Wiping cloths	16	14	-	1	1	-

TABLE 7

ESTIMATED FIBER CONSUMPTION IN NONWOVEN DISPOSABLE TEXTILES BY TYPE OF FIBER, 1968

	Total Materials		Percent
	Millions of Pounds	Equivalent Bales	
Total, All Fiber	109	258,900	100%
Staple cotton	7	18,000	7
Waste cotton[1]	13	29,800	11
Rayon & Acetate	84	198,600	77
Polyester	2	5,000	2
Nylon	2	5,000	2
Other	1	2,500	1

[1]Includes small quantity of cotton linters.

- - - - - Quality Consideration - - - - -

Absorbency	Resistance to:
Coolness	Chemicals
Drape	Fire
Hand	Fraying
Non-irritability	Heat
Opaqueness	Linting
Permeability	Pilling
Strength	Static Electricity

- - - - - Research Needs - - - - -

* Develop means of making low cost, nonwoven fabric with hand, appearance, and drape similar to woven cotton fabric.
* Develop automated fabrication techniques to reduce costs costs associated with cutting and sewing operations.
* Develop low cost, practical means of ultimate disposal.

Research is needed in all of the above areas to enable disposables to displace conventional textiles, but primary emphasis should be placed on the task of developing a low cost cotton nonwoven through research in areas outlined previously for all nonwovens.

APPENDIX IV

Conclusions of the Report Entitled The Changing Capability of the Textile Industry To Support National Defense*

The report entitled, "The Changing Capability of the Textile Industry to Support National Defense", by Stephen J. Kennedy,** summarizes the actions involved in fulfilling our nation's needs in the clothing and textile area during the mobilizations of World War II, Korea, and Vietnam. It also notes the many technological, logistic, and economic changes that have occurred in recent years. The report presents 14 specific conclusions; these, together with the report itself, have been studied by members of the ad hoc Cotton and Textile Defense Capability Committee, appointed by Congressman Sisk.

While a review of the report in detail may be warranted at a later date, the Committee believes that a review and comments on the individual conclusions will accomplish the basic purposes of the Committee's Charter.

It should be noted that the Committee's comments address the report's conclusions insofar as cotton and wool blends are concerned. However, the absence of comments related to such items as nylon fabrics and tapes or other materials do not alter the Committee's findings as to the need for an accelerated and well-supported research and development program. The change, if any, would be in the degree to which the findings apply.

A proposed research and development program formulated by the Committee is submitted as an addition to these comments on the Kennedy report. ***

Conclusion #1 -The production base of the textile industry can no longer be considered to be relatively static. Where long term planning is concerned, it must be recognized that mills making a particular product in one year may, in response to market changes, no longer be making that product, or be able to make it, even only a year or two later.

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* Summarized by Arlie L. Bowling, National Cotton Council of America, Memphis, Tenn.
** Technical Report 73 - 50 - CE, U.S. Army Natick Laboratories, Natick, Mass., April, 1973.
***Appendix B

Comment: The Committee agrees that significant changes have occurred in the production base of the industry, notably the widespread use of synthetic fibers and rapid growth in the knitting and tufting industries. Additionally, wider and faster looms in place today produce roughly the same quantity of fabric that the 400,000 broad weaving units did during the years 1950-1965. As population increases and the opportunities for export increase, there will probably be a yearly gain both in weaving and knitting capacity. With knitted fabrics established as a viable apparel for outwear, substitutions can be made in the civilian sector to permit broad weaving capabilities to be turned to national defense needs. However, the industry continues to change, as exemplified by the recent trend toward open-end spinning. The Committee recommends periodic evaluation by the Department of Defense to determine the industry's ability to meet DOD requirements.

Conclusion #2 -Since the functional performance requirements for military textiles essentially limit them at this time to broadwoven goods, the future of this segment of the textile industry is a matter of major concern to national defense.

Comment: The Committee concurs in the critical dependence of the military on broadwoven goods.

Conclusion #3 -Production of broadwoven goods has not been rising in recent years proportionate to the growth of consumer demand for textiles, nor is it likely, in the near future, to be an attractive area for investment of new capital for significant expansion. Imports, which can be expected to continue to expand beyond the present 15 percent of the market although at a somewhat reduced rate, and competition from knitted fabrics, constitute limiting factors on growth of broadwoven goods production.

Comment: The Committee concurs that broadwoven goods production has not been proportionate to growth in consumer demand for textiles. Excessive imports of such goods should be avoided through proper administration of textile trade agreements. Also, the Committee recommends more rapid amortization of weaving machinery as well as other types of textile plant and equipment.

Conclusion #4 -Some of the segments of the broadwoven goods industry of most direct importance for military textiles are quite limited in capacity, particularly duck, fine combed cotton goods and worsteds, and are in a downward trend.

Comment: The Committee concurs in the limited capacity available for the production of broadwoven duck, fine combed cotton, and worsteds. The situation, in 1975, is as predicted, and there is no sign of reversal in the trend.

Conclusion #5 -The trend in the textile industry and the U.S. textile market toward increased use of the non-cellulosic man-made fibers, either in blend with the natural fibers or as replacements for them, will necessitate some redevelopment of present military textiles in order to keep sources of supply available.

Comment: The Committee concurs and notes that the Army Material Command (and other services as well) have initiated a number of programs to explore the immediate application of polyester/wool and polyester/cotton blends for military use.

Conclusion #6 -From the standpoint of national security, too great a commitment to the man-made fibers should be regarded with caution when regarded from the standpoint of the time frame projected in this study, 1980-85. The balance of trade deficit in energy fuels which can be anticipated by that date could have serious consequences upon the military, political and economic security of the United States, since our country would become increasingly dependent on the political and economic security of a relatively small number of countries in the Middle East. Under these conditions, it would appear to be a prudent course of action for the military to be prepared for the use of alternate textile fibers, the supply of which would not be dependent upon oil or gas, and which would require the minimum amount of energy for their conversion into military textiles. This would indicate the desirability for the military services to be able in such an emergency to obtain quickly large quantities of military textiles made from cotton and wool. From this standpoint, the maintenance of textile manufacturing facilities capable of producing textiles from cotton, and the continued use of textiles predominantly made from cotton by the military, would appear to be in the interests of national security.

Comment: The Committee concurs that national security should not become dependent on the political and economic policies of any small group of countries that can significantly limit our use of energy fuels or fibers. Alternative fiber sources should be available for military use. Long term procurement policies of the Defense Department should recognize the importance to national security of quickly available stocks of those fibers essential to defense mobilization.

Conclusion #7 -The present policy of the military services with respect to the use of cotton should be continued. It should be supported by positive actions by appropriate government authorities to (a) - minimize the fluctuations in the price of cotton which adversely affect its desirability to textile manufacturers; (b) - assure a carry-over of adequate size to meet possible military needs as to quantity, grade and staple at any time in the crop year.

Comment: The Committee agrees that cotton fiber needs to be available for defense mobilization purposes. Cotton tends to lose markets when prices fluctuate widely. Therefore, a continuous adequate supply is needed to assist in stabilizing the price of cotton. Adequate cotton carryover is essential as a part of this supply, not only to meet military mobilization requirements, but also to prevent temporary shortages of raw cotton and inordinately wide fluctuations in price causing too much or too little production. To assist in price stabilization for cotton, and to effectuate Department of Defense cost savings, the Committee recommends (a) increased Defense Department purchases of cotton textiles during periods of textile and economic recession; (b) adequate stocks of cotton textiles such as apparel, duck for tenting, and other textiles essential to mobilization should be carried as reserve stocks to make it possible for the Defense Department to, not only meet mobilization requirements, but also to facilitate the textile industry's ability to serve the civilian population.

Conclusion #8 - The lack of a potential reserve of labor in the major textile manufacturing areas, which could well continue or intensify over the next several years, could pose a serious problem to achieving a high level of output on military textiles quickly in the event of mobilization.

Comment: The Committee concurs that available reserves or surpluses of labor are no longer plentiful in textile producing areas. However, methods of accelerated in-plant training of operating personnel have improved. It does not appear to be practical to "stockpile" trained labor reserves outside the industry. The Committee recommends that recognition and priorities be given to employment in critical textile jobs in mobilization planning. The Department of Defense should consider ways and means of providing official recognition and opportunities for military personnel trained in the textile area, as well as a planned program for interchange between military and industrial textile counterparts.

Conclusion #9 - Lack of a broad-based textile machinery industry within the United States, with so large a proportion of presently installed mill equipment having been made overseas, could create a serious spare parts problem in a crisis situation. Loss of production capacity during the early part of the period while domestic manufacturers tooled up to produce needed parts for foreign equipment could seriously limit the capability of the industry to reach high production levels quickly.

Comment: The Committee recognizes possible difficulties in obtaining spare parts. However, in the last few years a trend toward more foreign machinery manufacturers setting up manufacturing, assembly and/or spare parts warehousing has developed. Certain items might be found to be in short supply for a period of time, but a number of small companies have responded to the need for upgrading equipment since World War II. An estimated 400 firms ranging from machine shop types to rather sizable manufacturing installations to supply parts now exist to service the textile industry. The majority of looms making broadwoven goods are American made. A more accurate assessment of the spare parts problem is recommended in the Appendix to these conclusions.

Conclusion #10-The industries which convert textiles into the end items used by troops: parachutes, protective combat clothing, uniforms, equipment, personnel armor, etc., can be expected to lose contact with military items during a prolonged period of peace. They may accordingly be ill-prepared to move quickly into production of military items in an emergency. Some industries which produce almost entirely for the military, such as those making parachutes, personnel armor, and large tents, may be so reduced in size as to be quite inadequate as a production base from which to provide large scale production.

Comment: The Committee concurs and recommends that the services reevaluate the extent to which programs in manufacturing technology are keeping current. The Committee specifically notes the validity of this conclusion with respect to many items having only military application, and need for a reexamination of this area in the light of the recent economic pressures upon the industry.

Conclusion #11-(A) A broad-based research and development program to develop alternate textile materials which will be in consonance with industry's capabilities for large scale production within the projected time frame 1980-1985, and yet which will meet all critical and essential technical requirements, should be undertaken as a matter of priority.

(B) In view of the rapid changes taking place in the industry on the one hand, and the need for prudent reserve about too great a commitment to man-made fibers based upon oil, of which a large part will have to be imported in the time frame suggested, such a research and development program should proceed along several lines simultaneously, including especially the upgrading of the performance of cotton textiles or limited mixtures of other fibers with cotton. The support of industry and the U.S. Department of Agriculture should be obtained on as broad a base as possible to assure the availability of materials conforming to all military needs.

Comment: The Committee whole-heartedly endorses the foregoing. For a variety of reasons, some of which are peculiar to the industry segment involved, the research and development support in the clothing and textile area has been inadequate to keep pace with the military's needs. The Committee also notes that this problem is compounded by the many recent technological changes in the industry, and the unique requirements of military textiles that prohibit ready interchange with items acceptable to the civilian sector. To resolve this, the Committee recommends support of a research and development program, managed by the Army, as further outlined in Appendix B. In preparing this recommended program, the Committee notes that it offers the potential of not only alleviating future mobilization problems, but of improving the technological posture of the industry with subsequent advantages to the economy. The Committee also notes that within the Department of Defense, the pressures of many high priority programs frequently leave little emphasis on clothing and textile research. Inasmuch as the DOD procures clothing and textile items to the extent of approximately $500,000,000 per year, the Committee recommends that the research and development in this area be assigned a higher priority, commensurate with the mobilization problem noted, and the concomitant beneficial effects to the economy.

Conclusion #12-The complexity of the textile and related industries and their unlikeness to the hard goods industries which has baffled and frustrated so many military personnel who have not had previous relation to these industries, would indicate that the need for a commodity training program, such as a graduate program in textiles at university level for officers who are to be assigned in the fields of procurement, supply or administration in this area. The success of the World War II Quartermaster textile and clothing operation was due largely to the fact that practically all officers involved in it were drawn from the textile and clothing industries. The availability of officers with such training in the future will be essential to effective operation of a future mobilization program.

Comment: The Committee concurs, and directs the attention of the services to the recommendation. At the same time, it acknowledges the efforts of the services mobilization reserve programs, which are intended to satisfy this requirement.

Conclusion #13-(A) With respect to the first of the two parts of the basic question raised in this study, viz., the availability of a broad industry base to supply needed military textiles in large quantities quickly upon mobilization, it is clear that at present such a broad base does not exist for duck, fine combed cotton goods, or worsted uniform fabrics. Also, because of the special manufacturing eqiupment required to make these fabrics, very little conversion of other mills' capacity could be turned into producing them. Alternate materials are needed as either partial or total replacements for these materials.

(B) But even for total textile needs, there can be serious question whether conversion of the industry could be accomplished quickly enough, together with that of the industries which should have to convert textiles into the end items used by troops, to bring production up to usage rate by the end of the year, if large scale mobilization were necessary. As shown in this study, there are numerous unfavorable factors which could delay attainment of a required high level of production quickly. The repetition of what occurred during the Korean War, when quantity production could not be attained until the second year of the war, should be recognized as a potential hazard.

Comment: The Committee believes that the research and development program recommended (see Conclusion #11) will, if properly supported, provide answers to the foregoing technological problems. However, the Committee notes that a significant portion of the problem occurring during the Korea mobilization was (during the most critical period, the first 90 days) not problems of a production nature, but delays in initiating production contracts. Accordingly, the Committee commends the report to the attention of the DSA in this regard.

Conclusion #14-As to the other aspect of whether, if the conflict were prolonged, the industry base would be adequate to meet the needs both of the military and the civilian population, the answer is clearly negative. With a large segment of the total civilian demand now being met by imports, which can be expected to increase in coming years, the demands for military textiles would so limit the amount available to consumers that, with imports shut off, severe limitations upon civilian usage would be required. The resulting morale aspects and the problems of price controls, black markets, etc., could be serious as was demonstrated during World War II, where the supply situation was far less critical than it would be in the future or even today.

Comment: The Committee feels that the primary concern of the report, with which it concurs, deals with problems that would be encountered during mobilization. The longer term problems of a sustained conflict are likely to find solution in the research and development program proposed and therefore do not warrant further consideration at this time. This is not to say that the problems identified can be ignored; it should be a matter of continuing assessment as the proposed research and development program proceeds.

APPENDIX B

PROPOSED RESEARCH AND DEVELOPMENT PROGRAM

Introduction:

This proposed research and development program has been outlined in response to the Committee's reaction to conclusions enumerated in the U.S. Army Material Command's Technical Report 73-50-CE, the Kennedy report, on the changing capability of the textile industry to support national defense. The report recommends a broad-based research and development program to evaluate the production base of the textile industry and its capabilities to meet all critical and essential technical requirements for mobilization.

Support:

Recognizing that the Department of Defense procures in excess of 500 million dollars a year in clothing and textile items, the program proposed at a rate of 20 million dollars a year is modest by any industry standards. More important, it must be recognized that the economic conditions in the clothing and textile industry today do not permit the support of any aggressive research and development effort, nor have they in recent years. For this reason, the support of this program will not only alleviate the problems of mobilization outlined in the report, but it will provide a significant assist to the industry as previously noted.

The proposed budget requirement of $20 million recognizes the importance of the textile mobilization problem and the magnitude of the effort needed to undertake necessary research and development. It is not feasible to itemize the costs of the several research proposals separately, until priorities are set and changing regulations imposed by the Environmental Protection Agency, and Occupational Safety and Health Administration or other requirements are identified as related to each.

Approach:

As indicated above, the research and development program proposed addresses itself to a variety of needs, ranging from basic research in textile technology through the manufacturing technology required to meet the needs outlined in subject report. The program proposed would provide a powerful stimulus to upgrade the technology of the industry and thus the nation's ability to, not only meet its anticipated mobilization needs, but also the competition from other nations which has eroded the U.S. position in textile technology. In addition to the pressures of a rapidly changing technology and the foreign competition, the problems created by environmental and safety statutes further accentuate the need for accelerated and expanded research in the area of clothing and textile technology.

Because the primary need to be served by this research and development program is to alleviate an existing problem faced by the Department of Defense, it is proposed that the overall program be managed by the U.S. Army Natick Laboratories, which currently performs the major portion of research in this area within the Department of Defense. It is also recognized that significant portions of the research proposed can be effectively performed by other Federal Agencies, by industry, and by educational institutions. The Army Natick Laboratories, in managing this program, will be responsible for drawing on such organizations in order to maximize the use of the nation's resources in this area.

Scope:

The research and development program proposed comprises effort which can be identified in nine areas for planning purposes.

1. A study of chemical, textile and agricultural industries as they relate to clothing and textile needs for the Department of Defense.

This effort which would comprise a study of the combined effects of economic, environmental, and safety aspects (as well as potential materials shortages) on a long-term availability of cotton, wool or other items required to satisfy military needs, is a critically needed first step. Although this is not a typical research and development effort, the results of this study would guide the research effort in other areas of the program. As noted in the Kennedy report, there is considerable evidence of economic, technical, energy, and other factors that would influence materials available for mobilization. Research and product development is needed to provide fibers and products to meet military needs in the years ahead.

2. Evaluation of manufacturing equipment, production rates and spare parts problems in the textile industry.

This portion of the program would not only provide accurate assessment of such problems as the availability of spare parts for foreign-produced equipment in the event of mobilization, but would also address itself to means for obtaining the greatest flexibility and producibility from existing equipment to satisfy military needs in the event of mobilization. The effort would specifically include an investigation of means to increase productivity on existing or modified equipment. Open-end spinning is an example of one. Another is the shortage of spindles available to produce lightweight and absorbent fine count cotton yarns needed for mobilization.

3. Evaluation of capabilities of the dyeing and finishing industry with respect to material shortages and other restraints such as safety and environmental.

This segment of the industry is singled out for special attention because it is most severely impacted by the foregoing restraints. The effort would not only involve complete assessment of the long-term ability of the industry to provide resources for mobilization but would also include research and development effort directed to alleviate the specific problems identified. For example, the availability of natural gas is critical in textile finishing plants where an intense, clean open heat is necessary.

4. A study of "sheet" materials required to fulfill the needs of the Department of Defense.

Many Department of Defense applications which now depend heavily upon such materials as broadwoven goods constitute potential shortage problems in the event of mobilization because of the declining trend in such manufacturing capabilities in the U.S. For such applications, "sheet" materials (including non-woven materials, fibrillated materials, perforated polymer combinations, and similar materials) may well provide acceptable substitutes for Department of Defense needs. An area of immediate concern is the urgent need for the development of a more readily available tentage material.

5. Investigation of fiber blends.

The Department of Defense must, in the event of mobilization, fulfill its needs by utilization of manufacturing technology in place at the time of mobilization. During recent years, significant changes in fiber blend composition and construction have occurred in the industry as it has sought to satisfy market needs and to meet competition. Such changes can be expected to continue in the years ahead, and the Department of Defense must therefore perform the necessary research and development to characterize the full range of blends and constructions with respect to their ability ot satisfy military requirements in uniforms and other applications. With such a bed of data, the Department of Defense could, in time of mobilization, rapidly assess the optimum composition and construction of fabrics available from industry at the time. An example of work envisioned in this area would be the continuation of current efforts to determine the mechanisms of wear in cotton fabrics, as well as cotton blends, and to use this information to predict the wear life in actual field operations.

6. Investigation of material combinations in military clothing and equipment.

The combination of textiles, foams, fibers, and other new materials into structures that will fill military needs would be a logical portion of research and development effort. Because of the peculiar nature of military clothing and equipment, the industry has little incentive to undertake such research and this area has not received adequate support in the Department of Defense in recent years. This effort may include incorporation of sheet materials (see Item 4). The research and development conducted in this area could lead to expanded use of conventional fiber and fabric products by incorporation of such materials in new constructions or in combination with other matierals. This could well lead to significant new products for the American consumer and new markets for industry as well.

7. Study of End Item Manufacturing Techniques.

In periods of mobilization, the time to produce critically needed items is often the critical problem in the early stages of conflict. In the construction of clothing articles and other items commonly based on textile technology (such as parachutes and tents), the time to assemble fabrics into the end items is apt to be the critical path in most instances. On an interim and probably even long term basis, totally new concepts in producing such end items should be explored. In the case of garments, stitchless seaming through use of such approaches as improved adhesive systems warrant consideration. A more radical departure is to investigate the use of such items as formable or moldable garments. The successful development of such technology could significantly ease the mobilization problems associated with the time to assemble such items.

8. Evaluation of various approaches to stockpiling.

Recognizing the economic restraints associated with stockpiling, a study should be conducted to evaluate the optimum balance to be achieved between available technology, time to convert, and economics in converting raw materials such as cotton to end products. This would, of necessity, be an on-going effort, in view of the many changes occurring in textile technology today. As an example of this, production of cotton yarns utilizing open end spinning appears to be in a period of significant expansion in the U.S. Such developments in technology, which significantly increase manufacturing rates, would be critical inputs in attempting to reach a decision as to the amount and nature of products to be stockpiled.

9. Investigation of manufacturing technology as it relates to military requirements.

As noted above, new developments such as open end spinning, malimo weaving (sewing), weftamatic knitting, appear to offer the promise of significant changes in production rates in textile technology. Similarly, the development of new construction techniques offer the possibility of producing fabrics at yardage rates from 20-40 times faster than conventional looms. Such new technologies must be available to determine the military applications for which such constructions may be suitable. For mobilization purposes, it is possible that trade-offs can be made between durability and manufacturing rates and such studies would also need to be on a continuing basis.

CHAPTER 2

WOOL AND MOHAIR

Wool for centuries has been the primary animal fiber used for textiles and continues its primary role today. Mohair from the angora goat is the only other animal fiber produced in any significant amount in the U.S. Other animal fibers closely related to wool and mohair in structure and properties used in small amounts are the hairs of alpaca, vicuna, llama, camel and rabbit.

The competitive position of wool and other natural fibers has been seriously threatened by the man-made fibers. The first man-made fiber was rayon, a regenerated cellulose made from purified chemical wood pulp, termed "dissolving pulp." The production of rayon in the U.S. started in 1910, and its use increased rapidly during the 1930s. The production of nylon, the first purely synthetic fiber, started in 1939. This was followed by the acrylics and polyesters and other synthetic fibers. By the late 1950s, the man-made fiber industry had made serious inroads into traditional markets of the natural fibers.

The amount of silk consumed in the U.S. decreased from 80 million pounds in 1930 to 2 million pounds in 1972. Cotton and wool consumption also decreased but to lesser degrees. Before 1940, more than 80 percent of all U.S. fiber consumption was cotton. By 1972, the consumption dropped to 35 percent. Sheep numbers in the U.S. have fallen from a high of 40 million before the 1940s to 16 to 17 million today. The consumption of the principal natural fibers outside the U.S. has also dropped, but to lesser degrees. However, as the man-made fibers become more widespread internationally, the competition between the natural and the man-made is expected to intensify.

According to Lundgren (1974), there are four important factors influencing textile fiber competition: "price, availability, promotion, and quality. As long as the man-made fibers were high in price, the natural fibers could maintain a strong position competitively. Sharp fluctuations in price and availability of these natural fibers has a damaging effect on their competitive strength. For example, wool lost important traditional markets to man-made fibers during the early 1950s when wool was in high demand and short supply. These markets were not regained when price and availability normalized.

"Product promotion in today's highly competitive markets has tremendous influence. The large sums spent in promoting man-made fibers has paid off in helping increase their acceptance.

"But, ultimately, it is the quality of the fiber that is important. Significantly, no fiber today possesses all the qualities desired in textile use. When rayon was first made, it had inferior strength, but the property has been improved considerably through research. On the other hand, nylon and the other purely synthetic fibers have excellent strength but low moisture absorbing power, a requirement for comfort in apparel goods. Some of the newer man-made fibers offer exceptional properties such as resistance to heat and chemicals, but these fibers are too expensive except for special uses where cost is secondary.

"The man-made fibers were able to achieve widespread use in clothing and household textiles by virtue of such properties as ease-of-care, durable press, non-shrinkage, resistance to insects. These fibers, however, have their faults, including yellowing, pilling and mussing after repeated wear and cleanings, and snagging, bagging and sagging in double knits.

"The significantly higher moisture absorbing capacity of cotton and wool helps provide for greater comfort in clothing and in other uses where water must be absorbed. Cotton and wool are easily cleaned and can be dyed to a wide range of attractive colors that are fast to sunlight and laundering, and they have lasting good appearance."

Although a reliable figure for the total energy consumption per unit of wool production is not available, it is generally accepted that wool production is even less energy demanding than cotton production. Cotton, in turn, requires 5 to 7 times less energy per pound production than the man-made fibers (National Cotton Council 1974a, b). Wool, therefore, has a very low energy demand compared to the man-made fibers.

ASSESSMENT OF THE WOOL AND MOHAIR TEXTILE INDUSTRY

Reference Materials System and Data for 1972

The materials flow for wool/mohair in the form of a reference materials system and activities is shown on the flow chart on the following page (Figure 1). Summarized statistics on wool and mohair, on apparel and carpet wool and on mill consumption, all for 1972, are from reports of the U.S. Department of Commerce and are shown in Table 1.

A more detailed listing of data on the U.S. wool situation for 1972 is shown in Table 2 supplied by the Wool Bureau, Inc. A statement on projections to 1985 and 2000 is included. Table 3 shows labor costs in the worsted sector for 1971-72.

A curve showing the monthly changes (May 1974 through April 1975) in M Btu/lb. is shown in Figure 2. This is an ATMI energy consumption efficiency measurement survey of 200 textile mills, some of which are woolen mills.

Projections for 1985 and 2000

Wool and mohair data for 1972 and projections for 1985 and 2000 are shown in Table 4. This data was furnished by Nelson F. Getchell of the Agricultural Research Service, and Edward H. Glade, Jr. and Sam Evans of the Commodity Economics Division of the Economic Research Service of USDA. They point out that the projections provided should not be viewed as official USDA forecasts, but are based on the best information currently available. Trend analysis was the primary methodology used in developing most of the estimates for the years 1985 and 2000. These show a declining sheep population and a corresponding drop in wool production. Estimates of total energy consumption represent only that energy expended on wool and mohair fiber.

FACTORS AFFECTING THE WOOL TEXTILE INDUSTRY

Increased Meat Production

The trend analysis projections in Table 4 indicate a declining sheep population in the U.S. and hence a declining wool production. In this country wool is a by-product of meat production and, according to Clair E. Terrill (1975), Staff Scientist, National Program Staff, Agricultural Research Service, USDA, there is likely to be a sharp rise in the sheep population beginning in the near future. This, he believes will cause a major perturbation of the trend. He points out that sheep produce meat more efficiently than

FIGURE 1

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES -- WOOL/MOHAIR

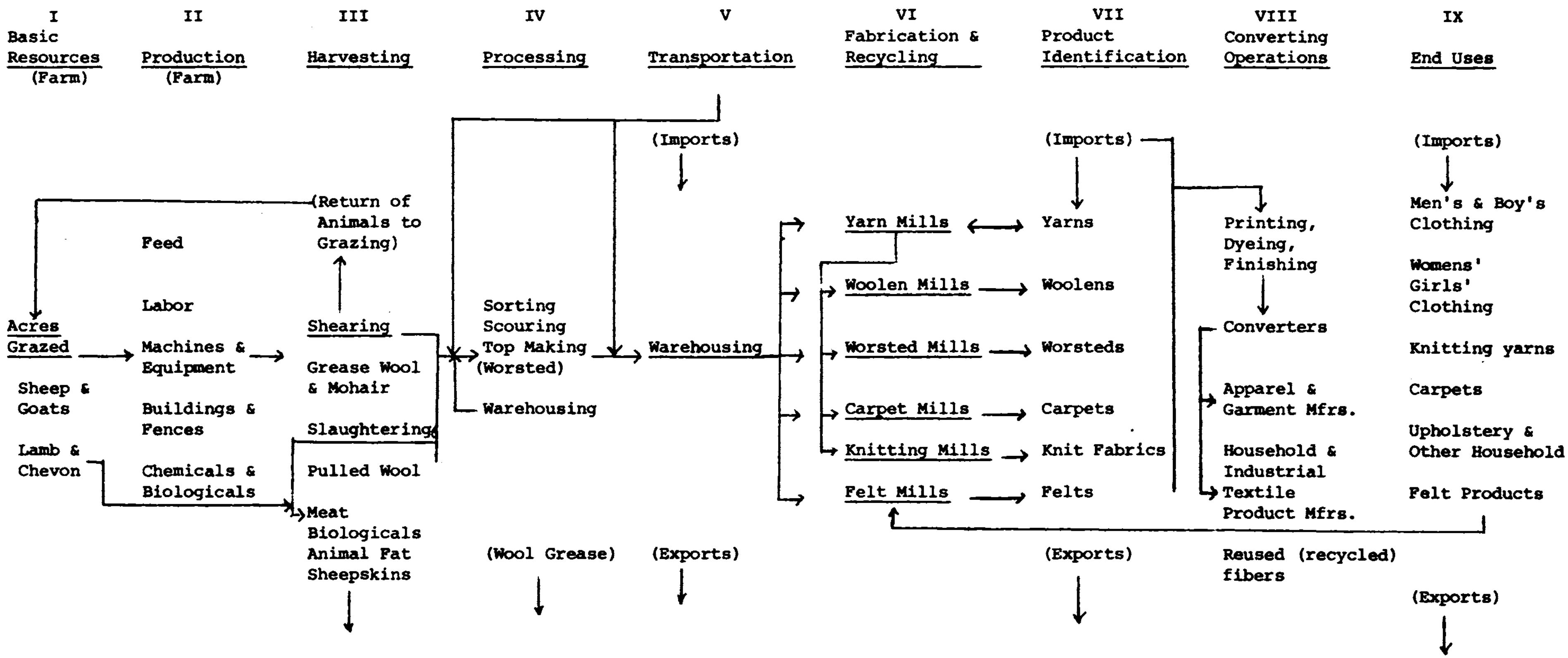


TABLE 1

WOOL AND MOHAIR STATISTICS
1972

Grease Wool Production	Production (1000 lbs.)	Price/Lb. (cents)	Value of Production ($1000)
Shorn wool	158,918	35.0	55,626
Pulled wool	8,000		
Total wool	166,918		
Mohair Production	10,190	83.0	8,458

Apparel and Carpet Wool, 1972
(Clean Content)

Apparel Wool	(1000 lbs.)
Domestic production	81,636
Exports	11,224
Imports (for consumption)	24,790
Total new supply	95,202
Carpet Wool	
Imports	71,849

Wool: Mill Consumption for 1972
(Scoured Basis)

Apparel Wool	(Million lbs.)
Woolen system	50.2
Worsted system	92.0
Total Apparel	142.2
Carpet Wool	76.4

Source: U.S. Department of Commerce Reports.

TABLE 2

U.S. WOOL SITUATION, 1972

Stocks of raw wool, scoured basis, (January 1), mil. lbs.	85.2
Apparel wool	57.6
Carpet wool	27.6
Production of raw wool, clean basis, mil. lbs.	82.4
Imports of raw wool, clean basis, mil. lbs.	96.6
Apparel wool	24.8
Carpet wool	71.8
Exports of raw apparel wool, clean basis, mil. lbs.	11.2
Wool consumption in mills, scoured basis, mil. lbs.	218.6
Apparel wool	142.2
Carpet wool	76.4

Raw wool equivalent of foreign trade, clean basis, mil. lbs.	Imports	Exports
Tops & advanced wool	0.4	25.5
Yarns	6.3	0.6
Woven fabrics	8.8	0.6
Wool blankets	0.7	0.1
Wearing apparel, total	31.2	1.3
Knit	20.0	0.4
Woven	11.2	0.9
Other manufactures	3.3	0.9
Noils & wastes	32.4	2.7
Carpets & rugs	12.3	1.1
Felts	-	0.5
	95.4	33.3

TABLE 2, Cont'd.

Domestic wool consumption (mill cons. + net imports of products), mil. lbs.	280.7
Apparel wool	193.1
Carpet wool	87.6
Raw wool prices, Boston, ¢ per lb., clean basis, average for the year	
Apparel wool:	
Domestic territory, find good Fr. Combing & Staple	115.7
Australian 64's, warp and ½ warp, duty-paid	157.6
Domestic 3/8 blood, good Fr. combing & staple	93.8
Australian 58/60's combing, duty-paid	147.1
Carpet wool:	
New Zealand 2nd shears B	79.2
Production of apparel fabrics (50% or more wool)	
Woven fabrics, mil. lbs.	154.4
Knit fabrics, mil. lbs.	10.7
Imports of apparel fabrics (50% or more wool)	
Woven fabrics, mil. lbs.	18.9
Knit fabrics, mil. lbs.	2.7
Consumption of wool by end use, % distribution 1973	
Total	100.0%
Sweaters (men's & women's)	7.9
Men's outerwear	18.6
Women's outerwear	22.7
Children's wear	6.6
Blankets	1.4
Retail piece goods	2.1

TABLE 2, Cont'd.

Consumption of wool by end use, % distribution 1973, cont'd.

Handknitting yarns	6.6
Socks	2.5
Upholstery fabrics	2.9
Carpets & rugs	21.2
Other minor end uses	7.5

Projections to 1985 & 2000

USDA estimates sheep population at less than 10 million by 1980. This means a decline of 4% per year from 1975. If this trend continues to 1985, the number of sheep will be about 8 million head, yielding approximately 35-45 million pounds of clean wool. By the year 2000, production of wool might be stabilized or declined at a slower rate from 1985 to 2000. This will depend entirely on the wool textile activities in the U.S. market.

Source: The Wool Bureau, Inc., New York

TABLE 3

LABOR COSTS IN WORSTED SECTOR

Study Done by London Headquarters, 1971

Labor earnings per hour	$ 2.58
Staff cost per hour (10% of labor)	.26
Labor and staff cost to produce 220 pounds in 30 hours, worsted yarn	85.20
Labor and staff cost to produce 110 linear yards of worsted fabrics in 60 hours	170.40

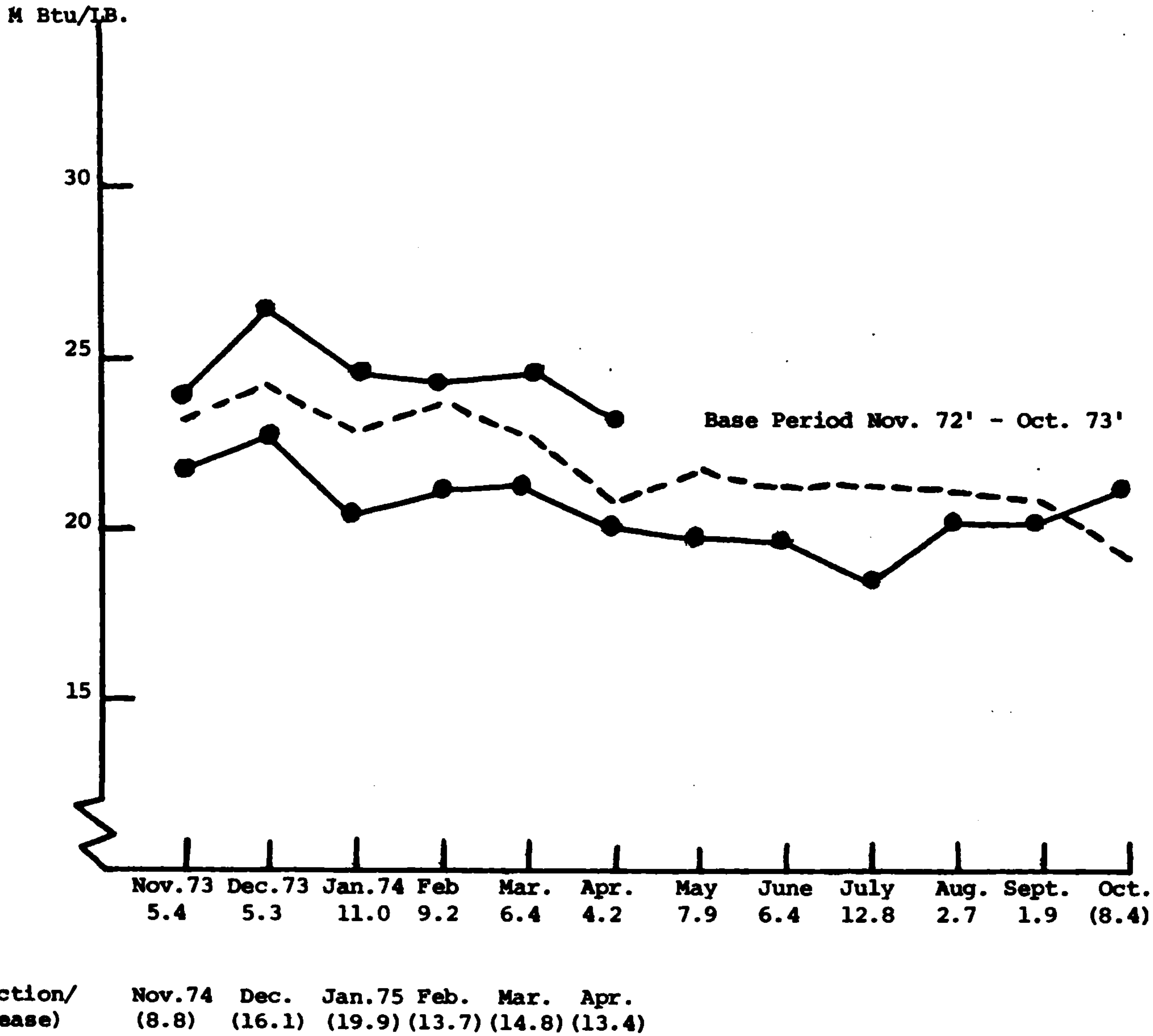
Census of Manufacturers, 1972

Labor cost (average hourly gross earnings)	
Textile mill products	$ 2.74
Apparel & related products	2.62
Weaving & finishing mills, wool	3.27
Wool yarn mills	2.90

Source: The Wool Bureau, Inc., New York.

FIGURE 2

ATMI ENERGY CONSERVATION EFFICIENCY
MEASUREMENT SURVEY



M Btu/LBS	
1974	TOTAL INDUSTRY
May	19.97
Jun	19.81
Jul	18.54
Aug	20.44
Sep	20.36
Oct	21.07
Nov	23.77
Dec	26.51
1975	
Jan	24.53
Feb	24.26
Mar	24.52
Apr	22.67

TABLE 4

WOOL AND MOHAIR PROJECTIONS

RMS Activity	1972	1985	2000
Basic resources			
Acres grazed		(not available)	
Number of sheep (mil. head)	15.8	13.5	12.8
Number of goats (mil. head)	1.5	1.7	1.9
Production			
Farm production cost ($/lb.)			
Harvesting			
Grease wool production (mil. lb.)	158.9	134.4	127.6
Pulled wool production (mil. lb.)	9.7	8.2	7.8
Mohair production (mil. lb.)	10.5	11.9	13.3
Labor:			
Shearing (thous. man-hours)	940	795	755
Clipping goats (thous. man-hours)	150	170	190
Costs:			
Shearing & clipping ($/head)	.60	.85	1.30
Shearing & clipping ($/lb.)	.07	.12	.16
Slaughtering		(not available)	
Processing			
Scouring:			
Scouring costs ($/lb.)	.05	.07	.10
Labor (man-hours per lb.)	.006	.005	.004
Energy consumption			
Electrical (KWH/lb.)	.07	.07	.07
Other		(not available)	
Wool grease recovered (lb./lb.)	.05	.05	.05
Clean wool from grease wool (lb./lb.)	.48	.50	.55
Clean wool from pulled wool (lb./lb.)	.729	.729	.729
Warehousing:			
Average cost of operation ($/lb.)	.04	.06	.09
Labor (thous. man-hours)		(not available)	

	1972	1985	2000
Transportation			
Raw wool exports (mil. lbs. clean basis)	11.2	9.7	9.3
Raw wool imports (mil. lbs. clean basis)	96.6	100.0	102.0
Mohair exports (mil. lb. clean basis)	18.8	9.5	10.6
Mohair imports (mil. lbs. clean basis)	0	0	0
Fabrication and recycling			
Yarn mills:			
Cost of production ($/lb. processed)	1.53	2.52	3.67
Labor (man-hours/lb. processed)	.13	.12	.10
Energy:			
Purchased fuel (mil. KWH eqv.)	500.0	475.0	450.0
Electric energy (mil. KWH)	179.2	159.0	145.0
Woolen & worsted mills: (including finishing)			
Cost of production ($/lb. processed)	2.70	4.45	6.48
Labor (man-hours/lb. processed)	.21	.19	.16
Energy:			
Purchased fuel (mil. KWH eqv.)	2,400.0	2,200.0	2,000.0
Electric energy (mil. KWH)	393.3	350.0	315.0
Carpet mills:			
Cost of production ($/sq. yrd. produced)	2.71	4.46	6.48
Labor (man-hours/sq. yd. produced)	.11	.10	.09
Energy:			
Purchased fuel (mil. KWH eqv.)	900.0	825.0	750.0
Electric energy (mil. KWH)	92.2	85.0	78.0

Wool and Mohair Projections, Cont'd.

	1972	1985	2000
Product identification			
Imports:			
Yarns, tops and fabrics (mil. lb.)	51.8	58.3	65.5
Carpets & rugs (mil. lb.)	12.3	13.8	17.4
Exports:			
Yarns, tops & fabrics (mil. lb.)	30.8	34.7	38.9
Carpets & rugs (mil. lb.)	1.1	1.2	1.4
Converting operations			
Printing, dyeing & finishing:			
(performed primarily in woolen & worsted mills)			
Apparel and housefurnishings manufacturers (no data available as wool fiber identity is lost at this state of product flow)			
End Uses			
Imports:			
Wearing apparel			
Knit (mil. lb.)	20.0	22.5	25.3
Woven and other (mil. lb.)	11.2	12.6	14.2
Exports:			
Wearing apparel			
Knit (mil. lb.)	.4	.5	.6
Woven and other (mil. lb.)	.9	1.0	1.1
Carpets (included under RMS Product Identification)			

Source: Edward H. Glade, Jr. and Sam Evans, Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture.

cattle, especially on forages alone. Furthermore, a wide array of technology has just become available which might lead to as much as 70 percent increase in efficiency in 10 years; another 70 percent is possible in the following 10-25 years. He projects an increase in sheep numbers and individual weight to begin in 2 years and to reach a 50 percent increase by 1985. As lamb and mutton become more available, the retail price will fall so that consumers will readily accept the meat, and the added efficiency of lamb production will permit the producer to receive an adequate return.

Wool production will increase as a by-product of the increased meat production. However, wool weights per animal will probably decrease somewhat, since primary effort will be on meat production. Wool quality may also decline, since the animal will be bred primarily for meat instead of for quantity and quality of wool.

Projections to 1985 and 2000 for sheep numbers and meat productivity and for wool production by Terrill are shown in Tables 5 and 6. This projected increase in wool production, contrary to trend projections due to a suggested increase in sheep production for meat, can be considered a perturbation on the high side of the trend forecasts for 1985 and especially for 2000.

Today's Changing Circumstances

Today's textile mills, fabric finishers, and garment makers are becoming progressively more streamlined, automated, and computerized. As they move toward higher speeds and greater efficiency, increasing emphasis is placed on the quality of the raw fiber. Complex developments in modern spinning methods have evolved only since the 1960s. Radical changes in the systems of mechanical handling of fibers are occurring. For example, spinning speeds have moved up from 8,000-12,000 r.p.m. to 12,000-18,000 for cotton and to a lesser degree for wool. Similar changes have been occurring in carding and combing. Shuttleless looms and high speed knitting, along with automated operations, are further reducing costs and increasing efficiency. To estimate these present costs, let alone future costs, is very difficult.

Today's consumer is also changing. In the U.S. he is more practical, more sophisticated, more affluent, more fashion conscious, more socially aware, more mobile, and more health and safety conscious. He likes casual wear and variety, but he wants quality in his textile products. The textile industry is seeking, through research, to satisfy his demands.

TABLE 5

PROJECTED SHEEP NUMBERS AND PRODUCTIVITY TO 2000

Year	Inventory Sheep and Lambs Jan. 1 (1000)	Ewes One Year and Older (1000)	Lambs per Ewe	Lamb Market Weight (lbs.)	Meat per Inventory Sheep (lbs.)	Total Lamb and Mutton (mil. lbs.)
1969	21,350	14,707	.95	103	25.29	540
1970-74	18,587	12,733	.96	-	28.05	521
1974	16,394	11,106	.95	(105)	27.69	454
1975	14,538	10,107	(.95)	(100)	(26.83)	(390)
1985	21,800	15,200	1.20	115	38.97	850
2000	235,000	155,000	1.80	138	70.04	16,459

Source: Dr. Clair E. Terrill, Agriculture Research Service, U.S. Department of Agriculture.

TABLE 6

PROJECTED WOOL PRODUCTION TO 2000

Year	Inventory Sheep and Lambs Jan. 1 (1000)	Sheared Wool (1000 lbs.)	Pulled Wool (1000 lbs.)	Total Wool Production (1000 lbs.)	Wool Produced Per Sheep (lbs.)
1969	21,350	165,655	17,100	182,755	8.56
1970-74	18,587	151,765	10,120	161,886	8.71
1974	16,394	132,931	5,700	138,631	8.46
1975	14,538	-	-	-	(8.50)
1985	21,800	173,719	11,581	185,300	8.50
2000	235,000	1,762,500	117,500	1,880,000	8.00

Source: Dr. Clair E. Terrill, Agricultural Research Service, U.S. Department of Agriculture.

Research

Production research has developed breeds with increased wool yields and improved fiber quality. New research has improved meat production.

Utilization research on wool includes the following:

a) ease-of-care wools by resin applications leading to superior machine washable wools by treatments that are economical and give goods that are aesthetic and of good feel,
b) superior durable press wools leading to 100 percent wools that can be machine washed, tumble-dried, worn without need for touch-up ironing, and remain smooth during wear,
c) durable two-way stretch by a simple procedure (announced by USDA's Western Regional Research Laboratory)-now requiring development on continuous basis for manufacturing operations,
d) durable resistance (to flames, soil, moths, and carpet beetles),
e) multipurpose finishes, and
f) accelerated dyeing and finishing technology with special emphasis on use of non-toxic chemicals and on processes which have no effluent pollution problem.

In garment making, research seeks simplified construction techniques, and also effective and durable adhesives for bonding fibers to eliminate sewing. Fiber blends are being studied to maximize the advantages of natural fibers and provide fabrics having properties desired by the consumer.

Marketing research and research on consumer needs are beginning to receive more attention. This research aims to find ways to stabilize the price and availability of natural fibers, and to provide continuing up-to-date feedback to industry of consumer desires and trends in textiles.

Environmental and Energy Factors

Accurate information on environmental data, energy and costs are difficult to obtain. This is partly due to the rapid changes occurring in the textile processing industry. Reports on current developments along these lines appear regularly in the textile industry journals. For example, Textile Industries is currently publishing a series of articles on air pollution and the textile industry. In Part 2 of this series (May 1975) is a good condensation of the process considerations and other data along these lines. The same issue, page 99, has a table of estimated energy requirements for finishing fabrics by different methods. The Textile World, June 1975 issue, features textile processing cost reduction. For example, this article states "Energy savings up to 70 percent are theoretically possible by virtue of retaining rather than dumping hot dye bath runs." This article goes on to state "beck dyeing is very inefficient in utilization of energy. A typical dyebeck requires over 4 million Btu of energy simply to heat the water from room temperature to the dyeing conditions. Obviously the need for energy conservation suggests that changes in beck dyeing procedure should be considered."

Improvements will be made in pollution control and also in a decrease in energy consumption in some operations. These will affect future costs of processing.

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CHAPTER 3*

THE CELLULOSICS

INTRODUCTION

The cellulose filaments and fibers are the first of the man-made textile fibers and they have been manufactured for several decades. Unlike the synthetic fibers, which were made from petrochemical monomers, the cellulosics begin with the polymer cellulose in its material fiber form, such as cotton and wood fiber, that is then recast into continuous filaments, film and plastics resulting in a modified form of cellulose of a different shape and character than the original.

Since wood and cotton cellulose are renewable resources, they offer promise as a long-term raw material substitute for petroleum derived fibers and plastics. The cellulosics textile fibers, furthermore, have a wide range of desirable properties, such as high moisture absorption, biodegradeability and low oil requirement for manufacture. Notwithstanding, most of the growth in man-made textile fibers during the past three decades has been on crude oil or natural gas (Table 1). This is the combined result of a very cheap raw material (oil at one cent per pound) and a massive R&D effort by the chemical industry of Europe and the U.S. since World War II. Meanwhile, cellulosic research was virtually abandoned. If petrochemical-based products are to be even partially replaced in the future by those based on cellulose, a major investigative effort will have to be launched to develop a new technology.

Furthermore, in a quest to establish the technology for conversion of wood to organic chemicals, sight must not be lost of the fact that the bulk of all organic chemicals manufactured are intermediates or additives for the production of polymers. Since wood and plant cell wall

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*Most of the data in this chapter have been provided by Herbert Hergert or abstracted from his paper on "The Future of Wood Cellulose in Textiles and Plastics Applications" presented at the Eighth Cellulose Conference, Syracuse, N.Y., May 19-23, 1975.

TABLE 1

WORLD MAN-MADE FIBER PRODUCTION*
(Million Lbs.)

Year	Rayon & Acetate	Non-Cellulosic
1966	7364	5227
1968	7780	7889
1970	7565	10351
1972	7833	13994
1973	8080	16727
1974	7700	16400

*Except acetate cigarette tow, olefin and textile glass fiber.

constituents are polymeric, it seems logical from an energy conservation point-of-view, to take advantage of this polymeric nature. Direct substitution would seem to have higher priority than the development of techniques for breaking wood and plant constituents into simple compounds that must then be reassembled into polymers.

MATERIALS FLOW AND PRODUCTION DATA

The major base raw material sources for the production of the cellulosics are cotton and wood. Theoretically other types of vegetable fibers could be used, such as straw, reeds, bagasse, kenaf, jute, etc. but the present-day pulping procedures have not yet produced a cellulose usable in commercial esterification and etherification processes. Since the forest offers the largest source for future growth in the supply of chemical cellulose and does not require cropland, future emphasis will continue to be placed on wood cellulose.

The materials flow chart for the production of chemical cellulose (dissolving pulp) is shown in Figure 3. This chemical cellulose or dissolving pulp is the starting material for the several processes used for converting it into filaments, fibers and other products. Figure 1 is the materials flow chart for the production of rayon staple fiber products and Figure 2 is that for acetate textile filaments and their end uses. A simplified composite flow chart for the cellulosics is presented in Figure 4. This includes quantitative data on the materials inputs and outputs for 1974.

Quantitative data on production and manufacture of cellulosic products are difficult to obtain. This is because there are so few plants that some data cannot be provided without revealing individual corporate figures which are not publicly available. For the same reason it is not possible to develop reliable forecasts. Table 1 shows world cellulosics production for recent years compared to non-cellulosic man-made fibers.

The production of rayon has stabilized since 1962 at about 900-1000 million lbs. and similarly for acetate since 1965 at about 600-700 million lbs. annually (see Table 1, Chapter 4, Section C). Other data on rayon and acetate shown in Chapter 4, Section C are (a) production quantities compared to other man-made fibers for the years 1940-1973 (Table 1), (b) mill consumption curves compared to other fibers for the years 1940-1973 (Figure 3), (c) mill consumption figures compared to other fibers for 1940-1973 (Table 2), and (d) consumption of products made from acetate and rayon, including exports for 1949-1972 (Table 3).

FIGURE 1

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES -- RAYON STAPLE FIBER

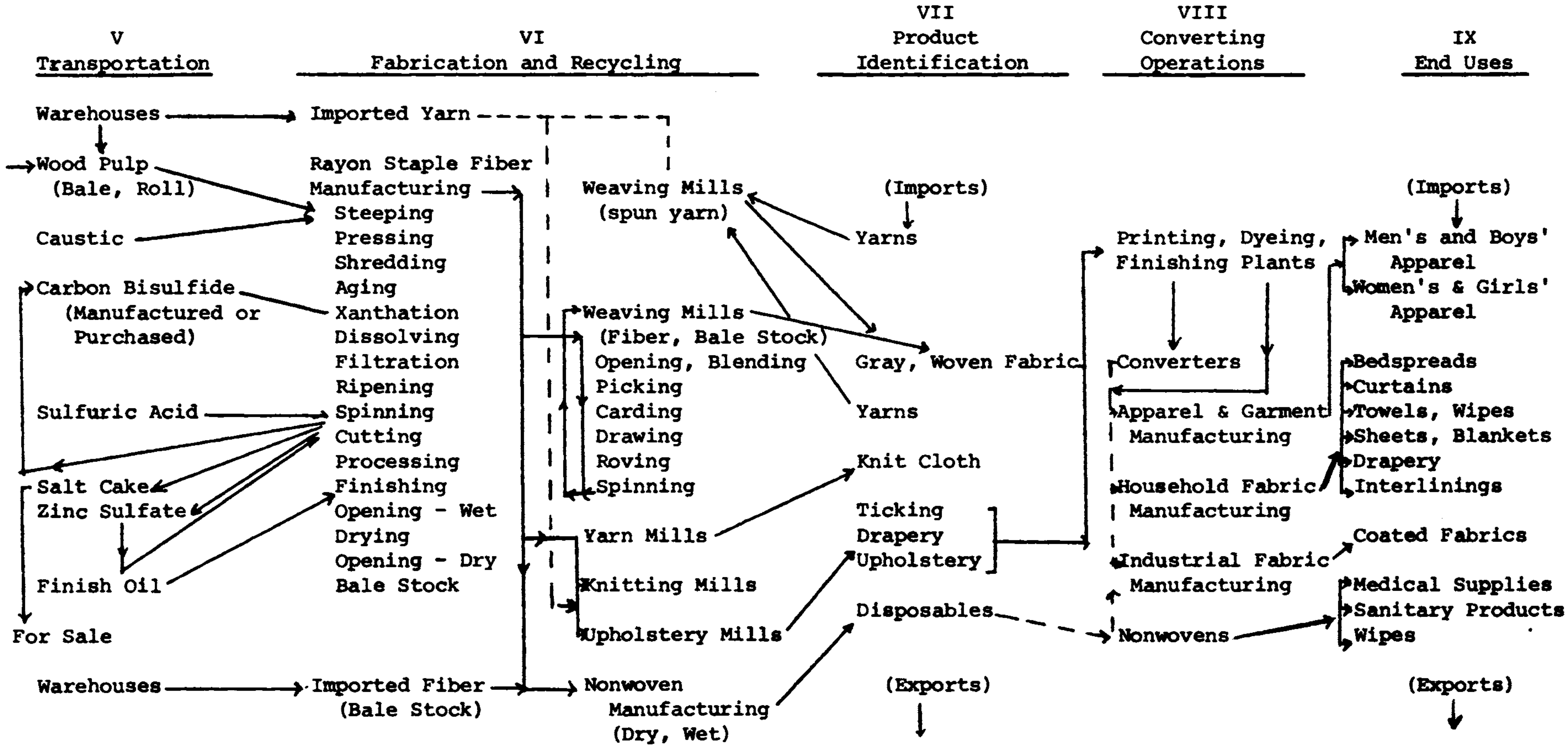


FIGURE 2

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES -- ACETATE TEXTILE FILAMENT

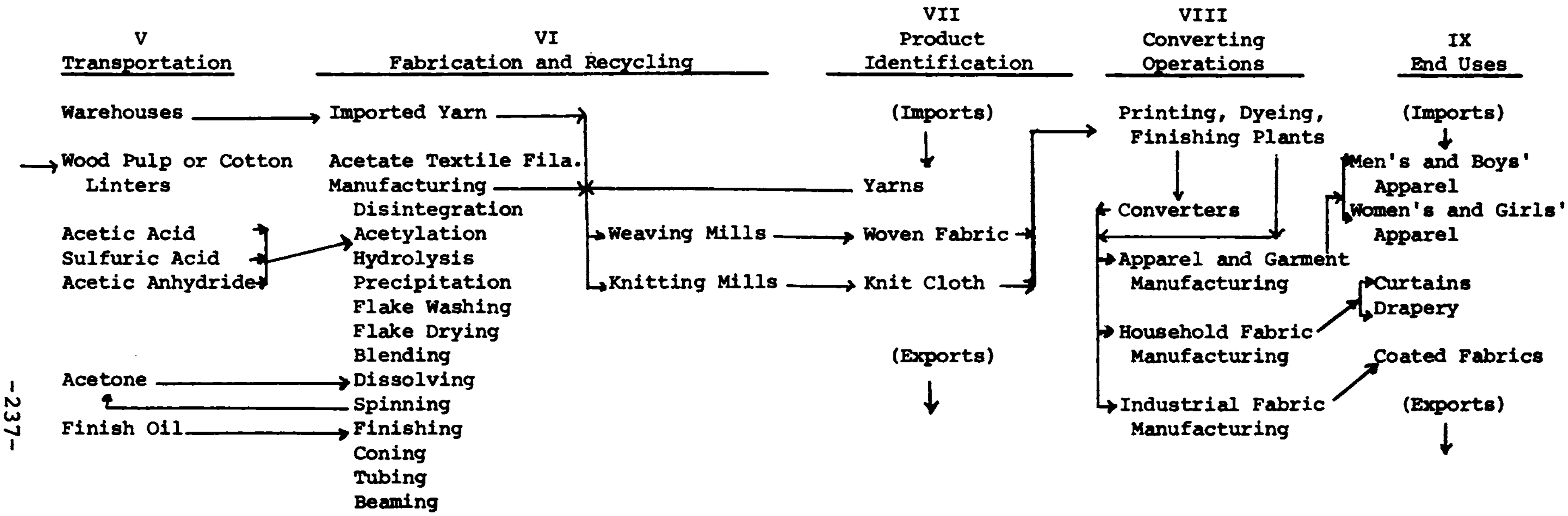


FIGURE 3

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES - CHEMICAL CELLULOSE

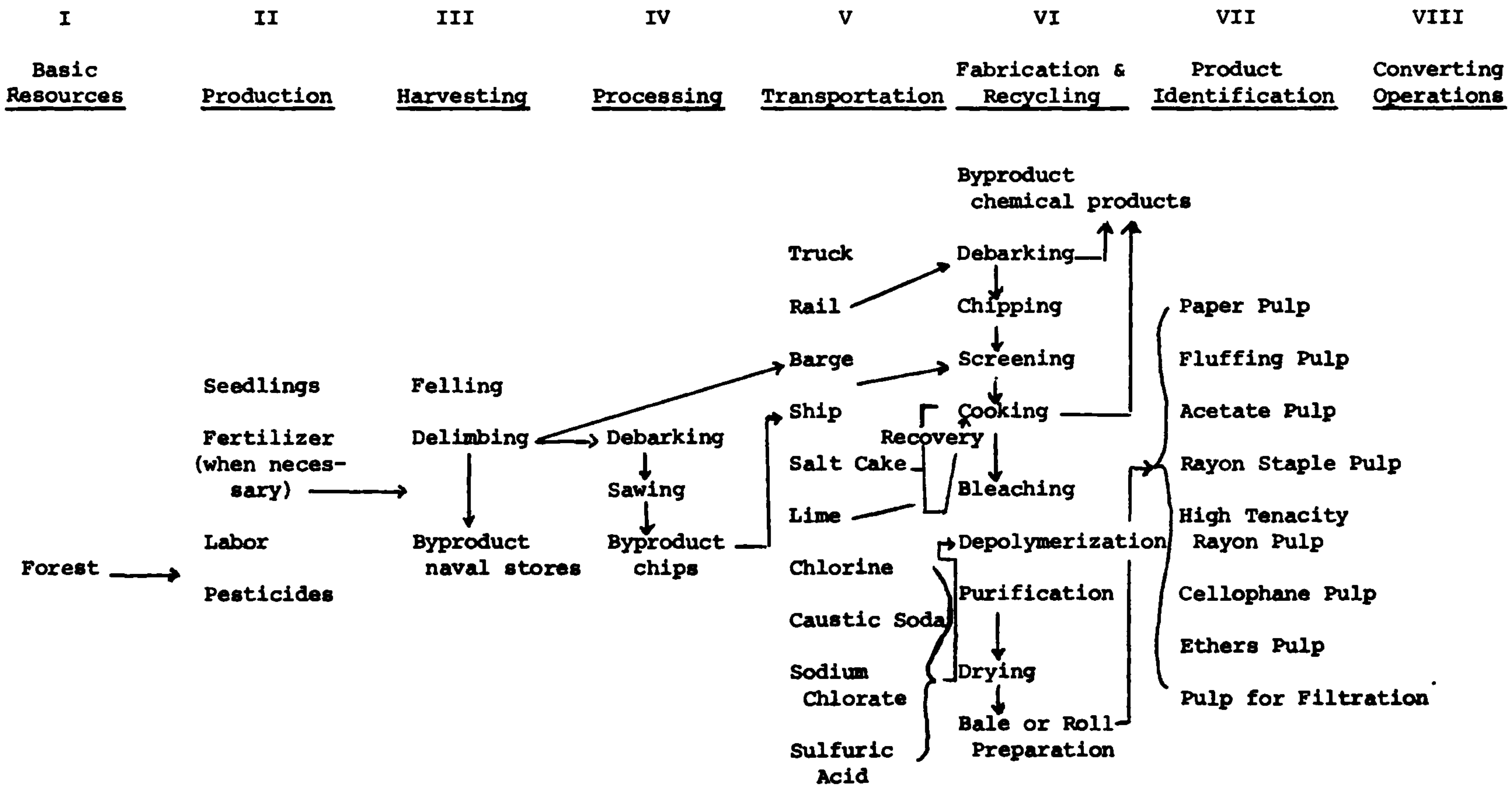
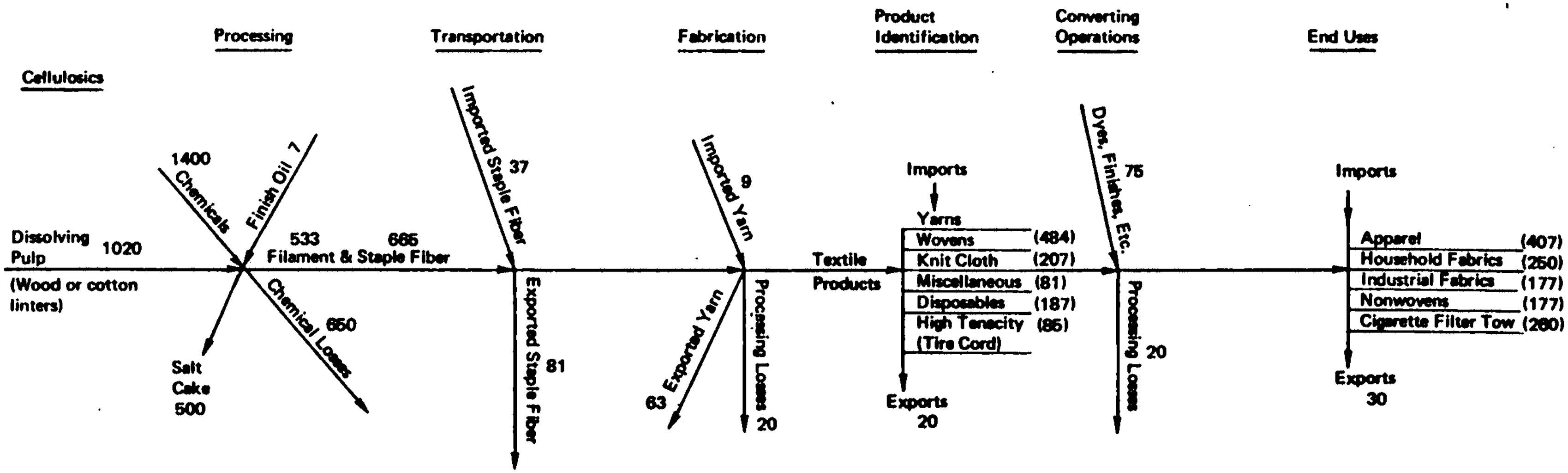


FIGURE 4

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES - CELLULOSICS



All Numbers for 1974 in MM lbs.

FUTURE FORECASTS

Plant capacity for dissolving pulp and its consumption in North America for 1972 and forecast to 1980 are shown in Table 2. This same table also shows U.S. rayon and acetate textile fiber consumption for 1973 and forecast for 1980.

The present production and consumption trends, which have been stabilized over the past 10-12 years, suggest only a possible modest growth for 1985 and 2000, probably at about the same rate as population growth and/or GNP.

Forecasts for the future of the cellulosics industry depend heavily on a number of unpredictable factors. Foremost among these are research developments and government regulations for pollution abatement. If "zero discharge" of polluting substances is required the numbers in Table 2 for 1980 will very likely have to be revised downward, because additional dissolving pulp and rayon producers will probably choose to shut down their plants due to hopelessly unfavorable economics. However, if appropriate technology can be developed, as outlined below, then there is a likelihood that 1985 will show a strong upward trend from 1980. Major perturbations that could affect cellulosics production may be as follows:

<u>Positive Effects</u>:

1. New system for regenerating cellulose (would result in strong growth in "rayon").
2. Removal of federal subsidies on growing cotton.
3. Major increase in growing food crops, such as soybeans, in place of cotton.
4. R&D results in significant improvements in rayon or acetate properties.
5. Oil at $20/barrel (very modest effect).

<u>Negative Effects</u>:

1. Substitute for acetate filament in cigarette filters (unlikely).
2. Improved strains of cotton giving much higher yield per acre or greater resistance to pests.
3. Use of nonwovens (disposable diapers, etc.) restricted by legislative regulation.
4. Complete enforcement of the 1983 "zero-discharge" requirements by EPA (very strongly negative because of intensive energy and capital requirements for secondary treatment).

TABLE 2

CHEMICAL CELLULOSE (DISSOLVING PULP) PLANT CAPACITY
Thousand Short Air Dry Tons

	1972	1975	1980	1985
U.S.A. (incl. Alaska)	1805	1695	1465	?
Canada	290	495	370	?

CHEMICAL CELLULOSE (DISSOLVING PULP) CONSUMPTION IN NORTH AMERICA
Thousand Short Air Dry Tons

	1972	1975	1980
Acetate	280	305	325
Rayon Staple Fiber	430	305	390
Rayon Filament (incl. tire cord)	130	65	10
Cellophane	175	180	180
Other	290	120	165
	1305	975	1070

U.S. RAYON AND ACETATE TEXTILE FIBER CONSUMPTION
Millions of lbs.

	1973	1980
Acetate (staple and filament)	320	315
Rayon Staple	710	630
Cotton	3820	3200

Source: Daily News Record, p. 4, June 16, 1975.

CHEMICAL AND ENERGY REQUIREMENTS

The chemical and energy requirements for chemical cellulose manufactured from wood are shown in Table 3. Rapid escalation in wood, chemical and fuel costs were experienced during the last two years. Most mills still use fuel oil as part of their energy source, but it is quite possible to be entirely independent of oil usage (except for transport of the wood to the mill) by increased burning of wood and bark residues or coal. This decision is currently based on the economic trade-offs between the cost and use of oil in existing boilers vs. capital required for substitute wood and bark-burning boilers and fuel-handling facilities. The relatively high caustic soda consumption is of particular concern because of the severe imbalance in caustic/chlorine usage potentially resulting from dislocations in the polyvinylchloride industry. The latter has been a major consumer of chlorine, but this usage could rapidly decrease if PVC manufacturers cannot find economic means for reducing vinyl chloride emissions to the zero detectability level. The substitution of oxygen/alkali bleaching for part of the chlorine previously consumed in paper pulp bleaching will also contribute to this imbalance. A possible corrective may be available if current research on substitution of chlorine monoxide for chlorine dioxide in pulp bleaching is successful. Chlorine monoxide can be generated by the reaction of chlorine and sodium carbonate.

TABLE 3

ENERGY AND CHEMICAL REQUIREMENTS FOR CHEMICAL CELLULOSE MANUFACTURE

	Actual usage per lb. product
Wood, lb.	2.70 - 3.30
Caustic soda, lb.	0.10 - 0.22
Chlorine, lb.	0.07 - 0.09
Chlorine dioxide, lb.	0 - 0.01
Sulfur, lb.	0.04 - 0.17
Steam, lb.*	8.25 - 13.30
Electricity, kWh	0.30 - 0.52
Total energy in oil equivalents	0.80 - 1.20
Actual oil used, lb.	0.30 - 0.55

*Includes steam for liquor evaporation.

The energy and major chemical requirements for high performance rayon staple fiber are shown in Table 4 and compared with those of polyester staple manufactured by a

TABLE 4

ENERGY AND CHEMICAL REQUIREMENTS FOR RAYON STAPLE

Component, lb.	Amount, lb.	Energy Required* lb. of oil equivalent
Wood pulp	1.02	1.1
Caustic soda	0.90	0.37
Carbon disulfide	0.35	-
Sulfuric acid	1.35	-
Steam	17 - 30	1.1 - 1.8
Electricity, KWH	0.7 - 0.8	0.3
		Total Oil Equiv. 2.8 lb./lb.

*Includes energy requirement for caustic soda manufacture, 1.04 KWH per lb.

continuous process from terphthalic acid and ethylene glycol in Table 5. The viscose process has a very high chemical requirement including caustic soda, which not only suffers from the caustic/chlorine imbalance mentioned previously, but requires substantial amounts of energy (in the form of electricity) for its generation. Although oil is not required for rayon manufacture (coal or wood can be used as fuel), the high energy input required means that rayon cost and pricing is not independent of the factors affecting the cost of polyester.

RESEARCH

Research needs can be divided into two categories, those for the existing viscose process and those for an ideal, new cellulose regeneration system.

Present technology requires a clean, good quality wood for the production of acceptable dissolving pulps. The use of whole-tree pulping followed by some type of crude separation of bark and wood has been recommended as offering significant cost reduction and increases in yield of usable pulp wood chips per acre. The experimental results shown in Table 6, wherein fully bleached hemlock inner bark was incrementally added to pulp prepared from bark-free hemlock wood and subsequently converted to viscose, shows that viscose filterability is unacceptable when only one percent bark is present in the wood furnish. Whole tree chips, even after several stages of refining, contain levels of bark substantially higher than this, and therefore, they are clearly unacceptable in wood pulp destined for viscose plants using today's technology.

Another problem is encountered in the pulping of tropical hardwoods. Pulping of 20 different species and conversion to high wet modulus rayon gave products deficient in physical properties compared to those attainable from the more homogeneous north temperate forest. Silica, phytosterol glucosides, calcium oxalate, triterpenes and other minute particulate materials contained in the wood appear to be the major culprits.

Significant expansion of the chemical cellulose production industry will surely depend in part on successful R&D in the following areas:

1. An expanded economic raw material base. This will require (a) effective means for separation of bark and contaminants from whole tree chips, and (b) improved methods for particulate removal (silica, etc.) following pulping or bleaching.
2. Genetic tree strains higher in cellulose.

TABLE 5

ENERGY AND CHEMICAL REQUIREMENTS FOR POLYESTER STAPLE

Component	Amount, lb.	Actual Oil Required*	Energy Required lb. of oil equiv.
Terphthalic acid	0.90	0.89	0.64
Ethylene glycol	0.38	0.39	0.35
Energy		-	0.33
		1.28	1.32

Total Oil Equiv. 2.60 lb./lb.

*Based on selected feedstock

TABLE 6

EFFECT OF BLEACHED BARK ON VISCOSE FILTERABILITY (CELLOPHANE-TYPE SYSTEM)

Wood Pulp, %	Bark, %	FN*
100	0	810
99	1	3620
98	2	5860
95	5	10600

*Filtration Number, 1000 is maximum acceptable.

3. More efficient tree removal and transport methods.
4. Development of pulping processes for better product yield based on starting material. Approximately 25 percent of cellulose is currently lost in the preparation of high alpha wood pulp.
5. Less capital-intensive pulp mills are needed to compete effectively with oil-based synthetics. Methods for achieving this should include (a) completely countercurrent bleaching to minimize water and heat use, (b) lower cost and more effective secondary treatment, and (c) re-examination of the national environmental priorities which have legislated zero-discharge facilities in the early 1980s. The cost-benefit ratio of removing the last 1-2 percent from effluents is highly questionable.
6. Profitable by-products. The large sugar and iso-saccharinic acid-containing waste streams from a chemical cellulose plant ought to be upgraded to a higher end-use than that of fuel. They offer ideal opportunities for fermentation to single cell protein, provided markets exist and lower cost and energy-consuming fermentation plants can be developed so that economics are favorable.

Rayon staple fiber offers major growth opportunities in the future for use in nonwovens and textile blends with cotton and polyester. Major research needs in rayon production fall into two categories, (1) for the existing viscose process and (2) those for an ideal new cellulose regeneration system, as listed below:

1. For existing plants:
   a. More effective emission controls. Odor problems are very similar although less intense than those experienced with kraft pulp mills.
   b. Lower caustic and energy consumption. Sihtola's double-steeping process is a good start in this direction.
   c. Improved rayon properties. Better "cover" and wet modulus under regular rayon operating conditions would be desirable.
   d. Elimination of the zinc requirement.

2. For new plants:
   a. Process tolerant of lower alpha pulp and/or pulp derived from bark-containing chips or wood species not desirable for paper manufacture.
   b. No effluent, no sulfur process. $DMSO/NO_2$, DMF/NO_2 or DMSO/paraformaldehyde may be a

forerunner of the type of non-aqueous system needed.

c. Dry spinning (if possible).
d. Cellulose in the product should be higher D.P. than in rayon.
e. Low capital investment.

For the acetate process, long-term expansion could be helpful by research for the development of a process for direct acetylation to the diacetate with generation of acetic acid by-product. Stronger diacetate fiber with no shrinkage upon washing might expand usage textiles (current market growth is mainly in filament tow for filtration) provided the present desirable aesthetics (elongation, softness, luxurious feel, etc.) can be retained.

Greater future opportunity lies with cellulose research rather than research on pulping by-products, such as lignin for future production of man-made fibers, films and plastics. The real opportunity for meeting the challenge of petroleum lies in cellulose research according to Hergert. He points out that this message is understood in the USSR based on the volume of cellulose research now being reported out of the Soviet sphere.

CHAPTER 4

SYNTHETIC FIBERS

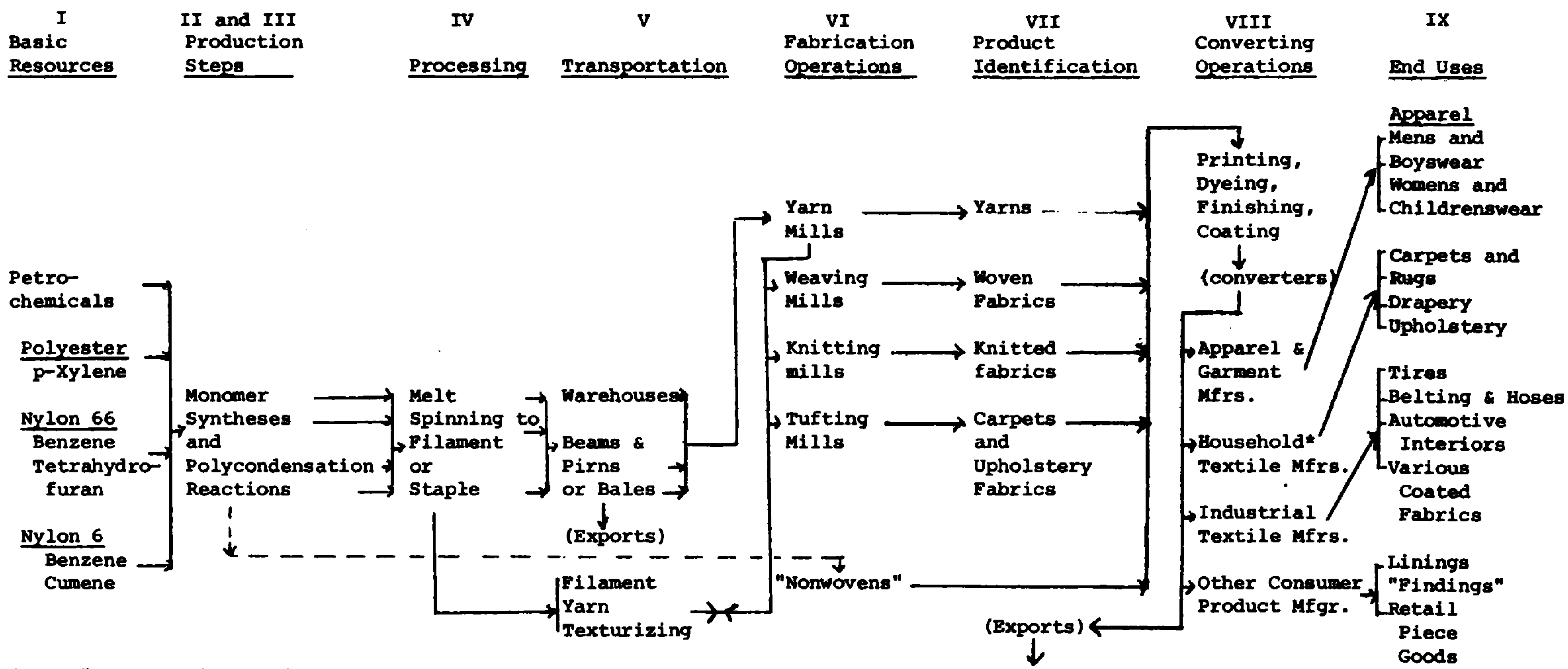
Although the purpose of this report is to assess our renewable fiber resources, it is important to include a brief statement on the synthetic fibers which are based on nonrenewable petroleum and natural gas. This is especially true since the man-made fibers have now captured a major share of the textile fiber market and their competitive position continues to grow. Nylon was the first synthetic fiber produced in 1939. By 1971 synthetic fiber production surpassed the sum of all natural fiber production. In 1972, there were 5,586 million lbs. of synthetic fibers consumed in the U.S. compared to 4,105 million lbs. of natural fibers. If rayon and acetate (1,568 million lbs.) and textile glass (569 million lbs.) are added to the synthetic fibers, then the total amount of man-made fibers consumed in 1972 was 7,723 million lbs.

In this report, synthetic fibers refer only to those made from petrochemicals, i.e., polyester, nylon, acrylic and olefins. Rayon and acetate are made from natural fibers, primarily wood, and are recast into filaments and fibers of different form and character than the original wood fibers. Together with glass and the synthetics, these form the so-called man-made group of fibers.

The chemistry of the synthetic fibers is fairly complex. It starts with the crude petroleum which is converted by the petrochemical industry to the necessary monomers that are then polymerized to the desired polymer for the particular fiber to be fabricated. There are several chemical paths which can be followed to produce the desired polymer. Materials flow for (a) polyester and nylon (Figure 1) and (b) for acrylic and olefins (Figure 2) are given in the following flow charts. These begin with the monomers as the basic resource for the textile industry.

FIGURE 1

MATERIALS FLOW FOR NONRENEWABLE FIBER RESOURCES - POLYESTER AND NYLON

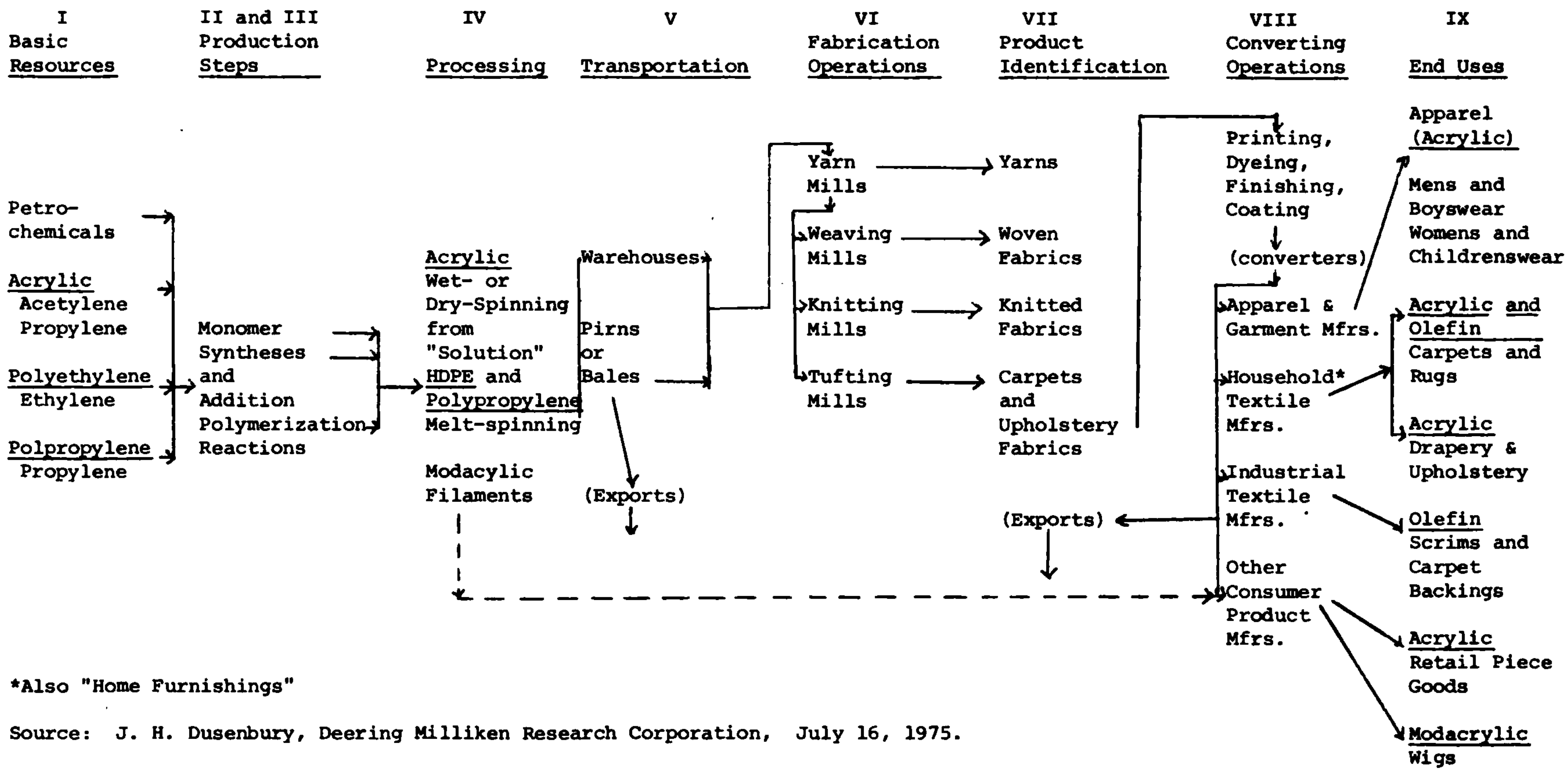


*Also "home furnishings"

Source: J. H. Dusenbury, Deering Milliken Research Corporation, July 16, 1975.

FIGURE 2

MATERIALS FLOW FOR NONRENEWABLE FIBER RESOURCES - ACRYLIC AND OLEFINS



*Also "Home Furnishings"

Source: J. H. Dusenbury, Deering Milliken Research Corporation, July 16, 1975.

Statistical data on all the major fiber types are given in the following tables and figure*:

Table 1	Production of Man-Made Fibers - By Fiber Type
Figure 3	Mill Consumption of Fibers - Natural Versus Man-Made
Table 2	Mill Consumption of Fibers - Natural Versus Man-Made
Table 3	Consumption of Rayon and Acetate By Type of Product
Table 4	Consumption of Synthetic Fibers By Type of Product
Table 5	Consumption of Total Man-Made Fibers By Type of Product

* These tables and figure are reproduced from Chemical Economics Handbook, courtesy of Stanford Research Institute.

TABLE 1

MAN-MADE FIBERS - PRODUCTION
By Fiber Type
(Millions of Pounds)

	CELLULOSICS		TEXTILE	NONCELLULOSICS					
	RAYON	ACETATE	GLASS FIBER	NYLON	POLYESTER	ACRYLIC	OLEFIN	ADD TOTAL	TOTAL
1940	327.7	143.5	1.4	2.7	0	0	0	2.7	475.3
1941	392.8	180.4	3.1	7.3	↓	↓	↓	7.3	583.6
1942	438.1	194.5	8.0	12.1	↓	↓	↓	12.1	652.7
1943	468.1	195.0	14.7	18.4	↓	↓	↓	18.4	696.2
1944	511.9	212.0	16.0	23.5	↓	↓	↓	23.5	763.4
1945	577.9	214.2	14.5	25.3	↓	↓	↓	25.3	831.9
1946	623.9	230.0	9.9	25.7	↓	↓	↓	25.7	889.5
1947	693.4	281.7	4.1	32.7	↓	0	↓	32.7	1,011.9
1948	746.8	377.5	8.6	51.2	↓	0.1	0	51.3	1,184.2
1949	674.1	321.9	8.2	70.1	↓	0.1	--	70.2	1,074.4
1950	815.8	444.2	23.5	90.6	0	1.0	0.2	91.8	1,359.1
1951	865.4	429.5	34.5	125.8	1.0	3.4	0.7	130.9	1,460.3
1952	806.3	330.6	45.0	160.8	2.4	12.9	0.3	176.4	1,358.3
1953	876.7	322.7	50.3	176.1	10.2	16.9	0.9	204.1	1,453.8
1954	820.4	277.3	59.2	202.3	10.0	28.0	1.5	241.8	1,398.7
1955	972.8	323.9	75.8	245.9	22.6	61.7	1.8	332.0	1,704.5
1956	897.8	300.1	96.5	249.0	30.1	75.7	2.1	356.9	1,651.3
1957	877.6	321.8	110.5	312.9	48.9	105.0	3.6	470.4	1,780.3
1958	737.3	371.7	103.8	304.4	32.2	108.5	4.8	449.9	1,662.7
1959	867.2	385.2	147.4	393.8	60.2	139.6	7.4	601.0	2,000.8
1960	740.3	396.2	177.0	411.6	75.2	135.7	13.7	636.2	1,949.7
1961	793.2	419.0	149.3	475.9	(101)	140.1	18.9	735.9	2,097.4
1962	920.4	479.7	190.3	612.7	(149)	170.0	(26.5)	958.2	2,548.6
1963	979.3	501.5	191.9	691.5	(207)	209.7	(32.7)	1,141.9	2,814.6
1964	1,005.9	579.9	239.5	805.4	(246)	287.7	(52.1)	1,391.2	3,216.5
1965	1,081.8	601.2	282.3	939.8	(378)	368.4	(77.7)	1,763.9	3,729.2
1966	1,064.7	607.3	332.4	1,080.1	(499)	352.9	(135.0)	2,065.0	4,069.4
1967	912.5	633.6	308.8	1,069.2	(708)	397.7	(162.5)	2,335.4	4,190.3
1968	1,104.4	649.9	402.7	1,350.5	(1,081)	521.0	(260.5)	3,210.0	5,367.0
1969	1,078.0	666.2	501.4	1,411.2	(1,302)	533.0	(265.7)	3,508.9	5,754.5
1970	875.0	683.2	467.3	1,354.7	(1,465)	491.9	(255.2)	3,565.8	5,590.8
1971	915.1	665.8	468.2	1,595.3	(1,819)	545.2	(317.6)	4,277.1	6,326.2
1972	964.9	639.4	571.6	1,974.5	(2,328)	625.9	(412.2)	5,340.6	7,516.5
1973	894.6	707.2	688.5	2,174.7	(2,888)	742.1	(487.6)	6,292.4	8,582.7

See MANUAL OF CURRENT INDICATORS for additional data.

(4) TEXTILE GLASS FIBER: Includes textile quality filament yarn and staple but excludes blown glass wool and pack. (Pack is used for filtration and insulation.)

(5) NYLON: Includes nylon 6, 66, and 610 yarn, monofilaments, staple, and tow.

(6) POLYESTER: Prior to 1961, includes staple, tow, and fiberfill only; for subsequent years it also includes yarn and monofilaments. Yarn and monofilament data are taken from the CEH report on Polyester Fibers.

(7) ACRYLIC: Includes acrylic and modacrylic staple and tow. Excludes yarn and monofilaments, production of which has never been significant.

(8) OLEFIN: Prior to 1962, includes polyethylene and polypropylene yarn and monofilaments only; for subsequent years it also includes staple and tow. Staple and tow data are taken from the CEH report on Polyolefin Fibers.

(9) NONCELLULOSICS, ADD TOTAL: Because this is the sum of the listed categories only, it excludes production of anidex, azlon, fluorocarbon, nytril, saran, spandex, vinal, and vinyon. In 1973, total production of these other fibers is estimated to have been 13.1 million pounds.

(10) WASTE: Production data for all fibers exclude producers' waste. Some of this waste may be recycled back into the process and subsequently reported as production. Alternatively, waste fibers may be sold into textile-use outlets such as blankets, carpets, and others and thus represent fiber production additional to production of graded fiber. Most acetate waste is reprocessed or goes into the plastics industry and thus does not reach the textile-consuming market. Much of the nylon 6, acrylic, and modacrylic waste is recycled. Nylon 66 can also be recycled, depending on equipment. Waste production in the United States in 1973 as a percentage of primary output was estimated as follows: rayon, 4%; acetate, 1%; nylon, 4%; polyester, 3%; acrylic, 5%; and olefin, 2%.

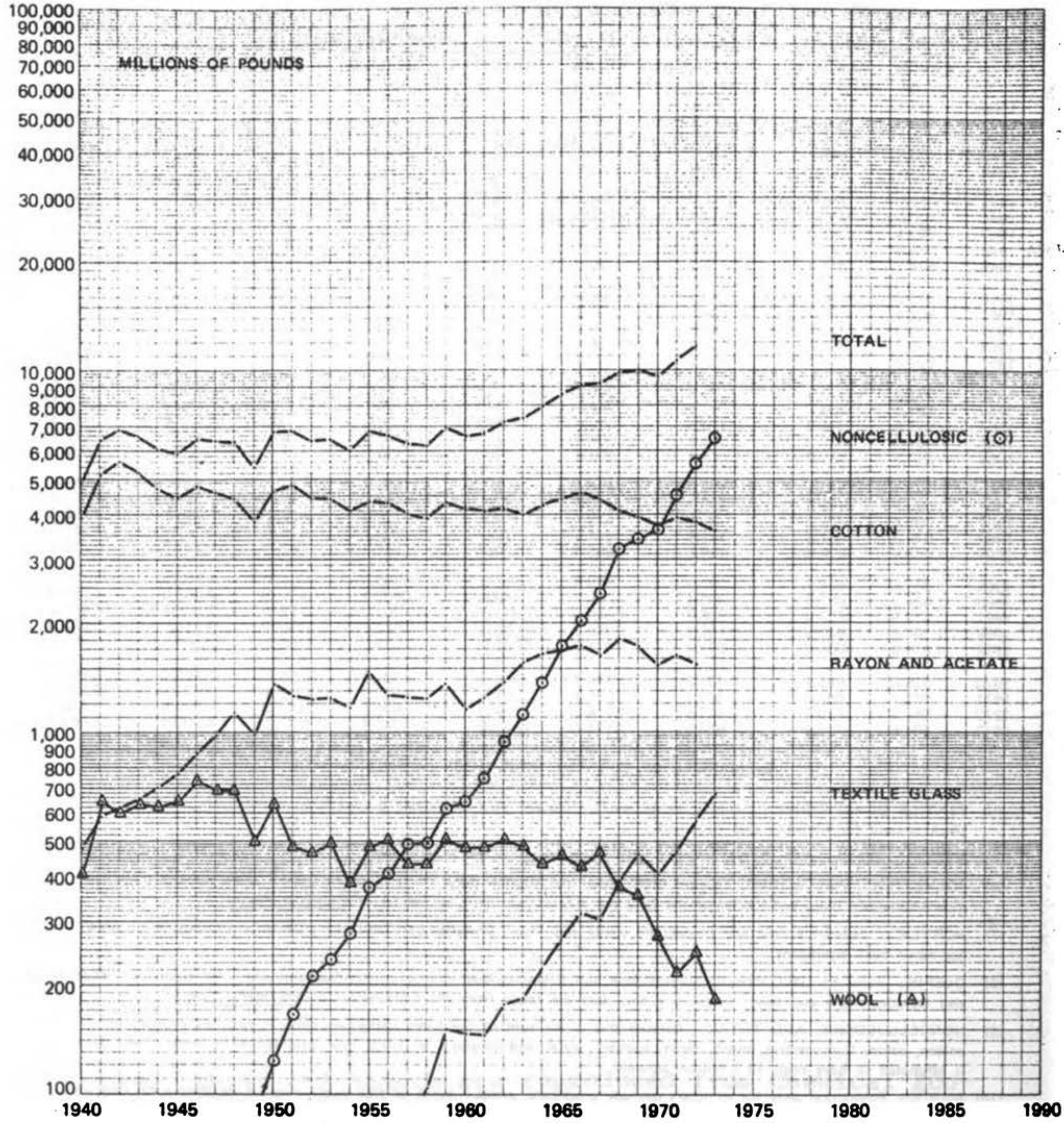
SOURCES: (A) CEH estimates (data in parentheses in the table and waste production estimates in footnote 10).

(B) TEXTILE ORGANON (all other data).

Source: Stanford Research Institute (1974) Chemical Economics Handbook. Menlo Park, California.

FIGURE 3

FIBERS - MILL CONSUMPTION
Natural Versus Man-Made - By Fiber Type



(1) ADDITIONAL CATEGORIES: FLAX, SILK, TOTAL NATURAL, and TOTAL SYNTHETIC are included in the table.

(2) MILL CONSUMPTION: All data, except those for acetate used in cigarette filters and for flax, are reported as MILL CONSUMPTION. Includes man-made fiber waste and imports of fiber for consumption in domestic mills.

(3) FLAX: Data are for imports and estimated domestic production in 1940-1963. Since 1963, data are for imports only.

(4) WOOL: Includes apparel and carpet wool on a scoured basis.

Source: Stanford Research Institute (1974) Chemical Economics Handbook. Menlo Park, California.

TABLE 2

FIBERS - MILL CONSUMPTION
Natural Versus Man-Made - By Fiber Type
(Millions of Pounds)

	NATURAL					MAN-MADE				
	COTTON	FLAX	SILK	WOOL	TOTAL	RAYON AND ACETATE	NON-CELLULOSIC	TEXTILE GLASS	TOTAL	TOTAL
1940	3,959	12	48	408	4,427	482	3	1	486	4,913
1941	5,192	10	26	648	5,876	592	9	3	604	6,480
1942	5,633	23	<1	604	6,260	621	16	8	645	6,905
1943	5,271	14	-	636	5,921	656	22	14	692	6,613
1944	4,790	10	-	623	5,423	705	30	16	751	6,174
1945	4,516	7	1	645	5,169	770	35	15	820	5,989
1946	4,808	13	14	738	5,574	876	44	10	930	6,504
1947	4,666	9	3	698	5,376	988	47	5	1,040	6,416
1948	4,464	6	7	693	5,170	1,149	64	7	1,220	6,391
1949	3,839	6	4	500	4,349	994	85	8	1,087	5,436
1950	4,683	11	10	635	5,339	1,375	123	21	1,519	6,858
1951	4,869	11	7	484	5,371	1,282	167	31	1,480	6,851
1952	4,471	7	13	466	4,957	1,238	212	41	1,491	6,448
1953	4,456	7	8	494	4,966	1,243	236	47	1,526	6,492
1954	4,127	7	8	384	4,526	1,187	279	55	1,521	6,047
1955	4,384	8	11	483	4,886	1,491	371	77	1,939	6,825
1956	4,332	8	13	506	4,859	1,276	409	94	1,778	6,637
1957	4,040	7	8	432	4,487	1,263	493	97	1,853	6,340
1958	3,944	4	5	432	4,385	1,236	498	104	1,838	6,223
1959	4,336	4	8	508	4,856	1,379	620	151	2,150	7,006
1960	4,196	5	7	480	4,688	1,175	645	148	1,968	6,656
1961	4,108	6	7	481	4,602	1,253	752	147	2,152	6,754
1962	4,192	6	6	504	4,708	1,392	944	178	2,514	7,222
1963	4,029	5	6	486	4,528	1,576	1,122	182	2,880	7,408
1964	4,287	7	7	431	4,732	1,662	1,386	221	3,269	8,001
1965	4,453	8	6	457	4,924	1,700	1,753	268	3,721	8,645
1966	4,621	10	5	428	5,060	1,734	2,052	314	4,100	9,160
1967	4,414	8	3	467	4,892	1,634	2,421	303	4,358	9,250
1968	4,104	8	4	378	4,494	1,819	3,211	384	5,414	9,908
1969	3,973	7	3	355	4,338	1,736	3,468	460	5,660	10,001
1970	3,774	6	2	273	4,055	1,561	3,670	405	5,636	9,691
1971	3,965	4	2	219	4,190	1,646	4,557	467	6,670	10,860
1972	3,850	6	2	247	4,105	1,568	5,586	569	7,723	11,828
1973	3,642	-	3	182	-	-	6,587	676	-	-

See MANUAL OF CURRENT INDICATORS for additional data.

(5) RAYON AND ACETATE: Includes acetate consumption for cigarette filters. Rayon and acetate mill consumption data shown here differ slightly from the sum of the consumption data in the CEH reports on Rayon and Cellulose Acetate Fibers because the data shown here include consumption of waste.

SOURCES:
(A) THE COTTON SITUATION, U.S. Department of Agriculture, Agricultural Marketing Service (FLAX data for 1940-1953).
(B) U.S. IMPORTS, FT 246, U.S. Department of Commerce, Bureau of the Census (FLAX datum for 1973).
(C) TEXTILE ORGANON (all other data).

Source: Stanford Research Institute (1974) Chemical Economics Handbook. Menlo Park, California.

TABLE 3

MAN-MADE FIBERS - CONSUMPTION
By Type of Product
(Millions of Pounds)

RAYON AND ACETATE

	Apparel: Men's and Boys'	Apparel: Women's, Misses', Children's and Infants'	Apparel: Total	Home Furnishings	Industrial	Other Consumer-Type Products	Exports of Domestic Goods	Total
1949	104	306	410	74	269	144	124	1,021
1950	129	352	481	130	304	152	82	1,149
1951	135	356	491	136	332	143	106	1,207
1952	130	323	453	148	416	135	83	1,235
1953	127	286	413	170	460	126	86	1,255
1954	111	241	352	177	348	121	90	1,088
1955	100	225	325	245	427	139	66	1,202
1956	94	217	311	261	344	145	72	1,133
1956	89	109	298	268	376	169	66	1,177
1957	80	206	286	283	343	171	63	1,146
1958	75	207	232	271	285	177	50	1,065
1959	73	218	291	309	340	184	48	1,172
1960	58	234	292	264	302	207	31	1,096
1961	59	288	347	284	280	216	26	1.153
1962	64	320	384	357	285	223	33	1,282
1963	72	401	473	437	275	248	34	1,467
1964	76	395	471	487	285	274	34	1,551
1965	81	371	452	506	290	303	43	1,594
1966	--	--	572	496	273	212	55	1,608
1967			592	429	216	232	49	1,518
1968			663	486	257	254	43	1,703
1969			669	433	230	255	41	1,628
1970			585	352	200	251	42	1,430
1971			578	378	256	242	36	1,490
1972	--	--	543	330	262	241	36	1,412

See MANUAL OF CURRENT INDICATORS for additional data.

(2) Data in the source for 1949 to 1965 are not directly comparable to later data. Data for 1966 are given for both series. In 1973, the source revised reporting categories and consumption data for 1966-1972. Beginning with 1966 data, the source transferred the amount of fiber consumed for apparel linings from OTHER CONSUMER-TYPE PRODUCTS to APPAREL. Data since 1966 are not comparable to data prior to 1966 in these two categories. Data in all other categories are comparable.

(3) RAYON AND ACETATE: Includes rayon and acetate consumed in all products except acetate consumed in cigarette filters. See the CEH report on Cellulose Acetate Fibers for data on acetate used in cigarette filters. See footnotes 6-11 for explanation of consumption categories.

(4) NONCELLULOSIC FIBERS: Data include consumption of acrylic, modacrylic, nylon, olefin (polyethylene and polypropylene), polyester, saran, spandex, TFE-fluorocarbon, and vinyon fibers. Data exclude consumption of steel and textile glass fibers. See footnotes 6-11 for explanation of consumption categories.

(5) TOTAL SYNTHETIC FIBERS: Data are add totals of RAYON AND ACETATE and NONCELLULOSIC FIBERS consumption. See footnotes 6-11 for explanation of consumption categories.

(6) APPAREL: Beginning in 1966, only TOTAL APPAREL consumption is reported by the source. Apparel linings are included in TOTAL APPAREL since 1966. Prior to 1966, apparel linings are included in OTHER CONSUMER-TYPE PRODUCTS.

(7) HOME FURNISHINGS: Includes bedding and blankets, linens, carpets, rugs, curtains, draperies, upholstery, slip covers, awnings, oil cloth, shower curtains, stamped art goods for embroidery, window shades, and vacuum cleaner bags.

Source: Stanford Research Institute (1974) Chemical Economics Handbook. Menlo Park, California.

TABLE 4

MAN-MADE FIBERS - CONSUMPTION
By Type of Product
(Millions of Pounds)

NONCELLULOSIC FIBERS

	Apparel							
	Men's and Boys'	Women's, Misses', Children's and Infants'	Total	Home Furnishings	Industrial	Other Consumer-Type Products	Exports of Domestic Goods	Total
1949	7	44	51	5	31	2	2	91
1950	12	53	65	7	58	2	3	135
1951	17	60	77	10	79	3	5	174
1952	25	80	105	16	87	6	5	219
1953	39	90	129	24	95	9	8	265
1954	40	113	153	31	109	12	11	316
1955	40	138	178	44	152	16	18	408
1956	48	150	198	58	172	19	22	469
1956	52	150	202	60	173	30	21	486
1957	64	164	228	72	200	34	27	561
1958	70	174	244	71	143	39	25	522
1959	90	198	288	86	172	43	31	620
1960	93	203	296	135	201	59	21	712
1961	119	233	352	176	219	67	18	832
1962	139	270	409	228	262	82	16	997
1963	168	295	463	296	282	105	20	1,166
1964	196	346	542	399	330	116	28	1,415
1965	278	414	692	518	384	145	35	1,774
1966	–	–	800	592	459	130	56	2,037
1967	↓	↓	991	730	502	147	53	2,423
1968			1,260	1,015	659	187	52	3,173
1969			1,277	1,195	696	237	63	3,468
1970			1,446	1,262	601	340	62	3,711
1971			1,773	1,610	677	485	59	4,604
1972	–	–	2,121	2,024	812	584	72	5,613

See MANUAL OF CURRENT INDICATORS for additional data.

(8) INDUSTRIAL: Includes transportation upholstery, automobile seat covers, tire fabric and cord, plastic reinforcement, hose, belting, laundry supplies, electrical wire insulation, roofing and other felts, bags and bagging, rope and twine, tents, tarpaulins and parachutes, filter fabrics, sewing thread, book binding, casket linings, flags and buntings, meat stockinette, cheese coverings, tracing cloth, and ribbons for office machines.

(9) OTHER CONSUMER-TYPE PRODUCTS: Includes apparel linings, retail piece goods, narrow-woven fabrics, handwork yarns, shoes and slippers, luggage, toys, medical, surgical and sanitary products, golf bags, tennis balls, and boat sails from 1949-1965. Beginning in 1966, data on apparel linings are excluded from OTHER CONSUMER-TYPE PRODUCTS and are included in APPAREL data.

(10) EXPORTS OF DOMESTIC PRODUCTS: Includes tire industry products, fabrics, yarn, and thread, not included elsewhere. Some apparel items fabricated for export are not included here because they are counted as the fabric is cut and are classified as domestic mill consumption.

(11) TOTAL: Total consumption data shown here are based on estimates of fabric required per finished manufactured article for a variety of end-use products. Data are not comparable with those for mill consumption in the CEH data sheet, "Fibers – Mill Consumption, Natural Versus Man-Made – By Fiber Type," because mill consumption data are based on fiber consumption reported by mills. Other differences in mill consumption and consumption data reported here result from possible double counting of waste processing losses and year-to-year variations in raw material, yarn, and cloth inventories held by cloth converters, garment cutters, and others.

(12) See the source for a comprehensive discussion of the categories included, as well as detailed definitions and notes on the coverage of the textile fiber end-use survey.

Source: Stanford Research Institute (1974) Chemical Economics Handbook. Menlo Park, California.

TABLE 5

MAN-MADE FIBERS - CONSUMPTION

By Type of Product

(Millions of Pounds)

	TOTAL							
	Apparel							
	Men's and Boys'	Women's, Misses', Children's and Infants'	Total	Home Furnishings	Industrial	Other Consumer-Type Products	Exports of Domestic Goods	Total
1949	111	350	461	79	300	146	126	1,112
1950	141	405	546	137	362	154	85	1,284
1951	152	416	568	146	411	146	110	1,381
1952	155	403	558	164	503	141	88	1,454
1953	166	376	542	194	555	135	94	1,520
1954	151	354	505	208	457	133	101	1,404
1955	140	363	503	289	579	155	84	1,610
1956	142	367	509	319	516	164	94	1,602
1956	141	359	500	328	549	199	87	1,663
1957	144	370	514	355	543	205	90	1,707
1958	145	381	526	342	428	216	75	1,587
1959	163	416	579	395	512	227	79	1,792
1960	157	437	588	399	503	266	52	1,808
1961	178	521	699	460	499	283	44	1,985
1962	203	590	793	585	547	306	49	2,279
1963	240	696	936	733	557	353	54	2,633
1964	272	741	1,013	886	615	390	62	2,966
1965	359	785	1,144	1,024	674	448	78	3,368
1966	–	–	1,372	1,088	732	342	111	3,645
1967			1,583	1,159	718	379	102	3,941
1968			1,923	1,501	916	441	95	4,876
1969			1,946	1,628	926	492	104	5,096
1970			2,031	1,614	801	591	104	5,141
1971			2,351	1,988	933	727	95	6,094
1972	–	–	2,664	2,354	1,074	825	108	7,026

See MANUAL OF CURRENT INDICATORS for additional data.

SOURCE: TEXTILE ORGANON.

Source: Stanford Research Institute (1974) Chemical Economics Handbook. Menlo Park, California.

Future Forecasts

There is a deep reluctance on the part of economists associated with textile manufacturing and trade associations, the textile industry, and the petrochemical industry to forecast any production, demand or other figures relating to synthetic fibers, filaments and textile products made therefrom. Some of the major companies have ceased making internal forecasts for any period of time greater than five years. Two major points, however, developed as a result of the above. They are: 1) About two-thirds of textile fiber is now man-made and the growth is greater than the GNP growth. This will probably continue until around 1980. About 1980, the man-made fiber growth will begin to parallel the GNP and will do so thereafter. 2) Economists in the petrochemical and synthetic textile fiber industry are calculating on the future price of oil ranging from a high of $16 per barrel to a low of $8 per barrel. They state that if there is success in the U.S. in developing other energy sources that the future price of oil could well drop to $8 per barrel.

Regardless of oil price, they are positive that petroleum will still be the major raw material for textile fibers in the years ahead. One argument put forth is that by 2000 the demand for food production will be so great that there will be less land available for fiber production. Furthermore, sheep that are grown for meat production yield a poorer quality of wool and in lesser amounts than sheep developed primarily for wool production.

Trend analyses of both the natural and synthetic fibers, as shown in the accompanying tables and figures, support the position of the economists associated with the petrochemical and synthetic fiber industries, that synthetic fibers will continue to grow and dominate the textile markets in the future. This is also supported (Fisher and Pry 1971) by a mathematical substitution model applied to the substitution by synthetics for natural fibers for textiles (see Appendix II, Section A of this report).

Major perturbations can, of course, alter the established trend in the future. Negative factors could be an excessively high oil price, new strains for cotton for higher yields and pest resistance, major increases in sheep and wool production, new technology for cellulosics, and governmental incentives favoring renewable fiber or restricting petroleum or petrochemicals.

A problem facing the cotton industry is byssinosis (Gray 1975) or brown lung disease. This is apparently caused by a substance associated with the fine dust (probably trash: leaves, stems, etc.) from cotton in the opening, picking and carding areas of the textile mills. However, the problem does not appear to be quite as serious as originally thought.

In the more distant future, the synthetic fibers could move from a petroleum base to a coal base. Coal gasification for the production of monomers for conversion to synthetic fibers is possible, but requires a new technology which today is cost prohibitive.

REFERENCES CITED

1 Fisher, J.C. and R.H. Pry (1971) "A Simple Substitution Model of Technological Change", Technological Forecasting and Social Change, 3, 75-88.

2 Gray, C.L. (1975) "Byssinosis Danger Pinpointed", The Greenville News, Greenville, S.C., Sept. 29, 1975.

SECTION D

FEATHERS, FURS AND LEATHER

CONTENTS

SECTION D

FEATHERS, FURS AND LEATHER

INTRODUCTION

This section deals with the renewable fibrous materials produced by animals in the form of hides, hair and feathers. These raw materials, with the exception of furs, are the by-products of the meat and poultry industries. This fact influences the geographic location of production in the world, and leads to a lack of response of supply to changes in demand, with resulting fluctuation in prices.

In this group of materials, hides and leather play by far the major role in production and end-uses. Furs are of secondary importance and feathers are used as a protein source in animal feed. Major emphasis, therefore, will be given to hides and leather.

A materials flow chart for products made from feathers, furs and leather is shown in Figure 1. A simplified flow trajectory is in the Introduction of this Report of Panel III.

FEATHERS

As shown in Table 1, over one billion pounds of chicken and turkey feathers were produced in the U.S. in 1972, which is about current average annual production. These are converted and used as a source of protein in animal feed.

According to the Feather and Down Association, an estimated 10 million pounds of waterfowl feathers and down were consumed in the U.S. in 1972. Most of this was imported, namely 8.2 million pounds (Table 1). Down is used in sleeping bags, arctic clothing, quilted apparel, quilts and pillows. An estimated 25 to 30 million pounds of synthetic fiber and foam goes into these same markets,

FIGURE 1

MATERIALS FLOW FOR RENEWABLE FIBER RESOURCES -- FEATHERS, FUR, AND LEATHER

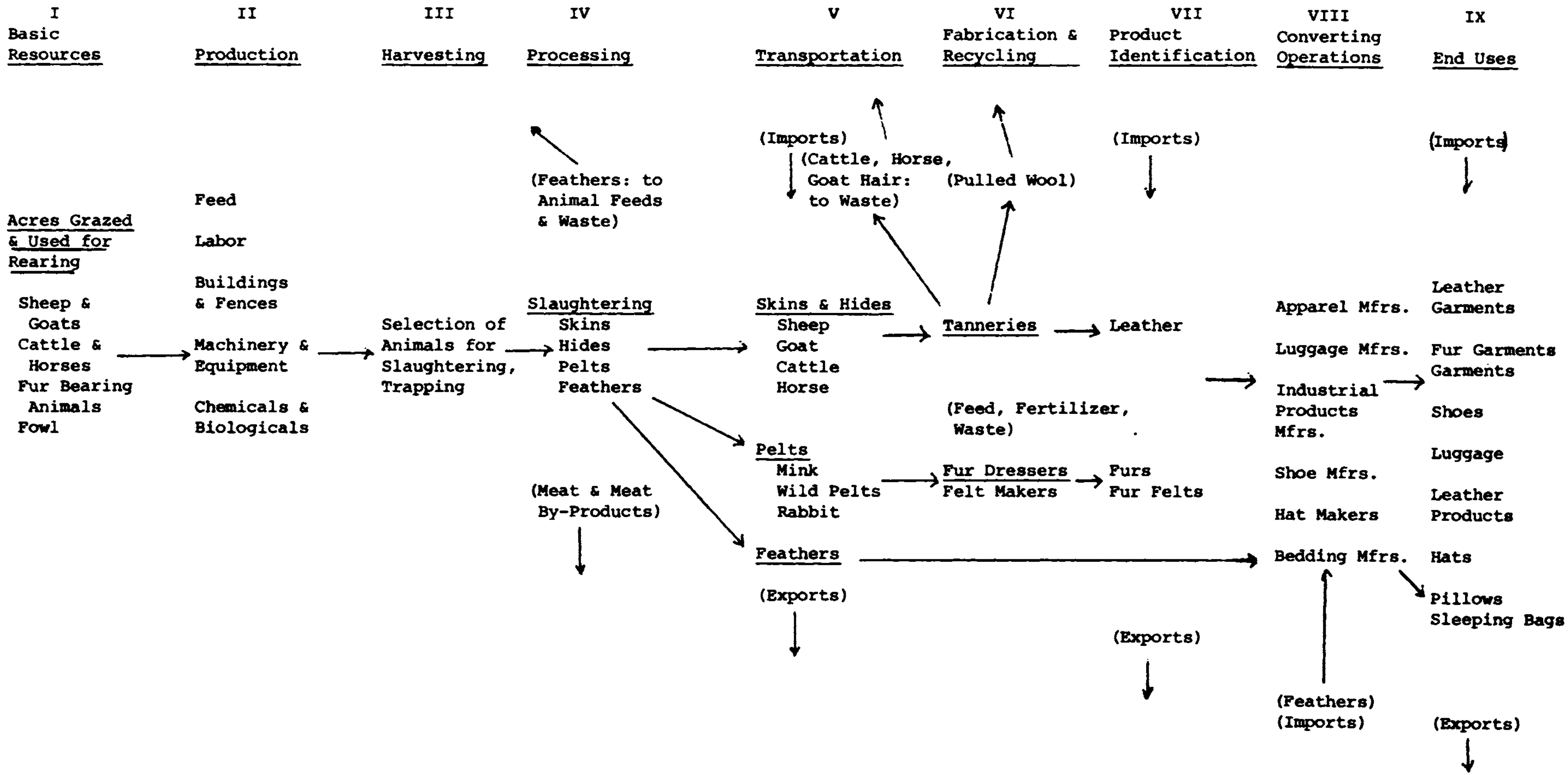


TABLE 1

SOME PRODUCTION, EXPORT AND IMPORT STATISTICS
FOR HIDES, LEATHER, FURS AND FEATHERS
YEAR 1972

	U.S. Production		Exports		Imports
	1000 Pieces	Million lbs.	1000 Pieces	Million lbs.	1000 Pieces
Hides					
Cattle	36,080	2,706	17,072		292
Hog		5			
Calf & kip			2,072		261
Goat & kid		289			3,355
Sheep & lamb			5,872		16,852
Total		3,000	25,016	879[1]	20,760
Leather					
Leather stock[2]		1,375			
Trimmed scrap[3]		200-300			
Leather[4]				143	
Hair & wool from slaughtering					
Pulled wool		8			
Cattle hair avail.		75[5]			
Cattle hair used[5]		7			
Furs					
Mink	3,000				
Rabbit	10,000 est.				
Wild pelts[6]	9,000				
Feathers					
Chicken		920[7]			
Turkey		187[7]			
Waterfowl feathers and down		1.8[8]			8.2 mil lbs.

[1]A 75 lb. rawhide, fleshed, trimmed and brine-cured yields 50 lb. cured hide. Other hides convered to cattle hide equivalents on the basis of leather area.

[2]Dry basis, trimmed. Leather stock is trimmed, fleshed, dehaired hides, ready for tanning.

[3]Trimmed scrap, partly used for fertilizer and animal food, but is mostly wasted. It could be a greater protein source.

[4]Tanners Council Projections (4/5/75)

[5]Of a total of 75 million lbs. available at slaughterhouses, only 7 million lbs. were used in 1972 for industrial products, such as rug pads, furniture padding, etc. The rest is wasted and adds to stream pollution.

[6]All kinds; 1969-70 data.

[7]Converted and used as a source of protein in animal feed.

[8]An estimated 10 million lbs. were consumed in 1972, of which 8.2 million lbs. were imported.

namely 2.5 to 3 times as much as the natural renewable product.

FURS

Furs and exotic hides and skins together account for about one-third of the world trade in all hides and skins. Production figures for the U.S. for 1972 for mink and rabbit, and for 1969-70 for wild pelts are given in Table 1.

ANIMAL HAIR

Animal hair and pulled wool are by-products of the tanning and leather industries. Pulled wool from sheepskins amounted to 8 million pounds in 1972 (see Section C, Chapter 2) or about 4.8 percent of the total grease wool production.

About 75 million pounds of cattle hair were produced in 1972 (see Table 1), of which only 7 million pounds were used, mainly for industrial products, such as felts or carpet underlays, furniture padding and insulation. This represents a wastage of over 90 percent of the available cattle hair in 1972 compared to only 16 percent in the 1950s (Armour's Analysis 1958). At that time there were more than 50 hair-derived products from cattle and hogs. Competition by synthetic materials, such as polyurethane foam and synthetic fibers and filaments, has caused the decline in use of animal hair. The waste hair contributes to pollution of streams and rivers. The hair removal process by caustic soda results in a waste effluent.

HIDES AND LEATHER

Hides and skins are used in a wide variety of end-products and rank first among the by-products of cattle. Footwear is by far the most important end-product. Cattle hides are the major source of leather for shoes. They also provide leather for upholstery, luggage, belting, athletic equipment and harness wear. Calf skins are made into fine grade leather for shoes, luggage, purses, gloves, book bindings and garments. Cattle hides, calf skins and goat skins are widely substitutable for each other, particularly for footwear. Sheepskins are used mainly for garments and footwear linings and to a lesser extent for gloves, handbags, chamois, and hat bands. Shearling leather is used for boots, slippers and clothing.

The leather tanning and finishing industry has grown rapidly on a worldwide basis over the past 15 to 20 years with the expansion of footwear industries. Countries with fast growing footwear production generally also expanded their tanning capacity. This has been particularly true of Spain, Italy, Japan, USSR and eastern Europe. The rising imports of hides into these countries reflects the shift in location of the leather industries. This has resulted in a gradual decrease in the tanning utilization of raw hides in the highly industrialized countries and an increase in the export of both hides and leather from them.

Despite a steadily expanding worldwide demand for leather, some substitution has occurred in most of its end-uses. This is particularly true of shoe soles. As far back as 1958, only 32 percent of shoe soles in the U.S. came from leather, the majority being made from synthetic polymers (vinyl types). The present major end-use, footwear uppers, is still largely unaffected by synthetics, but is being challenged by new synthetic products, termed poromerics. These are based on synthetic fibers and polyurethane and are generally similar in properties and appearance to leather.

Present Status of the Industry

The present status of the manufacture of leather in the U.S. based on the year 1972 is shown in Tables 1 through 7. In some tables, data for years preceding and following 1972 are also shown. Also some of the tables give projections for the future which will be discussed later.

In 1972 the U.S. production of hides was 3000 million pounds, of leather stock 1,375 million pounds, and of leather 898 million pounds (Table 1). By-products include 200 to 300 million pounds of trimmed scrap, 8 million pounds of pulled wool and 75 million pounds of cattle hair. The pulled wool is completely utilized, but only minor amounts of the cattle hair are used.

Exports of cured hides in 1972 amounted to 879 million pounds, and of leather 143 million pounds. The value of the latter was 67 million dollars. The value of leather imports in 1972 was 132 million dollars (Table 7). Since 1972 there has been a drop in leather imports to a value of $111 million in 1974 and a continued rise in exports to a 1974 value of $99.6 million. Although it is still too early to be certain, it would appear that leather exports are now closing the gap with imports. This change has taken place under adverse economic conditions and, according to a recent comment (Tanners' Council of America 1975a), "with any improvement in the general business climate it is certainly reasonable to expect further and substantial gains in the shipment of leather from the United States."

TABLE 2

DETAILED STATISTICS FOR LEATHER TANNING AND FOOTWEAR INDUSTRIES: 1972

Item	Leather tanning and finishing (SIC 3111)				Boot and shoe cut stock and findings (SIC 3131)	House slippers (SIC 3142)	Men's footwear, except athletic (SIC 3143)	Women's footwear, except athletic (SIC 3144)	Footwear, except rubber, n.e.c. (SIC 3149)
	Total	Tanneries (SIC 3111-11)	Converters (SIC 3111-22)	Contract tanneries (SIC 3111-33)					
PRIMARY PRODUCT SPECIALIZATION RATIO[1] . . . . PERCENT .	99	(NA)	(NA)	(NA)	94	95	93	97	88
COVERAGE RATIO[2] . . . . .DO . .	99	(NA)	(NA)	(NA)	95	87	97	95	85
ESTABLISHMENTS, TOTAL . . . . .NUMBER .	517	301	76	140	248	91	221	422	183
WITH 1 TO 19 EMPLOYEES. . . . . .DO . .	294	154	64	76	127	25	24	106	50
WITH 20 TO 99 EMPLOYEES . . . . .DO . .	148	89	8	51	106	40	32	84	36
WITH 100 EMPLOYEES OR MORE. . . . . .DO . .	75	58	4	13	15	26	165	232	97
ALL EMPLOYEES, AVERAGE FOR YEAR . . . . 1,000 .	25.7	18.5	1.4	5.9	8.7	8.5	61.5	77.4	28.7
PAYROLL FOR YEAR, ALL EMPLOYEES . . . MILLION DOLLARS .	200.0	150.7	12.0	37.3	50.1	48.1	358.2	408.3	158.1
PRODUCTION WORKERS:									
AVERAGE FOR YEAR. . . . . 1,000 .	22.1	15.8	1.0	5.3	7.6	7.1	54.4	70.0	25.6
MARCH . . . . .DO . .	22.5	16.2	1.0	5.3	7.5	6.8	53.8	69.4	25.1
MAY . . . . .DO . .	22.8	16.3	1.1	5.4	7.7	7.2	54.4	71.7	25.8
AUGUST. . . . . .DO . .	22.4	16.0	1.0	5.5	7.6	7.3	54.9	71.6	26.2
NOVEMBER. .DO . .	20.5	14.7	1.0	4.8	7.6	7.3	54.5	67.1	25.3
MAN-HOURS . . . . .MILLIONS .	41.9	31.3	2.0	8.6	14.0	12.7	106.3	128.5	46.9
JANUARY-MARCH . . . . .DO . .	10.7	8.1	.5	2.1	3.6	2.8	27.3	33.5	11.7
APRIL-JUNE. . . . . .DO . .	11.2	8.4	.5	2.3	3.6	3.3	27.4	33.7	12.2
JULY-SEPTEMBER. . . . . .DO . .	10.1	7.5	.5	2.1	3.4	3.3	25.4	30.7	11.4
OCTOBER-DECEMBER. . . . . .DO . .	9.9	7.3	.5	2.1	3.5	3.3	26.1	30.7	11.6
WAGES . . . . MILLION DOLLARS .	151.3	114.4	7.2	29.8	37.1	33.4	288.9	334.2	124.9
COST OF MATERIALS, ETC., TOTAL. . . . . .DO . .	708.0	523.6	152.0	32.5	120.5	66.5	623.0	591.6	208.0
MATERIALS, PARTS, CONTAINERS, ETC. CONSUMED . .DO . .	624.6	491.6	104.4	28.6	113.3	58.6	573.2	537.6	185.4
COST OF RESALES . . . . .DO . .	12.3	10.9	1.4	(Z)	4.0	1.8	42.2	31.8	18.2
FUELS CONSUMED. . . . . .DO . .	10.3	8.1	.3	1.9	.6	.2	1.5	1.4	.5
PURCHASED ELECTRIC ENERGY . . . . .DO . .	6.2	4.6	.3	1.3	1.1	.5	4.4	5.1	2.0
CONTRACT WORK . . . . .DO . .	54.6	8.3	45.6	.7	1.5	5.2	1.7	15.8	2.0
VALUE OF SHIPMENTS, INCLUDING RESALES . . . . . .DO . .	1 059.5	786.7	182.9	89.9	206.5	151.4	1 288.9	1 346.1	485.9
VALUE OF RESALES. . . . . .DO . .	14.0	12.3	1.7	(Z)	4.5	1.9	53.8	44.2	18.3
VALUE ADDED BY MANUFACTURE. . . . . .DO . .	368.3	279.6	31.3	57.4	86.2	85.7	674.4	763.6	272.6
MANUFACTURERS' INVENTORIES:									
BEGINNING OF YEAR, TOTAL. . . . . .DO . .	127.6	98.4	22.2	7.0	20.7	21.8	166.9	124.7	77.8
FINISHED PRODUCTS . . . . .DO . .	35.7	27.9	7.3	.6	7.0	11.8	82.3	47.2	43.1
WORK IN PROCESS . . . . .DO . .	61.2	45.9	11.4	3.9	2.6	1.8	24.9	28.5	11.5
MATERIALS, SUPPLIES, FUEL, ETC. . . . . .DO . .	30.6	24.6	3.5	2.5	11.1	8.2	59.7	49.2	23.1
END OF YEAR, TOTAL. . . . . .DO . .	149.0	119.0	23.0	7.0	21.2	23.6	193.0	141.7	75.5
FINISHED PRODUCTS . . . . .DO . .	37.8	29.5	7.3	.9	6.9	12.2	84.9	52.1	37.0
WORK IN PROCESS . . . . .DO . .	75.9	60.7	11.7	3.5	2.8	2.2	30.7	32.6	12.3
MATERIALS, SUPPLIES, FUEL, ETC. . . . . .DO . .	35.3	28.8	3.9	2.6	11.5	9.3	77.4	57.0	26.1
EXPENDITURES FOR PLANT AND EQUIPMENT, TOTAL . . .DO . .	17.4	12.7	1.3	3.4	3.0	1.7	14.9	15.8	8.1
NEW PLANT AND EQUIPMENT, TOTAL. . . . . .DO . .	16.3	11.9	1.3	3.0	2.9	1.7	14.3	14.8	6.4
NEW STRUCTURES AND ADDITIONS TO PLANT . . . .DO . .	3.6	2.6	.3	.7	.8	.7	2.9	2.9	1.5
NEW MACHINERY AND EQUIPMENT . . . . .DO . .	12.7	9.4	1.0	2.3	2.1	1.0	11.4	11.9	5.0
USED PLANT AND EQUIPMENT. . . . . .DO . .	1.2	.7	(Z)	.5	.2	.1	.7	.9	1.7

(NA) Not available. (Z) Less than half of the unit of measurement shown (under 50 thousand dollars or man-hours; under 50 employees).

[1]The proportion of product shipments (both primary and secondary) of the industry represented by primary products.

[2]The proportion of primary products shipped by the establishments classified in the industry to total shipments of such products by all manufacturing establishments.

Source: 1972 Census of Manufactures, U.S. Department of Commerce.

TABLE 3

SELECTED OPERATING RATIOS FOR LEATHER TANNING AND FINISHING: 1958-1972

Year	Payroll per employee (dollars)	Assets per employee (dollars)	Production worker as percent of total employment (percent)	Annual man-hours of production workers (number)	Average hourly earnings of production workers (dollars)	Cost of materials per dollar of shipments (dollars)	Cost of materials and payrolls per dollar shipments (dollars)	Assets per dollar of shipments (dollars)	Value added per employee (dollars)	Payrolls as percent of value added (percent)	Value added per man-hour of production worker (dollars)
	INDUSTRY 3111.--LEATHER TANNING AND FINISHING										
1972 Census	7,782	(NA)	86	1,896	3.61	.67	.86	(NA)	14,331	54	8.79
1971 ASM	7,506	8,082	85	1,976	3.36	.60	.81	.24	13,673	55	8.19
1970 ASM	7,118	7,444	85	1,960	3.21	.59	.81	.23	13,286	54	7.93
1969 ASM	6,531	6,860	85	1,943	3.01	.60	.82	.23	11,800	57	6.99
1968 ASM	6,302	6,590	86	1,965	2.85	.60	.82	.23	11,236	56	6.59
1967 Census	6,071	6,340	86	2,004	2.70	.63	.84	.22	10,401	58	6.06
1966 ASM	5,787	(NA)	86	2,037	2.51	.65	.85	(NA)	9,983	58	5.68
1965 ASM	5,639	(NA)	87	2,040	2.44	.63	.84	(NA)	10,228	55	5.75
1964 ASM	5,416	6,110	87	2,014	2.41	.61	.83	.24	9,619	56	5.49
1963 Census	5,198	6,030	87	2,000	2.38	.63	.85	.25	8,692	60	5.01
1962 ASM	4,967	5,800	86	1,954	2.31	.64	.85	.24	8,326	60	4.94
1961 ASM	4,752	(NA)	86	1,920	2.25	.64	.85	(NA)	8,049	59	4.86
1960 ASM	4,744	(NA)	87	1,923	2.24	.64	.85	(NA)	8,064	59	4.84
1959 ASM	4,684	(NA)	87	1,935	2.19	.63	.83	(NA)	9,109	51	5.39
1958 Census	4,459	(NA)	87	1,952	2.10	.63	.85	(NA)	7,428	60	4.35

Source: 1972 Census of Manufactures, U.S. Department of Commerce.

TABLE 4

PRODUCTS AND PRODUCT CLASSES

QUANTITY AND VALUE OF SHIPMENTS BY ALL PRODUCERS: 1972 and 1967

1972 product code	Product	Unit of measure	Total product shipments including interplant transfers: 1972 Quantity	1972 Value (million dollars)	1967 Quantity	1967 Value (million dollars)
3111- --	TANNED AND FINISHED LEATHER, TOTAL	....	(X)	1,026.4	(X)	846.2
31111 --	Finished Cattle Hide and Kip Side Leathers	Mil. sq. ft...	1,125.0	684.1	1,064.3	495.7
	Grains, except offal and welting leather (heads, shoulders, bellies, etc.):					
31111 15	Sole leather	...do...	98.7	64.1	151.7	83.3
31111 33	Bag, case, and strap leather (sides)	...do...	32.0	25.1	39.3	21.7
31111 35	Upholstery leather--top grains and machine buffs (hides)	...do...	38.2	38.6	29.2	18.9
31111 37	Upper leather, excluding patent (sides)	...do...	556.4	352.4	528.0	256.5
31111 41	Patent leather (sides)	...do...	85.1	51.9	30.9	13.5
31111 47	Other grains, including flat and handbag leather, lining leather (sides), garment leather (sides), and belting and mechanical leather	...do...	140.1	85.4	80.1	39.0
31111 55	Offal (heads, shoulders, bellies, etc.), except splits and welting leather but including sole leather, waist belt leather, and welting leather grains	...do...	37.3	17.8	60.8	24.0
31111 67	Finished splits, including shoulder splits, deep buffs, buffing, and fleshers	...do...	136.1	44.2	150.2	36.9
31111 00	Finished cattle hide and kip side leathers, n.s.k	...do...	*7.6	4.6	*4.1	1.9
31112 --	Finished Calf and Whole Kip Leathers:					
31112 11	Finished all calf and whole kip leathers	...do...	34.8	35.1	44.2	35.8
31113 --	Finished Sheep and Lamb Leathers	Mil. sq. ft...	111.6	54.7	168.3	60.9
31113 31	Garment	...do...	72.8	35.6	99.9	37.3
31113 41	Other, including glove, shoe, fleshers, skivers, and shearlings.	...do...	35.9	17.7	68.4	23.6
31113 00	Finished sheep and lamb leathers, n.s.k	...do...	*2.9	1.4	-	-
31114 --	Other Finished Leathers, N.E.C	...do...	107.7	47.9	142.9	75.3
31114 15	Goat and kid leathers	...do...	25.4	15.0	73.8	44.2
31114 31	Other animal leathers, including cabretta, horse, colt, mule, ass, and pony leathers	...do...	74.8	29.9	64.4	28.7
31114 00	Other finished leathers, n.e.c., n.s.k	...do...	7.5	3.0	4.7	2.4
31115 --	Rough, Russet, and Crust Leather (Not Finished in Same Establishment)	....	(X)	51.8	(X)	30.5
31115 31	Rough, Russet and Crust Leather, not finished in same establishment	....	(X)	51.8	(X)	30.5
31110 00	All other finished and rough leathers, n.s.k., for companies with 10 employees or more. (See note.)	....	(X)	42.0	(X)	25.4
31110 02	All other finished and rough leathers, n.s.k., for companies with less than 10 employees. (See note.)	....	(X)	23.8	(X)	9.7
31119 11	Receipts for contract finishing and tanning done for others on their materials	....	(X)	87.0	(X)	113.1

Source: 1972 Census of Manufactures. U.S. Department of Commerce.

TABLE 5

ENERGY CONSUMPTION IN MANUFACTURE OF LEATHER
- SALT CURED HIDES TO FINISHED LEATHER -

Basis: For salt-cured hides to finished product, an average hide weighing 75 lbs. will yield 40 sq. ft. of finished leather weighing 37-1/2 lbs.

1972 Energy Consumption[1] (no pollution control)

Electrical:	0.21 kwhr. or 717	Btu/lb. raw hide
Oil & Gas:	6700	Btu/lb. raw hide
Total:	7417	Btu/lb. raw hide

Equivalents: 0.556 M Btu/hide
13,907 Btu/sq.ft. of leather
30 M Btu/ton of leather[2]

Adding Pollution Treatment

1977 Standards: add 270 Btu/lb. (3.6%)
1983 standards: add 536 Btu/lb. (7.2%)
Treatment of dissolved solids (salt) pollution adds additional 7,200 Btu/lb. for an overall 107% increase.

Future Projection

1985: energy usage 25 M Btu/ton leather[2]
2000: energy usage 20 M Btu/ton leather

The above decreases in energy usage are based on higher fuel costs vs. tighter pollution control.

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(1) Leather Tanning and Finishing EPA-440/1-74-016-a (3/74)
(2) Haire and Sundgren (Weekly Bulletin 5/25/1974) of the Roit Corporation gives 31 M Btu/ton leather, compared to 40 M for paper. The minimum by current technology is 22 M Btu/ton.

TABLE 6

DEMAND BY U.S. CONSUMING INDUSTRIES

A THE SHOE MARKET (Non-Rubber)
(million pairs)

	Total Market (1)	Domestic Production	Imports Non-Rubber	% Imports of Total (2)
1965	681.2	626.2	55.0	8.1
1970	803.9	562.3	241.6	30.1
1973	803.9	488.3	315.6	39.3
1974	739.0	444.6	294.4	39.8
1975	755.0	458.0	300.0	39.7
1977	849.0	512.0	337.0	39.7
1980	900.0	543.0	357.0	39.7

(1) Projected market growth at less than population increase.

(2) Assuming minimal change in U.S. Government policy and posture on behalf of U.S. labor intensive industry.

B LEATHER GARMENT MARKET

	Total Market In Units (millions) Domestic or Imported	Equivalent Footage*
1970	5.9	177.0
1971	6.1	183.0
1972	6.1	183.0
1973	7.5	225.0
1974	8.2	246.0
1975	9.0	270.0
1977	10.0	300.0
1980	11.0	330.0

*Includes cowhide splits.

TABLE 6 (Continued)

C ALL OTHER LEATHER CONSUMING INDUSTRIES
(Upholstery, Handbags, Case, Strap, Harness & Saddlery, Glove, Mechanical)

Consumption in Equivalent Hides (000)	
1970	2,760
1971	3,057
1972	3,252
1973	3,282
1974	3,255
1975	3,618
1977	3,974
1980	4,412

TABLE 7

HIDE AND LEATHER PRODUCTION, EXPORTS AND IMPORTS[1]
WITH PROJECTIONS TO YEAR 2000 (Millions of Lbs.)

	1972	1974	1980	1985	2000
Cattle hide production	2,706	2,835	3,450	3,750	4,575
Hog hide production[2]	5[3]	15[3]	50	100	500
Total hide production[4]	3,000	3,058	3,650	4,000	5,225
Exports, cured hides[5,6]	879	922	1,075	1,178	1,539
Leather Production[6]	898	757	1,000	1,096	1,432
Leather exports[6]	143	210	338	370	484
		(expressed in millions of $ value)			
Leather exports[6]	67	101	180	(300)	(500)
Leather imports[6]	132	111	100	100	100
Leather production[7]	1,059	890	1,180	1,293	1,690

[1]Projections for hide production, based on cattle and hog slaughter by Dr. Harold M. Taylor, USDA, ERS, stationed at ERRC.

[2]Pulling of hog skins for leather started in 1972 and is predicted to grow. Alternate practice is to leave most of hob skin on meat with balance to gelatin manufacture. Projections by J.W. Harlan, USDA.

[3]Literature and industry sources.

[4]Includes equivalent of sheep, goat, horse and miscellaneous hides which are in static or declining production. Based on data from Tanners' Council Statistical Workshop, 4/5/75.

[5]Basis: A 75 lb. rawhide, flexhed, trimmed and brine-cured yields 50 lbs. cured hide. Other hides converted to cattle hide equivalents on the basis of leather area.

[6]Data for 1972, 1974 and 1980 from Tanners' Council Projections (4/5/75). Projections for 1985 and 2000 made using 1980 ratios of total supply of hides. This assumes a static situation of slow growth. U.S. and/or foreign governmental and environmental activity could shift export/import ratios greatly.

[7]From 1972 Census of Manufacturers. 1972 ratio of $/lb. used in projections.

An overall view of the leather tanning and finishing industry for 1972 is shown in Tables 2, 3 and 4. these Tables are from the 1972 Census of Manufactures and show general statistics, selected operating ratios and quantity and value of product shipments.

Energy and the Environment

The energy consumption in the manufacture of salt cured hides to finished leather is shown in Table 5. The 1972 total energy consumption was 7417 Btu/lb. raw hide or 30 million Btu/ton of leather. Additional energy will be required to meet pollution standards. For 1977 pollution standards the increase is estimated to be 270 Btu/lb. and for 1983 standards 536 Btu/lb. Additional treatment for dissolved solids (salt) would require an additional 7,200 Btu/lb. for an overall energy increase of 107 percent.

Despite the increased energy required for pollution treatment, the future increased costs for fuel and improved technology will bring about a decrease in future energy requirements to 25 million Btu/ton leather in 1985 and 20 million Btu/ton in 2000. The minimum energy attainable by current technology is estimated to be 22 million Btu/ton leather.

Demand for Leather

Since hides are a by-product of the meat industry, the supply of leather is directly related to animal slaughter and only indirectly to demand for leather goods. This sometimes leads to a lack of response of supply to changes in demand.

Cattle and calf slaughter is expected to increase in the immediate years ahead due to increasing population and meat demand, which will result in an increased supply of hides. The Tanners' Council of America (1975b) gives the following figures for cattle and calf hide supply for the recent past and near future:

1972	39.2	million	hides
1974	41.0	"	"
1975	45.0	"	"
1978	48.5	"	"
1980	50.2	"	"

This same source also outlines the demand for leather in the U.S. by the consuming industries for the present and near future as shown in Table 6. The domestic production of shoes is now at its ebb point and should show increases ahead. The percentage of shoe imports jumped sharply from 1965 to 1970 and has now levelled at about 39-40 percent of the total market.

Demand for hides in the U.S. and other high-income countries is likely to be determined mainly by the rate of replacement of footwear by individual consumers, by their purchase of leather clothing and by the inroads of synthetic materials into end-uses for leather. It is assumed that per capita consumption of traditional dress shoes may approach saturation and, consequently, leather footwear consumption in the U.S. will keep pace with population growth rather than standard of living. However, traditional patterns of footwear may alter as people purchase specialized footwear for sport and other leisure activities and as consumers become more fashion conscious. Greater quantities of cattle hides may be used in leather garments.

If technical improvements are made in the quality of synthetic materials and the production costs lowered, then they might make inroads into the leather market. This could be particularly true if a shortage of hides should develop. Once synthetics penetrate the leather market, it might be difficult for hides and skins to regain more than a part of the lost ground even if falling prices would make hides and skins more competitive again. This is because the machinery developed for using synthetics does not lend itself to the manufacture of leather products. This has been experienced in markets for other agricultural products such as cotton and wool textiles.

Future Production Projections

Future projections for hide and leather production, exports and imports to the year 2000 are shown in Table 7. Total hide production is expected to increase by one-third in 1985 and by 74 percent in 2000. Leather production, however, will increase less, namely by 22 percent in 1985 and by 60 percent in 2000. Exports of both cured hides and of leather will increase appreciably; imports will decline to a fairly constant level.

Although hide production is directly related to meat production, the output by weight of cattle and calf hides during the past 25 years has expanded more slowly than production of beef and veal. This is due in part to the breeding of more beef cattle with thinner hides and partly to the achievement of increases in carcass weight with which the biological growth of hides did not keep pace. For example, from 1955-1957 to 1966-1968, the production of hides and skins expressed as a percentage of the weight of meat production fell steadily from 10.9 to 9.7 percent in all high-income countries. This trend is expected to level off.

The projection of prospective supply versus demand indicates that in the 1980s and beyond, production of hides and leather will meet demand and allow moderate export surpluses. The degree of this relationship will depend upon the extent of any future penetration of synthetic materials into the leather market. A mathematical substitution model predicts (Fisher and Pry 1971) continued substitution of synthetic materials for leather in the future based on past trend. However, the degree will depend upon various perturbation factors and to what extent adjustments are made with respect to adverse changes.

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SECTION E

SUMMARY AND RECOMMENDATIONS

CONTENTS

SECTION E

SUMMARY AND RECOMMENDATIONS

SUMMARY

The industries based upon fibers from renewable resources are among the most important in the nation. The paper, paperboard, textile, and leather products which they produce are essential to every person in our population.

The fiber producing resources--forest and crop lands--can continue to supply these basic renewable resources for our economy for the decades ahead and probably indefinitely, provided there is intelligent management and the guidance of sound governmental policies.

Society--and, hence, federal and state governments--should have a special interest in the maintenance and development of these renewable fiber raw materials, since they form a national resource largely independent of foreign imports. At no time in our history has there been a greater need to expand and improve the nation's renewable resources. Increasing worldwide populations and improved education and living standards in many countries will result in increased consumer demands, both domestically and abroad, for paper, paperboard, textile and leather products.

To maintain the operation of these industries based on renewable resources and to protect them from competition by products made from imported petroleum and other scarce nonrenewable materials will require sound management, strong R&D activity, and effective governmental incentives. In light of the great increase in future demand for paper and textile products, it is imperative that the industry expand its capacity and modernize its plant.

The research effort in the areas of fiber production and utilization for paper and textile products is very low in comparison with that expended on petrochemical and most other industrial products. At present (1975), the paper industry is expending about 0.6 percent of its sales dollar (or some 9 percent of its capital outlays) on research, or about $250 million. Much of this present expenditure goes for maintaining present equipment and technology, with perhaps 60 percent of it going into innovative research. It is estimated that to achieve the research necessary to keep the industry viable and competitive, present research funding needs to be increased to $550 million now, and then kept level with inflation.

In the cotton industry, the research expenditure for 1972 was about $40 million for production and marketing of the cotton. Research expended by the textile mills has been inadequate to keep U.S. technology competitive with the developments abroad. The funding of research should be increased by at least 50 percent to a present total of at least $60 million to keep the renewable fibers and their processing competitive with those that are derived from nonrenewable fibers. The annual research figure should then be kept level with inflationary increases.

Commercial implementation of newly developed processes and products will require capital investments of hundreds of millions of dollars. This is a great challenge for the renewable fiber industries over the next ten years--how to find the capital required to meet developmental, environmental, and energy demands.

RECOMMENDATIONS

There should be economic incentives to maintain the growth of the renewable fiber industries and for them to invest in innovative activities by:

1. outright grants,
2. investment tax credits,
3. financial assistance for capital costs and research for environmental control, energy efficiency and R&D activity in engineering, production and marketing of new products and processes, and
4. legislation to encourage the adoption of the technology and concepts to expand and improve the use of the natural fiber resource and the protection of the environment.

The renewable fiber industries should be encouraged to reduce further the consumption of energy, and thereby help improve not only the overall energy situation, but reduction in costs and improvement in competition with nonrenewable materials. This can be done by:

1. reducing energy used in processing,
2. heat exchange and recycling, closed loop systems,
3. improved generation of energy from processing wastes, and
4. producing lower energy/high yield products.

There should be strong concentrated research effort with governmental support. Present government and institutional support of research in the paper, cotton, wool, cellulosics, and leather areas is miniscule compared with that dealing with other materials and processes. The energy and scarce materials crises demand immediate steps to permit the basic renewable fiber industries to improve their products, create new products, reduce energy, improve their competitive position with respect to petrochemical and other nonrenewable materials, and improve processing efficiency by increasing yields, reducing wastes, lowering costs, and enhancing the quality of the environment.

To achieve these goals in research, research funding for paper and paperboard should be increased from its present $250 million to $550 million and for cotton from its present $40 million to at least $60 million. Similar increases (50-100 percent) are needed in the other renewable fiber product areas (wool, leather, cellulosics). The increased funding in all cases should then be kept level with inflation.

Governmental regulations, especially those pertaining to the environment should be implemented and administered in such a way that (a) their impact upon the consumer and the renewable fiber resource industries is reasonable and (b) such that the health of these renewable industries is not endangered, but instead maintained in sound condition for the benefit of our national society.

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